IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:	Pascal DRILLET et al.	
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Title:	Coated Steel Strips, Coated Stamped Products and Methods	

Declaration of Dr. Michael Miles

POSCO-1003

ArcelorMittal Ex. 2028
Posco Co. LTD. v. ArcelorMittal
IPR2025-00371
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EXHIBITS

Ex. 1001	U.S. Patent No. 10,961,602 to Drillet ("the '602 Patent")
Ex. 1002	Excerpts from the Prosecution History of the '602 Patent ("the Prosecution History")
EX-1003	Declaration of Dr. Michael Miles
EX-1004	Curriculum Vitae of Dr. Michael Miles
EX-1005	Engels et al., "Controlling and Monitoring of the Hot-Stamping Process of Boron-Alloyed Heat-Treated Steels" (2006) ("Engels")
EX-1006	Translation Certificate of Michael L. Magee
EX-1007	Excerpt from "New Developments in Sheet Metal Forming" (2006)
EX-1008	Declaration of Prof. Mathias Liewald
EX-1009	Declaration of Christoph Wohlstein
EX-1010	"Engels" and "Hein," in English and German, provided by the German National Library
EX-1011	[Reserved]
EX-1012	[Reserved]
EX-1013	[Reserved]
EX-1014	Cornette et al., "High Strength Steels for Automotive Safety Parts," SAE Technical Paper Series 2001-01-0078 (2001) ("Cornette")
EX-1015	Declaration of Mel DeSart

EX-1016	U.S. Patent Application Publication No. 2004/0009366 (“Takagi”)
EX-1017	Japanese Patent No. JP3738754
EX-1018	Translation and Certificate of Translation for portions of EX-1017
EX-1019	Hein et al., “Hot Stamping of USIBOR 1500 P: Part and Process Analysis Based on Numerical Simulation” (2006) (“Hein”)
EX-1020	Hein et al., “Pressharten von USIBOR 1500 P: Simulationsbasierte Bauteil- und Prozessanalyse” (2006)
EX-1021	Vaissiere et al., “Development of Pre-Coated Boron Steel for Applications on PSA Peugeot Citroën and RENAULT Bodies in White,” SAE Technical Paper Series 2002-01-2048, reprinted from the Proceedings of the 2002 SAE International Body Engineering Conference and Automotive & Transportation Technology Conference (2002) (“Vaissiere”)
EX-1022	Declaration of June Ann Munford - #1
EX-1023	U.S. Patent No. 6,296,805 (“Laurent”)
EX-1024	French Patent Publication No. FR2833504
EX-1025	Translation of EX-1024 and Certificate of Accuracy
EX-1026	GMW14400 material specification (“GMW14400”)
EX-1027	Declaration of June Ann Munford - #2
EX-1028	U.S. Patent No. 9,708,683 (“the ’683 Patent”)
EX-1029	Final Written Decision for IPR2019-01275, corresponding to EX-1028

EX-1030	Record of Oral Hearing for IPR2019-01275
EX-1031	Petition for IPR2019-01275
EX-1032	Somani et al., "Dimensional Changes and Microstructural Evolution in a B-bearing Steel in the Simulated Forming and Quenching Process," ISIJ International, Vol. 41 (2001) ("Somani")
EX-1033	Japanese Patent Publication JP2004244704
EX-1034	Translation of EX-1033 and Certification of Accuracy
EX-1035	WO Patent Application Publication No. WO02/103073
EX-1036	European Publication No. EP1865086
EX-1037	Translation of EX-1036 and Certification of Accuracy
EX-1038	Winkel, "Quenches for press hardening steel plate in the car industry" (2004)
EX-1039	Translation of EX-1038 and Certification of Accuracy
EX-1040	[Reserved]
EX-1041	[Reserved]
EX-1042	[Reserved]
EX-1043	[Reserved]
EX-1044	[Reserved]
EX-1045	[Reserved]
EX-1046	[Reserved]

EX-1047	Eriksson et al., “Testing and evaluation of material data for analysis of forming and hardening of boron steel components,” Modelling Simul. Mater. Sci. Eng. 10 277 (2002)
EX-1048	[Reserved]
EX-1049	WO Patent Application Publication No. 2004/106573
EX-1050	Translation of EX-1049 and Declaration of Accuracy (“Nishibata”)
EX-1051	Ahindra Ghosh, “Secondary Steelmaking, Principles and Applications” (2001)
EX-1052	U.S. Patent Publication No. 2004/0238080 (“Vandeputte”)

I, Dr. Michael Miles, of Springville, UT, declare that:

I. ASSIGNMENT

1. I have been retained by POSCO ("Petitioner") in connection with the above-captioned petition for Inter Partes Review ("IPR") of U.S. Patent No. 10,961,602 to Pascal Drillet et al. ("the '602 patent"). I understand the '602 Patent is currently assigned to ArcelorMittal ("Patent Owner"). I have been asked to provide my independent analysis of the '602 Patent based on the prior art publications cited in this declaration. I was previously engaged by Petitioner as an expert in IPR2019-01275, relating to U.S. Patent No. 9,708,683 (EX-1028), which is a parent patent to the '602 Patent.

2. I have been asked by Petitioner to offer opinions regarding the '602 Patent, including the unpatentability of claims 1-30 (which I may refer to subsequently as the "Challenged Claims") in view of certain prior art. This declaration sets forth the opinions I have reached to date regarding these matters.

3. I am being compensated by Petitioner at my standard hourly consulting rate for my time spent on this matter. My compensation is not contingent on the outcome of the IPR or on the substance of my opinions.

4. I have no financial interest in Petitioner or Patent Owner.

II. BACKGROUND

A. Educational Background

5. I earned a B.S. degree in Metallurgical Engineering in 1989 from the University of Idaho. I then earned my M.S. degree in Metallurgical Engineering in 1991 from the Ohio State University. I earned my Ph.D. degree in Materials Science and Engineering from Ecole des Mines de Paris in 1995. My M.S. research was focused on the formability of sheet metal alloys, including several steel alloys, an aluminum alloy, and a brass alloy. My Ph.D. work involved the modeling of hot forming processes, especially forging, where the heat transfer between the tools and the workpiece were taken into account.

B. Career History & Relevant Industry Participation

6. I joined Brigham Young University (BYU), in Provo, UT, in 2001 as an assistant professor in the manufacturing engineering technology program. At BYU, I became an associate professor in 2007 and a full professor in 2013. I served as program chair of the manufacturing engineering technology program from 2009 – 2016. I am currently a professor in the manufacturing engineering department (there was a program change in 2019) at BYU. My research focus is on the forming and fabrication of metal alloys, with emphasis on microstructure/formability relationships and the welding/joining of dissimilar alloys.

7. I have been funded by the National Science Foundation nine times on various research topics related to forming and joining of sheet metal alloys,

including microstructure/formability relationships in steels containing retained austenite. I have also received funding from the Department of Energy (dissimilar metals joining) and NASA (friction stir welding of aluminum alloys). In all of these projects, I have mentored students in carrying out the research, collaborated with companies and National Labs (General Motors, Honda, Megastir Technologies, Oak Ridge National Lab), and worked with these teams to publish our results in archival journals.

8. Prior to joining BYU, I worked as a project engineer from 1995 to 1996 at Pechiney Research Center in Voreppe, France. From 1996 to 1998, I was a tooling engineer and a project engineer for American National Can (a subsidiary of Pechiney) in Elk Grove Village, Illinois. From 1998 to 1999, I was an engineering manager for American National Can in Whitehouse, Ohio, then assumed the role of assistant plant manager from 2000 to 2001 at the same facility for Rexam PLC (American National Can was purchased by Rexam).

9. I am an inventor listed in the following United States Patents: End Closure with Improved Openability (US 6,024,239), Three-body joining using friction stir processing techniques (US 8,157,154), Friction bit joining using a friction rivet (US 9,764,375), and Systems and methods for friction bit joining (US 11,697,173). A listing of the year, patent number, and patent title is found in my Curriculum Vitae included in Appendix A. I am also a listed inventor on several

international patents.

10. Additional information regarding my background, qualifications, and presentations is included as part of my curriculum vitae.

11. It is for at least these reasons that I am an expert in sheet metal forming and the microstructure/property relationships that influence formability, including phase transformations that occur during the forming of advanced high strength sheet steels for automotive manufacturing.

III. MATERIALS REVIEWED

12. In forming my opinions, I have reviewed the ’602 Patent and considered relevant portions of each of the documents listed in the Exhibit List above and the other references cited in my declaration. In reaching my opinions, I have relied upon my experience in the field and also considered the viewpoint of a person of ordinary skill in the art at the time of the earliest claimed priority date of the ’602 Patent, i.e., late 2006. As explained below, I am familiar with the level of skill of a person of ordinary skill in the art regarding the relevant technology at issue as of that time

IV. DESCRIPTION OF THE RELEVANT TIMEFRAME, THE RELEVANT FIELD, AND A PERSON OF ORDINARY SKILL IN THE ART

13. I understand that the ’602 Patent claims a priority date of October 30, 2006. (which I will also refer to as the “Priority Date”). For the purposes of my

analysis, and in the absence of any information to the contrary, I have used the October 30, 2006 date as the relevant date for my analysis of the prior art.

14. I considered several factors to determine the skill level of a person of ordinary skill in the art of the ’602 patent in October 2006, including the types of problems encountered in the art, the solutions to those problems, the pace of innovation in the field, the sophistication of the technology, and the education level of active workers in the field.

15. Based on my knowledge, expertise, and the prior art cited in the ’602 Patent, it is my opinion that a person of ordinary skill in the field of the ’602 Patent would have had at least an undergraduate degree in materials science, manufacturing engineering, mechanical engineering, or equivalent knowledge, training, or experience, with at least two years of experience working in metallurgy.

16. Unless noted otherwise, when I state that something would be known or understood by one skilled in the art, or a skilled artisan, or a person having ordinary skill in the art (“POSITA”), I am referring to a person with this level of education and experience at the time of the alleged invention, which I am assuming to be in or around October 2006.

V. SUMMARY OF THE ’602 PATENT

17. I have reviewed and will now summarize the ’602 Patent. The ’602

Patent purports to provide novel manufacturing methods and structures associated with a "coating" formed by hot-stamping pre-coated steel blanks. The '602 Patent acknowledges that these coatings and their manufacture were already "important, especially in the automotive industry." EX-1001, 1:41-43. As the Background describes, processing to obtain a coating typically included "[p]re-coating of a steel sheet[], by hot dipping; [t]rimming or cutting for obtaining blanks; [h]eating the blanks in order to obtain alloying of the steel substrate with the pre-coating, as well as the austenitizing of the steel; and [h]ot forming followed by rapid cooling of the part in order to obtain predominantly martensitic structures." EX-1001, 1:45-51.

18. Starting with this well-established process, the '602 Patent alleges several improvements. First, the '602 Patent emphasizes the "importan[ce]" of "control of the homogeneity of the pre-coating thickness over the entire sheet" by "monitor[ing] continuously" the pre-coating thickness. EX-1001, 2:54-57, 4:65. However, the '602 Patent does not claim any pre-coating or homogeneity thereof.

19. The '602 Patent further notes (i) certain process parameters that are linked to the manufacture of "fully homogeneous martensitic structure[s]" and (ii) the advantages of "reduction of sulfur below a critical value." EX-1001, 2:64-3:7. But, as will be demonstrated below, both the claimed low sulfur amounts and the claimed "fully martensitic" products were recognized in the art. For example, Takagi, Vaissiere, and Somani each provide a detailed discussion of how the hot-

stamping process can be tuned to obtain martensitic structures. EX-1016, [0028]; EX-1021, 3, 6; EX-1032, 8.

20. Finally, the ’602 Patent describes that “particularly good weldability [] is associated with a special succession of coating layers on the parts.” EX-1001, 2:60-63. An example of the claimed coating, which includes four layers, is described with respect to the manufacturing process of “Example 2” and illustrated in FIG. 1 of the ’602 Patent, reproduced below. EX-1001, 12:30-61.

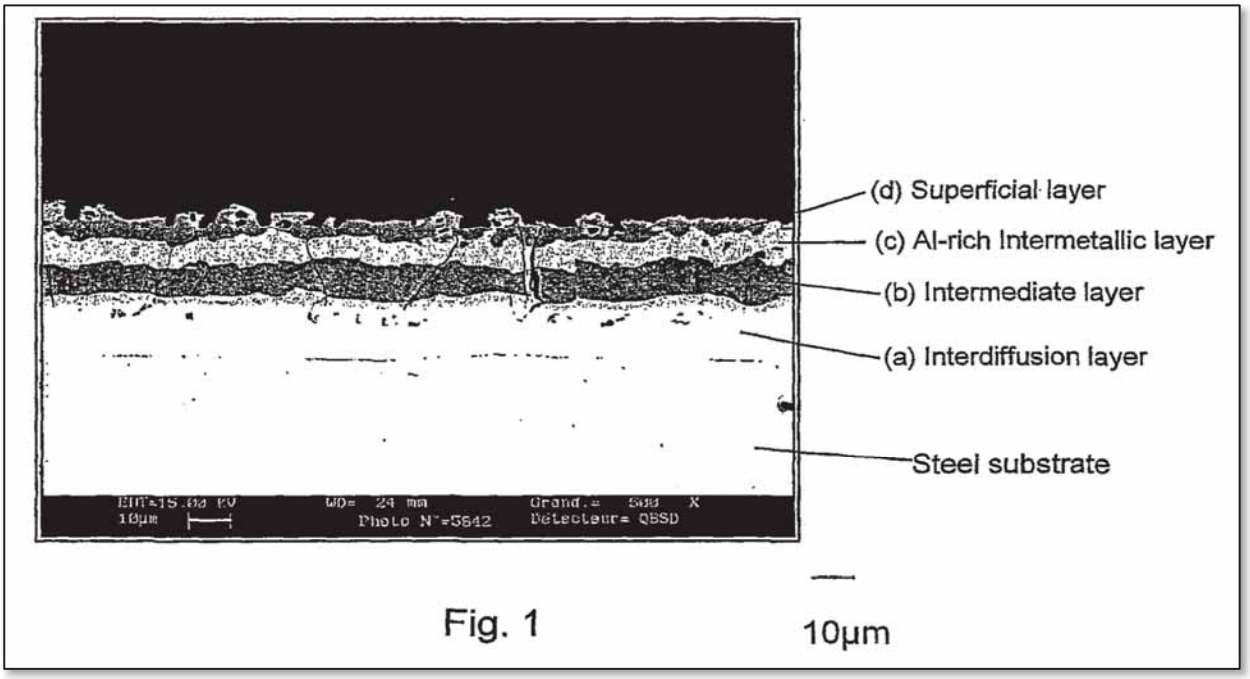


FIG. 1 of the ’602 Patent

21. I have reviewed relevant portions of the file history of the ’602 Patent (EX-1002). The only reference applied in a rejection during prosecution of the ’602 Patent was Laurent. EX-1002, 30-34. The allowance relied on the art’s alleged lack of teaching of layers having the recited iron compositions and total

thickness. EX-1002, 11. The two primary references on which I have based my discussion – Engels and Takagi – directly disclose the recited iron compositions, and Engels directly discloses the recited thickness greater than 30 micrometers, thereby teaching the features that justified allowance.

VI. GROUNDS 1A-102 and 1A-103: Claims 1, 9-11, 14, 18, 20-22, 24, 26-27, and 30 are anticipated by Engels, and claims 1-2 and 9-30 are obvious over Engels

A. Engels

22. Engels is a conference paper submitted as part of the "New Developments in Sheet Metal Forming Technology" conference held in May 2006. Entitled "*Controlling and Monitoring of the Hot-Stamping Process of Boron-Alloyed Heat-Treated Steels*," Engels provides an overview of hot-stamping as applied to "boron-alloyed steels." EX-1005, 136. For example, Engels notes that "blanks" having an "Al-Si-coating" are "austenitized at temperatures between 900 ˚C and 950 ˚C," "stamped," and "systematically cooled down under pressure." EX-1005, 137. A POSITA would have understood that the "Al-Si-coating" is a "pre-coating" that is transformed, via the hot-stamping process, into a coating found in a final hot-stamped part. "Systematically cooled down under pressure" in this context refers to "quenching," which in a hot-stamping process is performed directly in the stamping die.

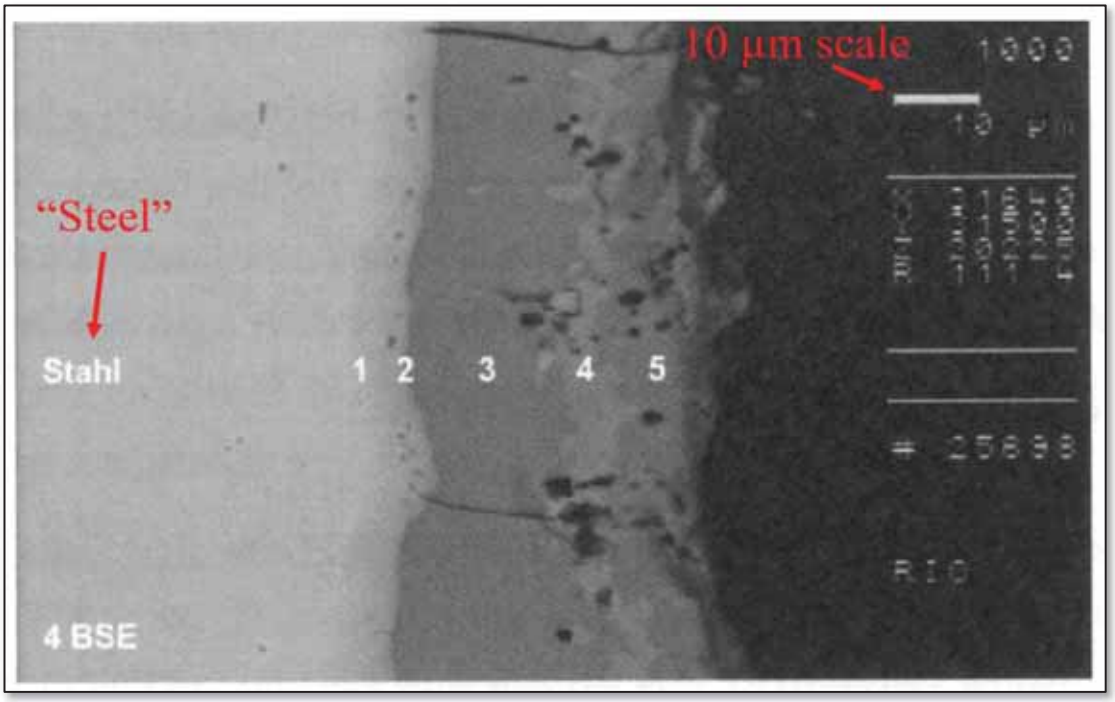
23. As a result, a "diffusion layer" (coating) forms, and Engels recognizes

that "it is crucial to look for a correctly shaped diffusion layer with regard to layer thickness, porosity and roughness, as this layer will decisively impact the corrosion and welding properties of the hot stamped parts." EX-1005, 142. Among the "parameters which have to be taken into account when setting the temperature profile" are "heating rate," "total processing time," "maximum austenitizing temperature," and "material thickness." *Id*.

24. Engels FIG. 5, an image captured using electron microscopy, shows a "cross-section polish of the diffusion layer of a hot-dip aluminum coated boron steel." EX-1005, 142. "Five phases which differ in their layer thickness and chemical composition can easily be distinguished." *Id*. These phases and their compositions and thicknesses are shown in Engels FIG. 5 and a corresponding table (reproduced below).

phase number	layer thickness, µm	Al	Fe	Si	Cr	Mn
		Volume-%				
1	5 – 9	7,2	89,2	1,9	0,3	1,4
2	< 1µm	unmeasurable				
3	11 – 18	51,4	45,9	1,9	0,1	0,7
4	3 – 8	33,9	54,3	10,6	0,3	0,9
5	5 - 11	53,2	44,1	1,9	0,2	0,6

Engels' Table



Engels FIG. 5

25. Several aspects of Engels FIG. 5 and Table bear special comment. First, a scale at the top-right shows a length of 10 µm, permitting the calculation of exact thicknesses from the image itself. As I know from personal experience, these scale bars are common in electron microscopy output and can be relied upon for precise measurements of in-focus materials such as the imaged coating. Second, the included annotation "Stahl" is German for "steel;" this portion of the image depicts the base steel underlying the coating. EX-1006.

26. Third, although the Engels Table lists compositions with "Volume-%," this is a translation error and would have been recognized as such by a POSITA. The original German version of this article describes the compositions as "Masse-%," which, as described in further detail in EX-1006, is correctly and

unambiguously translated as "Mass-%," not "Volume-%." EX-1006; EX-1010, 22. Further, the concept of a "Volume-%" for distinct elements in a homogenous compound of those elements is not well-defined. In a crystal structure formed by, for example, iron atoms, silicon atoms, and aluminum atoms intermixed and bonded to one another, it makes little sense to try to quantify how much of the total volume is assigned to each atom. "Mass-%" (or, equivalently, weight-%), by contrast, was and remains by far the most common composition metric among steel researchers. "Volume-%," meanwhile, is an essentially unknown and unused metric in steel research or, for that matter, in any materials science research with which I am familiar. Accordingly, in this Declaration, and consistent with how a POSITA would have understood Engels, I treat the compositions described in Engels' Table as percentages by mass or, equivalently, weight. Mass-% and weight-% are equivalent metrics because weight and mass are related by a constant factor that cancels out when calculating mass/weight proportions.

B. Analysis of Claims

[1pre]: A precoated steel product comprising:

27. Engels FIG. 5 depicts a precoated steel product or, importing the definition of "product" from the '602 Patent, a precoated steel stamped blank. EX-1001, 14:56. For example, Engels FIG. 5 shows a "diffusion layer" (coating) on underlying "boron steel" ("Stahl") that has undergone hot-stamping. EX-1005,

142-143.

28. With respect specifically to whether the part of Engels FIG. 5 is " stamped," Engels (entitled "Controlling and Monitoring of the **Hot-Stamping** Process of Boron-Alloyed Heat-Treated Steels"[1]) describes essentially continuous processes in which parts are transferred directly from a furnace (in which austenitization and coating formation occur) into a die to be stamped (or "formed") and quenched. EX-1005, 137-138. In the field of steel metallurgy, all of these steps were and are understood as portions of a single, unified process referred to, as a whole, as "hot stamping." The heating and the forming (stamping) are two parts of the same process, as the heating step is critical and necessary to the forming step, and in this context make little sense when viewed independently. For example, heating alone does not provide desired steel mechanical properties absent quenching, and stamping (and corresponding quenching in the die) cannot be performed without the heating step.

29. Indeed, as described by Engels, the "[t]ransfer time t_T between furnace and die" is a factor in determining the mechanical and surface properties of the resulting part, and other art notes that "[t]he transfer time between the furnace and the die has to be reduced as much as possible." e.g., to "less than ten seconds." EX-

[1] All emphasis is added except where indicated otherwise.

1005, 141; EX-1019, 167. In view of this continuous, unified process that includes immediate transfer to a die for stamping, a POSITA would have understood Engels FIG. 5 to illustrate a part that has undergone the entirety of that process, including stamping: to depict a part that has undergone only a portion of the process (e.g., furnace treatment without forming in a die) would have been viewed as much less illustrative and relevant. This is particularly true in view of the immediate context of Engels FIG. 5, which includes a discussion of how the forming and quenching process causes "structural change" in the part. EX-1005, 143. A POSITA would have naturally understood Engels FIG. 5 to depict a hot stamped part that has undergone those structural changes as part of the unified hot-stamping process, not a part whose processing has been arbitrarily arrested mid-way through. Accordingly, a POSITA would have understood that Engels discloses or renders obvious a *hot stamped coated steel product*.

30. I further note Engels' disclosure that the "heat treatment," not "stamping and tempering," determine the properties of the "diffusion layer" (coating). EX-1005, Table 1. Based on this disclosure, even if the Engels FIG. 5 coating had undergone heat treatment without being formed in a die, the coating would nevertheless teach characteristics of a formed coating, because the coating would remain substantially the same through the forming and tempering process. This description is consistent with that of the '602 Patent itself, which describes

that an "alliation" "reaction between the pre-coating and base steel" occurs "during the heat treatment **immediately preceding hot stamping**," and that the "coating" is "the pre-coating after having been subjected to an alliation reaction between the pre-coating and base steel. EX-1001, 14:26-39. That is, based on the '602 Patent's own description, a teaching of a coating formed by heat treatment renders obvious a teaching of a coating that has been heat-treated and also formed in a die, because the coating would be the same in either case.

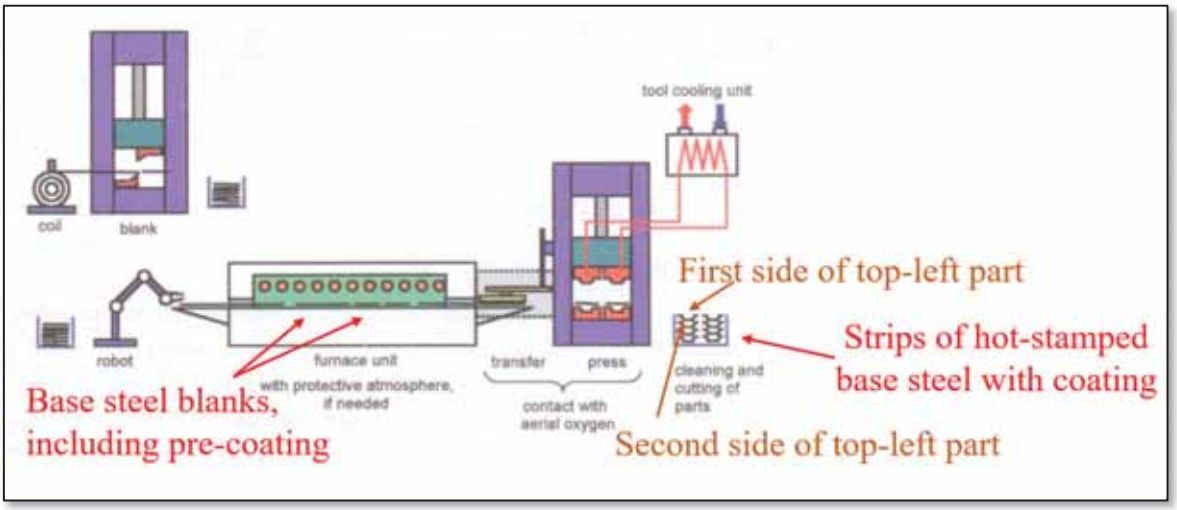
31. The addition of "stamping" would then be an obvious additional process to apply to the heat-treated part, in order to create a formed part having a shape and mechanical properties suitable for use, for example, in a vehicle.

32. Engels also discloses both the stamping of a "blank" (EX-1005, FIG. 1, 143) and the use of an "Al-Si" pre-coating (EX-1005, 137-138, 141-142).

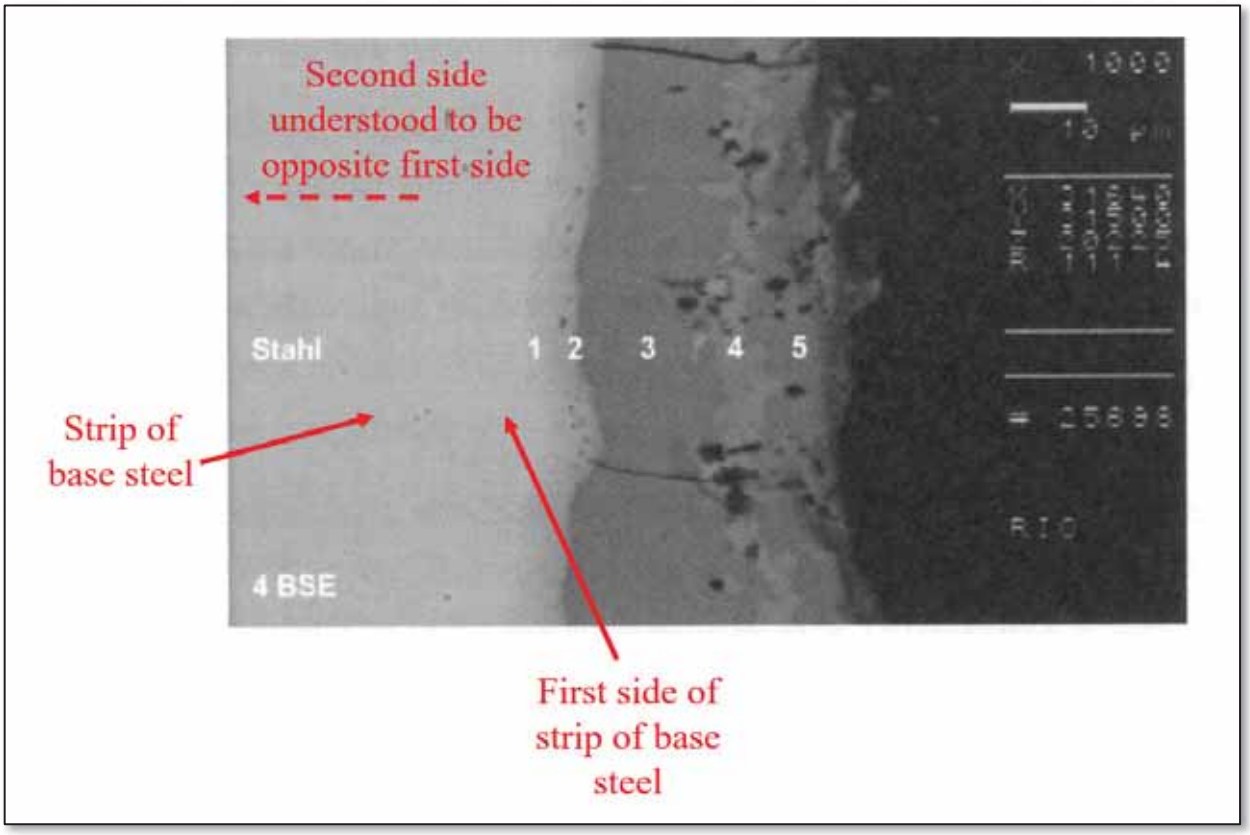
[1a]: a strip of base steel having a first side and a second side; and

33. Engels discloses or renders obvious a strip of base steel having a first side and a second side. For example, in its description of the hot stamping process, Engels illustrates blanks having first sides and second sides, as shown in annotated Engels FIG. 1 below. EX-1005, 137. A POSITA would have understood these blanks as being strips (as, indeed, they are illustrated in FIG. 1) composed of base steel with a pre-coating, which Engels refers to as an "Al-Si-coating." EX-1005, 137. The strips of base steel are austenitized and formed to produce hot-stamped

parts having the same base steel with the first and second sides, and an overlying coating. A strip of base steel and one of its sides (immediately underlying indicated phase 1) are shown in Engels FIG. 5; a POSITA would have understood that there would be a second side opposite the labeled first side.



Annotated Engels FIG. 1



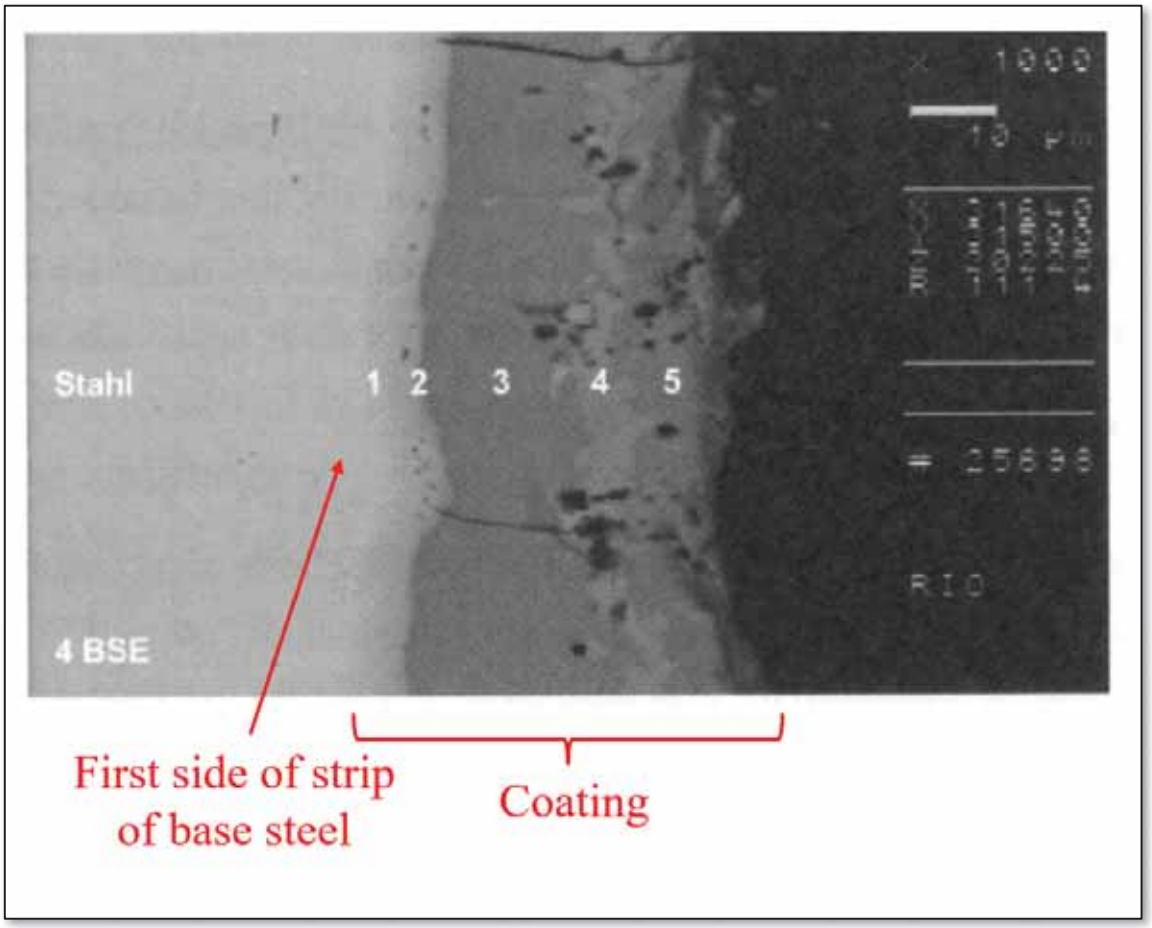
Annotated Engels FIG. 5

[1b]: a coating on at least one of the first side of the strip of base steel and the second side of the strip of base steel,

34. Engels discloses or renders obvious a coating on at least one of the first side of the strip of base steel. The coating is a "diffusion layer" having five phases, as shown in annotated Engels FIG. 5 below. EX-1005, 142-143.

35. Examining FIG. 5, I note that phases 3, 4, and 5 are highly distinguishable based on their different shadings. In backscattered scanning electron microscopy (SEM)images such as Engels FIG. 5 (as indicated by "BSE" at the bottom left), shading (light/dark) is reflective of the composition of the

imaged material. The boundary of phase 1 appears to be visible as a vertical strip of lighter shade. The researchers who authored Engels would have had access to precise composition data (for example, using energy dispersive X-ray spectroscopy (EDS)) that would have allowed them to accurately identify the different phases and determine thicknesses of each layer, for example, as reflected in Engels' table.



Annotated Engels FIG. 5

36. Phase 2 of Engels is a less cohesive layer, as reflected in Engels' disclosure that this layer is very thin and has an "unmeasurable" composition. EX-1005, 143. Based on my review of the literature, this is not a fluke of Engels

process but, rather, a common characteristic of the coatings of hot-stamped steels: a less distinct layer may or may not be found adjacent to the innermost layer of the coating, depend on the exact thermal process to which the coating was subjected.

37. For example, of Takagi's five samples, Nos. 1 and 4 include five layers, whereas Nos. 2 and 5 include four layers. EX-1016, FIG. 4. A comparison of the compositions of the layers of these coatings strongly suggests that the "missing" layer of Nos. 2 and 5 would be the equivalent of the Inter 1 layers of Nos. 1 and 4, such that the Inter 1 layers of Nos. 2 and 5 corresponds to the Inter 2 layers of Nos. 1 and 4 based on their composition and location within the coating. A POSITA would have understood that this Inter 1 layer corresponds to phase 2 of the Engels coating. Continuing the comparison and analogy, a POSITA would have understood that the Inter 2, Inter 3, and Outer layers correspond to phases 3, 4, and 5, respectively.

Similar compositions between
Inter 2 of Nos. 1, 4 and Inter 1 of Nos. 2,5

TABLE 1

No.	PRODUCTION		COATING LAYER STRUCTURE & COMPOSITION (%)						STEEL BASE HARDNESS (Hv)	COATING LAYER HARDNESS (Hv)			OXIDE WEIGHT (mg/dm²)	FORMABILITY	CORROSION RESISTANCE	WELDABILITY
	RAISED TEMPERATURE (℃)	HOLD TIME (min.)	COMPONENT & HARDNESS	INNER	INTER 1	INTER 2	INTER 3	OUTER		SOFTEST	AVERAGE	SOFTER RANGE (%)				
1	920	3	Al	7.7	31.0	48.4	31.6	54.8	450	310	415	51	300	○	○	○
			Si	2.0	3.9	1.2	5.7	0.8								
			Fe	89.6	65.9	50.1	62.0	44.5								
			Hv	310	360	750	700	800								
2	900	2	Al	27.2	48.4	31.6	—	54.9	415	380	455	22	275	×	○	○
			Si	4.1	1.2	5.7		0.8								
			Fe	67.2	50.1	61.9		44.1								
			Hv	380	760	720	—	810								
3	930	10	Al	9.4	—	—	—	11.6	400	305	385	78	550	○	×	×
			Si	1.3				1.8								
			Fe	88.4				85.7								
			Hv	305	—	—	—	410								
4	950	5	Al	6.0	27.8	51.9	30.4	47.4	440	280	400	59	385	○	○	○
			Si	1.5	4.3	0.6	5.3	2.2								
			Fe	90.7	66.7	46.8	63.1	49.8								
			Hv	280	340	720	690	800								
5	900	4	Al	3.2	54.5	33.4	—	54.5	440	300	410	56	335	○	○	○
			Si	0.4	2.5	15.3		6.8								
			Fe	94.3	42.7	51.4		38.4								
			Hv	300	740	700	—	810								

Annotated Takagi Table 1

38. This physical phenomenon is also indicated by the ’602 Patent’s disclosure that the interdiffusion layer “is itself composed of two sub-layers.” EX-1001, 12:46.

39. As a result, and consistent with an example in the ’602 Patent, Engels’ phase 2 would be understood as forming a sub-layer of an overall layer composed of both phases 1 and 2, the overall/composite layer having a composition similar to that provided for phase 1 and a thickness the same as or similar to the disclosed thickness of phase 1 (e.g., within 1 μm of the phase 1 thickness, a thickness difference that would not change the below discussion). I say that the composition would be similar to that of phase 1 because, as a POSITA would have understood,

phase 2 would form only a very small part of the overall layer, such that the overall layer's overall composition would be almost entirely determined by that of phase 1.

40. The foregoing interpretation is consistent with the '602 Patent's description that, in one example, layer (a) "is itself composed of two sub-layers." EX-1001, 12:46. However, I note that the claims of the '602 Patent lack any requirement that layer (a) be composed of two sub-layers.

41. All arguments provided herein that rely on associating Engels' phase 1 with layer (a) apply equally to this composite layer of phases 1 and 2.

[1c]: wherein the coating results from interdiffusion between the base steel, and an aluminum or aluminum alloy pre-coating,

42. Engels discloses or renders obvious that the coating results from interdiffusion between the base steel and an aluminum or aluminum alloy pre-coating. Engels describes that the "diffusion layer" (coating) is formed by heat treatment of "hot-dip aluminum coated boron steels." EX-1005, 141-142. "Hot-dip" refers to a process in which a base steel is dipped in a bath of aluminum or aluminum-silicon to form an aluminum or aluminum-silicon pre-coating. A POSITA would have understood Engels to describe specifically an aluminum-silicon pre-coating, based on the descriptions of "an Al-Si-coating" and an "22MnB5+AS diffusion layer," where "AS" would have been understood by a

POSITA as referring to "aluminum-silicon." EX-1005, 138, 141.

43. The thermal treatment described by Engels (e.g., "heating rate," "total processing time," and "austenitizing temperature," such as "temperatures between 900 °C and 950 °C") then causes "diffusion" between the material(s) of the pre-coating and the base steel. EX-1005, 136, 142. As a result, Engels' coating includes various phases composed of varying degrees of iron, aluminum, and silicon. EX-1005, 143. Based on these compositions and Engels' use of the term "diffusion," a POSITA would have understood that the coating was formed by interdiffusion between the iron of the base steel and the aluminum and silicon of the "AS" or "Al-Si" pre-coating.

[1d]: and wherein the coating includes, proceeding from the base steel outwards: (a) an interdiffusion layer having a first mean iron composition,

[1e]: (b) an intermediate layer having a second mean iron composition different from the first mean iron composition,

[1f]: (c) an intermetallic layer having a third mean iron composition different from the first and second mean iron compositions, the third mean iron composition being higher than the second mean iron composition; and

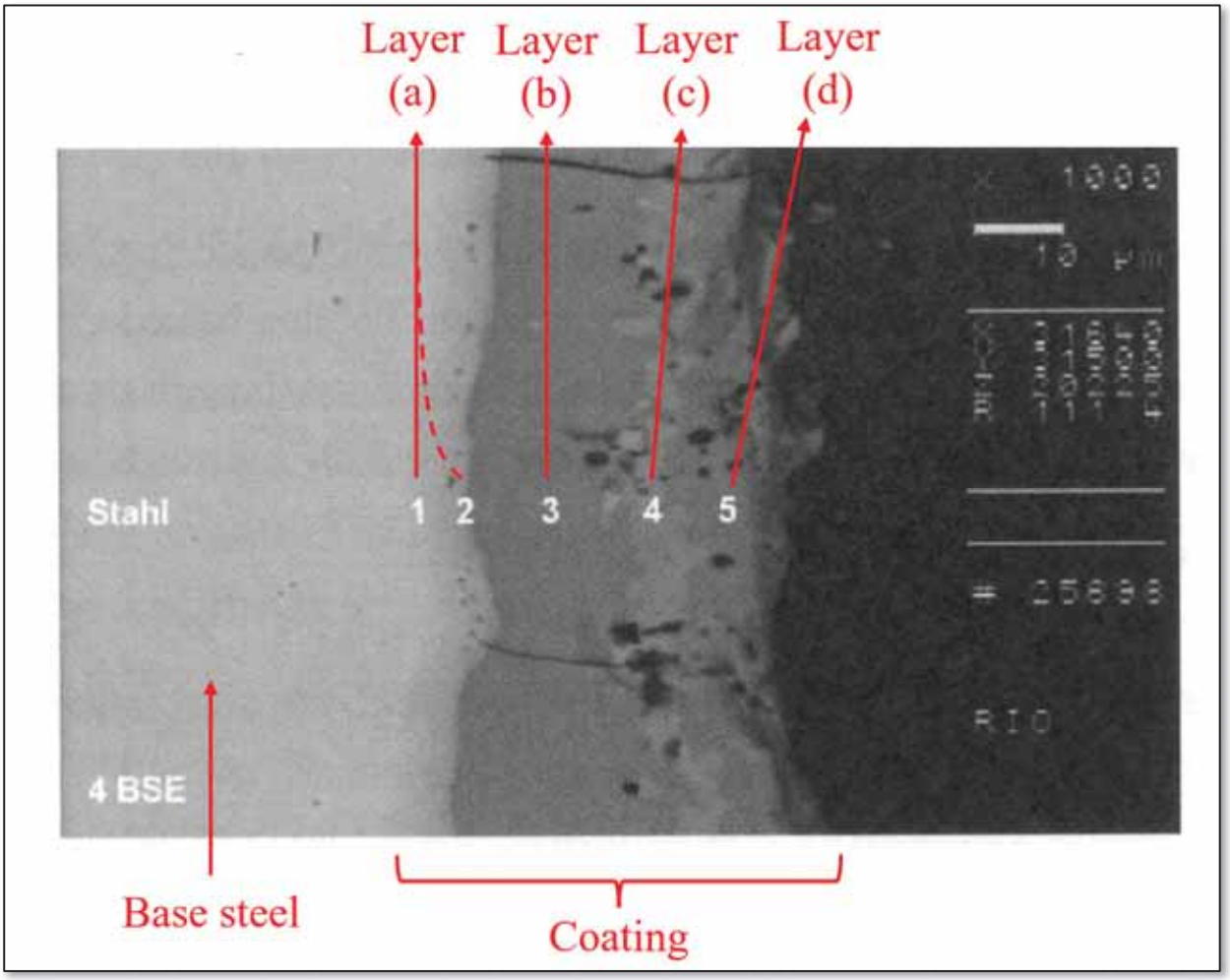
[1g]: (d) a superficial layer having a fourth mean iron composition different from the third mean iron composition,

44. Engels discloses or renders obvious that the coating comprises,

proceeding from the base steel outwards, (a) an interdiffusion layer, (b) an intermediate layer, (c) an intermetallic layer, and (d) a superficial layer, with the recited mean iron compositions. Engels describes that the coating includes "five phases which differ in their layer thickness and chemical composition." EX-1005, 142. As shown in Engels FIG. 5, each of at least phases 1 or 1+2 and 3-5 constitutes a layer and satisfies the foregoing limitation of claim 1 according to the following mappings:

- **Phase 1 or 1+2** teaches **layer (a) (the "interdiffusion layer")**. As shown in FIG. 5, phase 1 is arranged directly on the underlying steel.
- **Phase 3** teaches **layer (b) (the "intermediate layer")**.
- **Phase 4** teaches **layer (c) (the "intermetallic layer")**.
- **Phase 5** teaches **layer (d) (the "superficial layer").**

45. These phases are included in the coating ("diffusion layer") and "proceed[] from the base steel outwards."



Annotated Engels FIG. 5

46. The ’602 Patent does not describe that the names for each of the layers (that is, “interdiffusion,” “intermediate,” “intermetallic,” and “superficial”) denote any particular characteristics of the layers. However, phases 1 or 1+2, 3, 4, and 5 satisfy the meanings of each of those terms as proposed by Petitioner during IPR proceedings for the ’683 Patent. EX-1031, 22-24. Phase 1 (or phases 1 and 2 together) is formed by diffusion. EX-1005, 141. Phase 3 is intermediate between other phases, e.g., between phases 1/2 and 4. Phase 4 is intermetallic in that it is

composed of two or more metals or a metal and a nonmetal in an alloy. Engels Table. Phase 5 is superficial in that it is arranged at the surface of the coating. Engels FIG. 5.

47. Further, claim 1 does not recite that the layers must be adjacent to one another, such that, for example, the arrangement of phase 2 at least partially between phase 1 and phase 3 is no impediment to the mapping of phase 1 to layer (a) and phase 3 to layer (b). To the extent Patent Owner disputes this mapping, I discussed above that layer (a) can equally be mapped to a composite layer formed by phases 1 and 2. My comments herein with respect to layer (a) or phase 1 apply equally to this composite layer of phases 1 and 2.

48. Engels discloses or renders obvious that layers (a), (b), (c), and (d) have the recited mean iron compositions. Engels' Table provides elemental compositions for each of phases 1 and 3-5, which correspond to layers (a)-(d), respectively. Each of these layers has a different iron composition from one another, and phase 4 (corresponding to layer (c)), has a mean iron composition greater than the mean iron composition of phase 3 (corresponding to layer (b)).

Differing Fe compositions

	phase number	layer thickness, µm	Al	Fe	Si	Cr	Mn
			~~Volume-%~~ Mass-%				
Layer (a)	1	5 – 9	7,2	89,2	1,9	0,3	1,4
[Layer (a)]	2	< 1µm	unmeasurable				
Layer (b)	3	11 – 18	51,4	45,9	1,9	0,1	0,7
Layer (c)	4	3 – 8	33,9	54,3	10,6	0,3	0,9
Layer (d)	5	5 - 11	53,2	44,1	1,9	0,2	0,6

Fe% (layer (c)) > Fe% (layer (b))

Annotated Engels Table

49. Engels discloses the "chemical composition" of each phase, not explicitly a "mean" composition. However, a POSITA would have understood that, in the field of steel metallurgy, a disclosure of a composition for a material, phase, or layer implicitly is, and would have been understood as, a disclosure of a **mean** composition of the material, phase, or layer. For example, a researcher might sample several representative portions of a material and average the corresponding compositions to obtain values representative of a mean composition of the material. In the case of the hot-stamped coatings discussed herein, the POSITA would have likely selected at least several points in the coating's cross-section to analyze using EDS. Any other type of disclosed composition would be much less useful and less well-defined.

50. Absent a statement or suggestion otherwise – which Engels does not include – a POSITA would have understood Engels' disclosures of compositions to

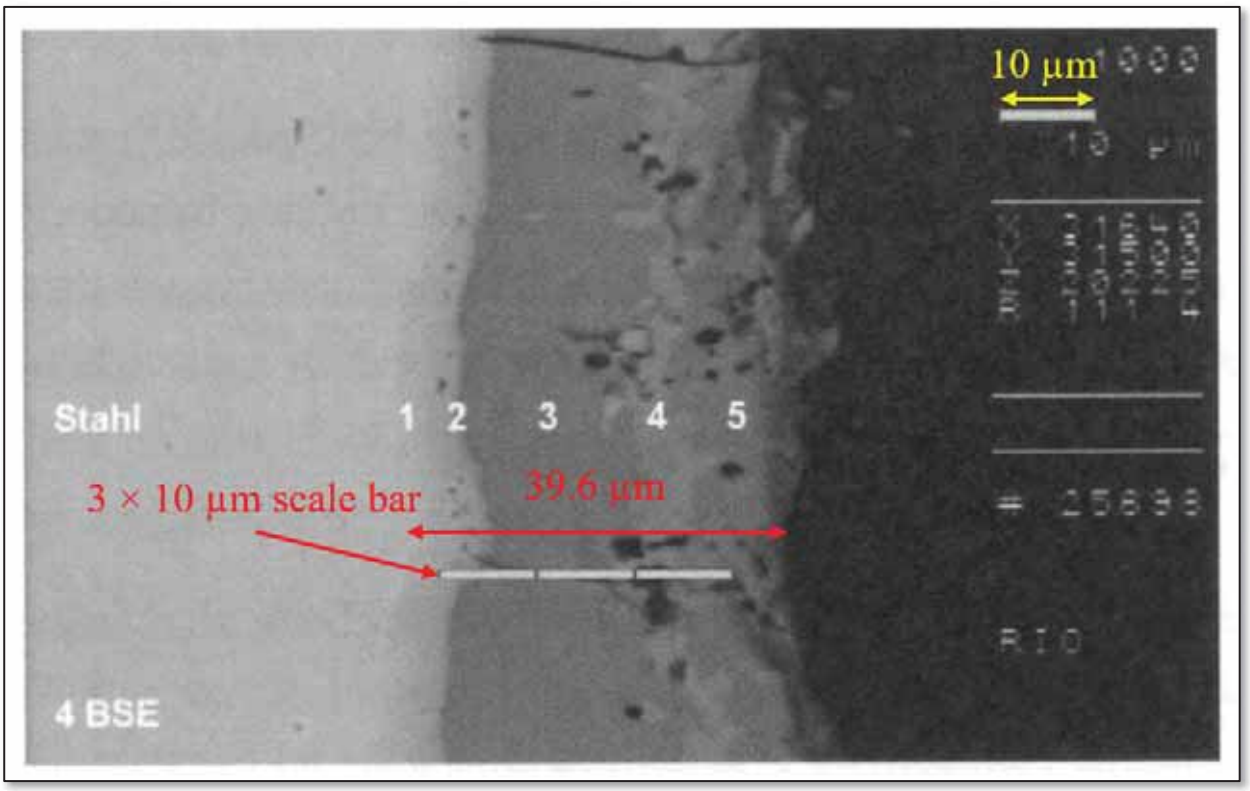
be disclosures of **mean** compositions, thereby satisfying this claim element.

51. Alternatively, to the extent Engels' compositions may not be "mean" compositions, it would have been obvious to treat these compositions as mean compositions when interpreting Engels and, for example, use these compositions as mean compositions when applying Engels' teachings. "Mean" composition is by far the most common way to report a composition and would have been the most accessible measure of a layer's composition for a POSITA seeking to apply Engels' teachings to hot-stamped steel. In order to obtain Engels' diffusion layer, a POSITA would have sought to form a diffusion layer in which Engels' compositions are mean compositions.

[1h]: wherein the coating of the hot stamped coated steel product has a thickness greater than 30 micrometers.

52. Engels discloses that the coating has a thickness greater than 30 micrometers. For example, I have performed a direct measurement in Engels FIG. 5 (shown below) based on the included 10 μm scale. This and other measurements herein (for example, measurements of layers in Hein and Cornette) were conducted by using an on-screen pixel ruler and the included scale to determine a conversion between pixels and μm, and then applying the conversion to pixel measurements of the layers/coatings. In all cases, the images used do not appear distorted, such that the dimensions can be measured with a high degree of accuracy.

53. In the case of FIG. 5, I measured the coating thickness based on the phase shadings, which, as I discussed above, are representative of different compositions. This measurement shows a thickness of **39.6 µm**, well beyond the recited 30 µm threshold value. This disclosure, in combination with the other teachings of Engels discussed above, directly teaches claim 1. A POSITA would have understood that measurements at other positions would result in different measured thicknesses, which would be more or less than 39.6 µm and would be equally valid as the 39.6 µm measurement. This statement also applies to other measured thicknesses of coatings and layers herein.



Annotated Engels FIG. 5

27

54. Alternatively, Engels renders obvious that the coating has a thickness greater than 30 μm based on the disclosed thickness ranges in Engels' Table. Many combinations of the disclosed ranges result in a total coating thickness greater than 30 μm. For example, assuming that each phase has a value in the middle of the disclosed range (7 μm for phase 1, 14.5 μm for phase 3, 5.5 μm for phase 4, and 8 μm for phase 5), and neglecting any thickness of phase 2, results in a coating thickness of **35 μm**. Even assuming that each phase has a value one-third of the way through its disclosed range (toward the lower end) results in a coating thickness of **31.3 μm**, again satisfying this claim element. Any marginal thickness contributed by phase 2 would not substantively alter this reasoning in the case where layer (a) is mapped to phases 1+2.

55. Generally, the Engels Chart discloses ranges of total coating thickness from 24 μm (assuming each phase has its lowest-disclosed thickness) to 46 μm (assuming each phase has its highest-disclosed thickness). This range overlaps the claimed range of "greater than 30 micrometers," which, according to my understanding, renders the claimed range obvious. I am informed that a presumption of obviousness applies where a claimed range overlaps with a range disclosed in the prior art, but that this presumption can be overcome if the prior art teaches away from the claimed range, or the claimed range produces new and unexpected results. Here, Engels does not teach away from the claimed range, and,

indeed, discloses a specific value within the claimed range. In addition, the ’602 Patent does not assert that the claimed range of “greater than 30 micrometers” is associated with any unexpected results relative to the range disclosed by Engels. Although the range is described as “a preferred embodiment,” the ’602 Patent fails to discuss any particular effects, results, or criticality associated with the range, and certainly does not describe that these results would be unexpected relative to the ranges disclosed by Engels. EX-1001, 6:44-45.

56. And, according to my understanding of materials science, such criticality or unexpected results would be very unlikely. For example, a POSITA would expect a 31 μm coating to exhibit essentially the same properties as a 29 μm coating.

57. Moreover, it would have been obvious to try varying and experimenting with the coating thickness based on Engels’ disclosure that “it is crucial to look for a correctly shaped diffusion layer with regard to **layer thickness** [] as this layer will decisively impact the corrosion and welding properties of the hot stamped parts.” EX-1005, 142. Coating thickness was generally recognized as an important parameter both for physical layer properties and for industrial application. For example, as discussed in more detail below in Section XIII.C, suppliers of hot-stamped steel parts for General Motors were required to provide coatings with a thickness greater than 35 μm. EX-1026, 7. And JP2004244704

describes that "[a] thickness of 20 μm or more is preferred because a thicker layer responsible for corrosion resistance results in greater overall corrosion resistance and a longer material life." EX-1034, [0013].

58. In addition, the prior art recognized that coating thickness could be tuned at least by adjustment of the pre-coating thickness. For example, FR2833504 describes that alloying of a pre-coating "generally corresponds to a 50% increase" in thickness for the resulting coating. EX-1025, 5:17-20. And GMW14400 provides guidelines for pre-coating thickness in order to achieve the required coating thickness. EX-1026, 7.

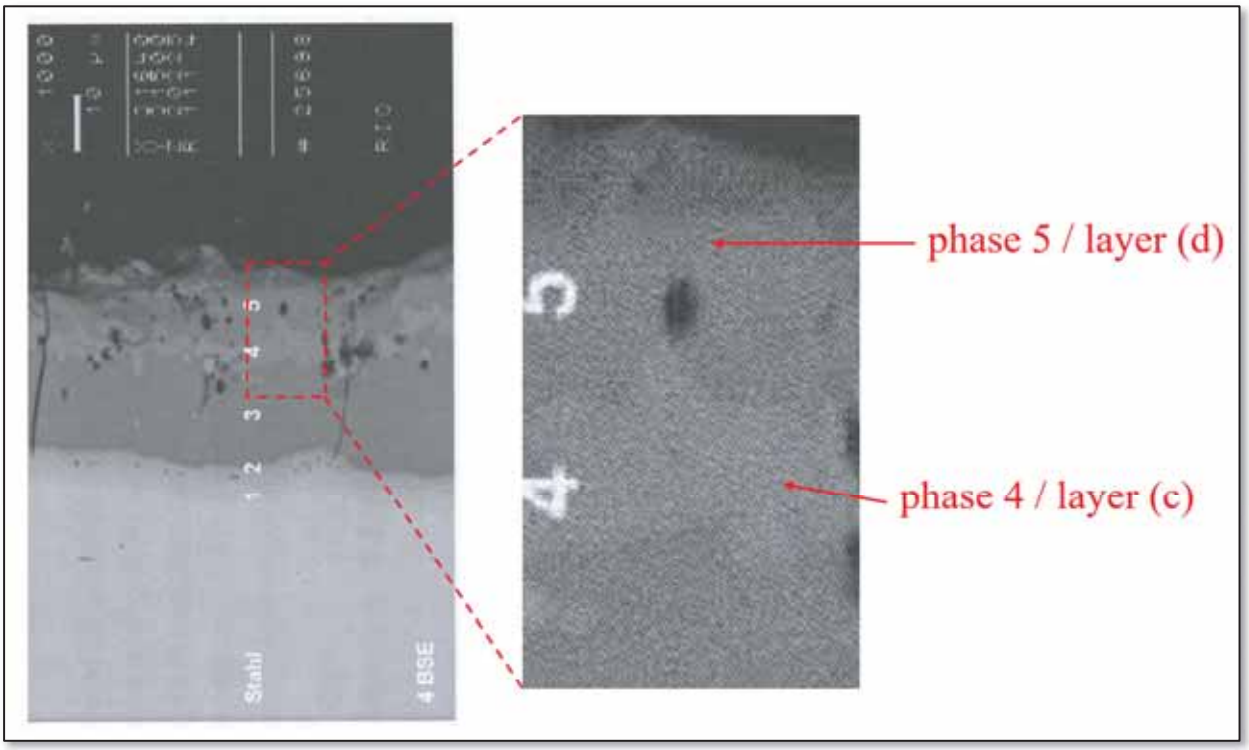
59. Accordingly, Engels directly discloses (Ground 1A-102) or renders obvious (Ground 1A-103) claim 1.

[2]: The precoated steel product as recited in claim 1 wherein the layers (c) and (d) are quasi continuous by occupying at least 90% of a level corresponding to each of the layers (c) and (d) and wherein less than 10% of layer (c) is present at an extreme surface of the product.

60. Engels renders obvious claim 2. For "*less than 10% of layer (c) is present at an extreme surface of the product*," Engels FIG. 5 shows that essentially none of phase 4 (corresponding to layer (c)) is present at the extreme surface of Engels' coating. EX-1005, FIG. 5. This is evident by an examination of Engels FIG. 5, in which the lighter-colored phase 4 is entirely or essentially entirely

covered by the darker phase 5.

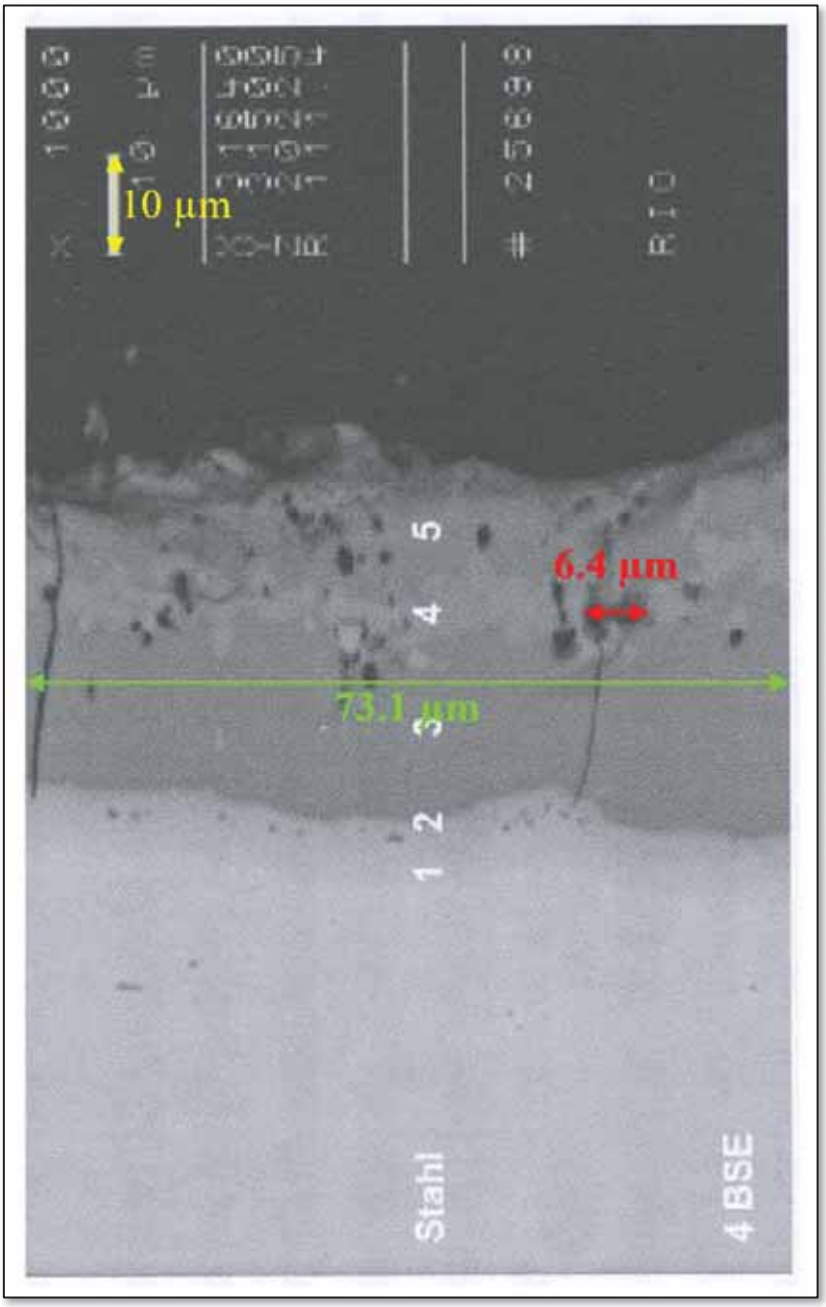
61. With respect to "the layers (c) and (d) are quasi continuous by occupying at least 90% of a level corresponding to each of the layers (c) and (d)," Engels FIG. 5 illustrates that each of phases 4 and 5 extends continuously or essentially continuously, e.g., as illustrated in the segment of FIG. 5 enlarged below. Claim 2 merely refers to "a level corresponding to each of the layers" and, thus, the enlarged segment of FIG. 5 demonstrates "a level" of phases 4 and 5 that satisfies claim 2.



Annotated Engels FIG. 5 (enlarged view)

62. Even across the entire SEM image in FIG. 5 above, phases 4 and 5 extend continuously or essentially continuously across the **entire image** (as shown

above), except perhaps for one segment of phase 4 indicated in red below. A POSITA would have considered the layer to be continuous or essentially continuous (or quasi continuous) despite this pore. To the extent that this pore is considered to make the layer discontinuous, the indicated segment occupies only about 9% of the total width of FIG. 5, such that phase 4 is “quasi-continuous.”



Annotated Engels FIG. 5

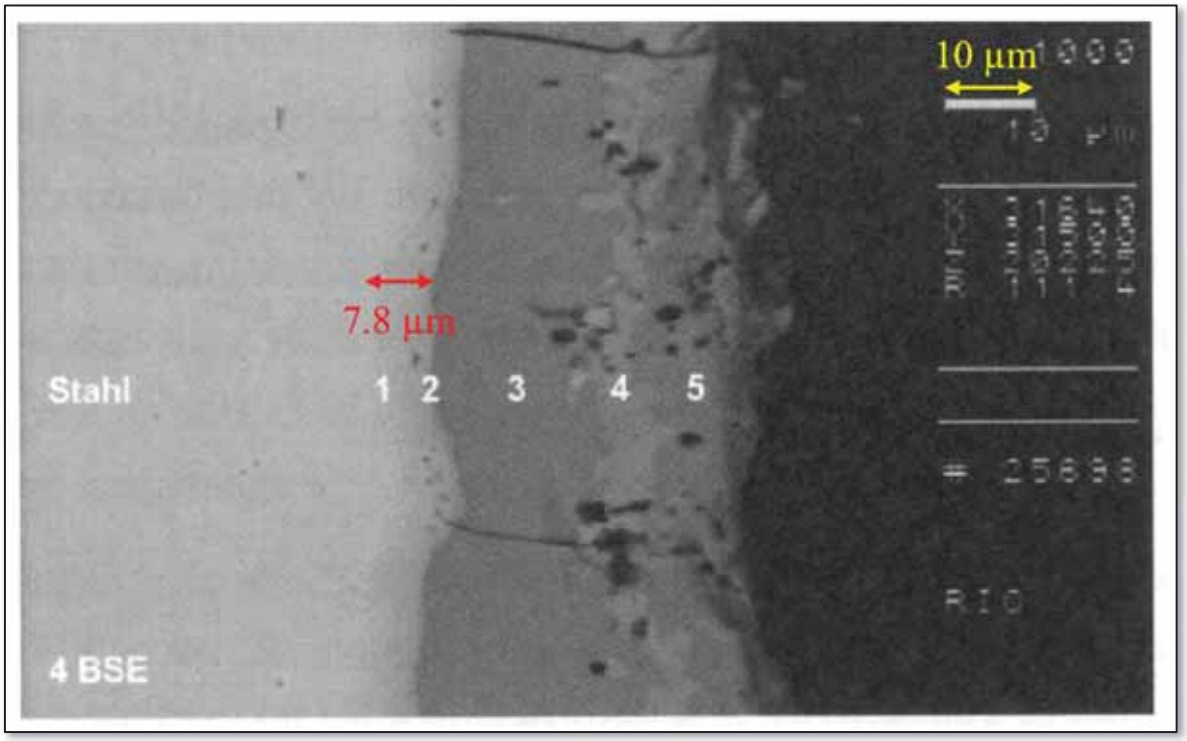
63. In view of the above, Engels renders obvious claim 2.

[9]: The precoated steel product as recited in claim 1 wherein the layer (a) has a thickness less than 15 micrometers.

[10]: The precoated steel product as recited in claim 1 wherein the layer (a) has a thickness less than 10 micrometers.

64. Engels discloses or renders obvious that layer (a) has a thickness of less than 15 or 10 micrometers. As disclosed in Engels' Table, phase 1 (corresponding to layer (a)) has a thickness in a range from **5-9 µm**, such that all thicknesses satisfy both "less than 15 micrometers" and "less than 10 micrometers." EX-1005, 143. Any marginal thickness contributed by phase 2 would not substantively alter this reasoning in the case where layer (a) is mapped to phases 1+2.

65. As confirmation, I directly measured a phase 1 or phase 1+2 thickness of **7.8 µm** in Engels FIG. 5, as shown below.



Annotated Engels FIG. 5

[11]: The precoated steel product as recited in claim 1 wherein the interdiffusion layer comprises the following components by weight based on total weight: 86 to 95% Fe, 4 to 10% Al, and 0 to 5% Si.

66. Engels discloses or renders obvious the foregoing composition. As discussed at [1d], the interdiffusion layer is mapped to Engels phase 1. Further, Engels' Table discloses that phase 1 has weight composition of **89.2% Fe, 7.2% Al**, and **1.9% Si**. EX-1005, 143. *See* above at Section VI.A for discussion of the interpretation of the composition values in Engels' Table as weight percentages.

67. Moreover, a POSITA would have understood the percentages

disclosed by Engels to be percentages "based on **total** weight." This is implied by Engels' additional disclosure of Cr and Mn content, which suggest that Engels is considering all non-negligible components, not just Fe, Al, and Si, in providing elemental concentrations. Absent disclosure otherwise, a POSITA would have understood that the disclosed compositions reflect percentages based on total weight, given that a POSITA would have expected the percentages to reflect the general overall composition with a possible small percentage of impurities.

[12]: The precoated steel product as recited in claim 1 wherein the intermediate layer comprises the following components by weight based on total weight: 39 to 47% Fe, 53 to 61% Al, and 0 to 2% Si.

68. Engels renders obvious the foregoing composition. As discussed at [1e], the intermediate layer is mapped to Engels phase 3. Further, Engels' Table discloses that phase 3 has weight composition, by total weight, of **45.9% Fe, 51.4% Al**, and **1.9% Si**. EX-1005, 143. See above at [11] for citations relevant to this interpretation of Engels' Table.

69. The disclosed Fe% and Si% of Engels phase 3 satisfy the ranges of claim 12, while the Al% is slightly outside of the claimed range (**51.4%** compared to **53-61%**). However, I am informed that a claimed amount that does not overlap with, but is close to, a prior art amount, is obvious absent evidence of unexpected results or teaching-away. Here, the '602 Patent describes no criticality or

unexpected results for a range of 53-61% Al compared to the very similar art value of 51.4% Al. Based on my metallurgical experience, I would not expect there to be any qualitative difference in layer properties between a 51.4% Al layer and a 53% Al layer.

70. A POSITA would have been motivated to experiment with various Al% so as to arrive at the claimed Al% range. First, a POSITA would have naturally understood that the concentration of a primary component in a layer would have been relevant for determining properties of that layer, e.g., determining "layer thickness, porosity, and[/or] roughness" as described by Engels. EX-1005, 142. Engels' disclosure of the Al composition of each phase would have reinforced this understanding. A POSITA would have also been aware of other art teaching Al% as a result-effective variable, e.g., Takagi's and JP2004244704's disclosures that Al% at least partially determines corrosion resistance. EX-1016, [0021]; EX-1033, [0012]. And a POSITA would have had a reasonable expectation of success in arriving at the claimed Al% based on Engels' disclosure of the various process parameters that determine characteristics of the coating ("heating rate," "total processing time," "maximum austenitizing temperature," and "material thickness"). EX-1005, 142.

71. I further note that a difference of 1.6% in Al concentration (the difference between 51.4% and 53%) would have been well within manufacturing

tolerances for a micron-scale layer in a thin, multi-layer coating. Layers would never be perfectly uniform, and the composition of the layer would be expected to vary from part-to-part and within a given part, e.g., because the composition of an area of measurement can be affected by adjacent areas of different compositions.

72. It follows that the disclosed composition of Engels' phase 3 renders obvious the claimed composition of the intermediate layer.

[13]: The precoated steel product as recited in claim 1 wherein the intermetallic layer comprises the following components by weight based on total weight: 62 to 67% Fe, 30 to 34% Al, and 2 to 6% Si.

73. Engels renders obvious the foregoing composition based on its teaching that phase 4 (mapped to the intermetallic layer; *see* [1f] above) has weight %, by total weight, of **54.3% Fe, 33.9% Al**, and **10.6% Si**. EX-1005, 143. See above at [11] for citations relevant to this interpretation of Engels' Table.

74. Of these values, the Al% is within the claimed range, while the Fe% and the Si% are outside, but close to, their claimed ranges. For the reasons discussed with respect to [12] above, absent a showing of criticality or unexpected results, the values taught by Engels are sufficient to render obvious the claimed ranges. For example, the '602 Patent fails to describe a "difference in kind and not of degree" resulting from an Fe% of 62% compared to 54.3%, or from a Si% of 6% compared to 10.6%, for a single layer in a four-layer coating. Indeed, based on

my professional and academic experience, a POSITA would not have expected there to be any such qualitative difference in properties, as the differences in composition are not greater than many ranges given for nominal steel compositions, which can routinely span 20% or more. *See*, e.g., EX-1047, Table 1.

75. A POSITA would have recognized each of Fe%, Si%, and Al% as result-effective, for example, based on Engels and common knowledge in the art as set forth for claim 19 above. In addition, a POSITA would have been aware of Takagi's teaching that Fe% is important for determining layer hardness, JP2004244704's disclosure that the Si% is associated with/an indicator of the Al%, and WO02/103073's disclosure that Si% and Al% modulate layer hardness, workability, weldability, and/or corrosion resistance. EX-1016, [0020]; EX-1033, [0012]; EX-1035, 25:21-28, 29:3-7, 31:6-12. These disclosures would have motivated a POSITA to perform routine experimentation in modifying these concentrations.

76. Further, as discussed for [12], Engels discloses various process parameters that determine characteristics of the coating ("heating rate," "total processing time," "maximum austenitizing temperature," and "material thickness"), providing a POSITA a reasonable expectation of success in arriving at the claimed values. EX-1005, 142.

77. Accordingly, Engels renders obvious the claimed composition.

[14]: The precoated steel product as recited in claim 1 wherein the superficial layer comprises the following components by weight based on total weight: 39 to 47% Fe, 53 to 61% Al, and 0 to 2% Si.

78. Engels discloses or renders obvious the foregoing composition. The superficial layer is mapped to Engels phase 5, as discussed at [1g]. Engels' Table discloses that phase 5 has weight composition, by total weight, of **44.1% Fe, 53.2% Al**, and **1.9% Si**. See above at [11] for citations relevant to this interpretation of Engels' Table. Each of these described composition values satisfies the recited range.

[15]: See [12] above.

[16]: See [13] above.

[17]: See [14] above.

[18]: The precoated steel product as recited in claim 1 wherein the interdiffusion layer has a thickness of from 1 micron to 15 microns.

79. As disclosed in Engels' Table, phase 1 (corresponding to the interdiffusion layer – see [1d] above) has a thickness in a range from **5-9 µm**, such that all thicknesses satisfy the recited range. EX-1005, 143. Any marginal thickness contributed by phase 2 would not substantively alter this reasoning in the case where layer (a) is mapped to phases 1+2. *See also* [10] above.

[19]: The precoated steel product as recited in claim 1 wherein the first

mean iron composition is 90 percent, the second mean iron composition is 43 percent, the third mean iron composition is 63 percent and the fourth mean iron composition is 45 percent.

80. Engels renders obvious that layers (a)-(d) have mean iron compositions of 90%, 43%, 63%, and 45%, respectively. Engels' Table discloses Fe% for the corresponding phases of **89.2%, 45.9%, 54.3%,** and **44.1%**. For similar reasons to those discussed for [12] and [13], absent a showing of criticality or unexpected results, the values taught by Engels render obvious the claimed values. The '602 Patent fails to describe a "difference in kind and not of degree" associated with the differences between claim 19's Fe% and Engels'. And, as discussed for [12] and [13], it would have been obvious for a POSITA to arrive at these values as the result of routine experimentation with a reasonable expectation of success.

[20]: The precoated steel product as recited in claim 1 wherein the fourth mean iron composition is lower than the third mean iron composition.

81. Engels discloses or renders obvious that the mean iron composition for layer (d) is lower than the mean iron composition for layer (c). Engels' Table discloses Fe% of **44.1%** and **54.3%** for these respective values, where phase 4 corresponds to layer (c) and phase 5 corresponds to layer (d). EX-1005, 143. *See* [1f]-[1g].

[21]: A precoated steel product comprising:

a strip of base steel having a first side and a second side; and a coating on at least one of the first side of the strip of base steel and the second side of the strip of base steel, wherein the coating results from interdiffusion between the base steel, and an aluminum or aluminum alloy pre-coating, and wherein the coating includes, proceeding from the base steel outwards:

(a) an interdiffusion layer having a first mean iron composition,

(b) an intermediate layer having a second mean iron composition different from the first mean iron composition,

(c) an intermetallic layer having a third mean iron composition different from the first and second mean iron compositions, the third mean iron concentration being higher than the second mean iron composition, and

(d) a superficial layer having a fourth mean iron composition different from the first, second and third mean iron compositions,

wherein the coating has a thickness greater than 30 micrometers.

82. *See* claim 1 above. Claim 21 is identical to claim 1 except for additionally reciting that the fourth mean iron composition is different from the first and second mean iron compositions. This element is disclosed in Engels' Table, which describes that the iron compositions are **89.2%, 45.9%, 54.3%,** and **44.1%** for layers (a)-(d), respectively. EX-1005, 143.

[22]: See [20] above.

[23]: The precoated steel product as recited in claim 22 wherein the fourth mean iron composition is higher than the second mean iron composition.

83. Engels renders obvious that the fourth mean iron composition (of layer (d)) is higher than the second mean iron composition (of layer (b)). Engels' Table discloses values of **44.1%** (phase 5) and **45.9%** (phase 3) for these mean iron compositions, respectively. EX-1005, 143.

84. For similar reasons to those discussed for [12], absent a showing of criticality or unexpected results, the values taught by Engels render obvious the claimed relationship. For example, a 1% increase in Engels' phase 3 Fe% and a 1% decrease in Engels' phase 5 Fe% would result in layers satisfying claim 23, and this modification would have been obvious for the reasons discussed for [12]. Moreover, based on my experience, a POSITA would not expect any qualitative difference in coating characteristics for Engels' disclosed Fe% compared to if the values were reversed (which would satisfy claim 23). And, as I noted for [12], the slight change in composition necessary to satisfy claim 23 would have been well within manufacturing tolerances.

[24]: A precoated steel product comprising:

a strip of base steel having a first side and a second side; and

a coating on at least one of the first side of the strip of base steel and the

second side of the strip of base steel, wherein the coating results from interdiffusion between the base steel, and an aluminum or aluminum alloy pre-coating, and wherein the coating includes, proceeding from the base steel outwards:

(a) an interdiffusion layer having a first mean aluminum composition,

(b) an intermediate layer having a second mean aluminum composition different from the first mean aluminum composition,

(c) an intermetallic layer having a third mean aluminum composition different from the first and second mean aluminum compositions, and

(d) a superficial layer having a fourth mean aluminum composition different from the first, second and third mean aluminum compositions, the second mean aluminum composition being greater than the third mean aluminum composition;

wherein the coating has a thickness greater than 30 micrometers.

85. *See* claim 1 above. Claim 24 is identical to claim 1 except that (i) mean **aluminum** compositions are recited instead of mean iron compositions, (ii) the fourth mean Al% is "different from the first, second and third mean" Al%, and (iii) "the second mean aluminum composition [is] greater than the third mean aluminum composition." These elements are disclosed in Engels' Table, which describes that the aluminum compositions are **7.2%, 51.4%, 33.9%,** and **53.2%** for layers (a)-(d), respectively. EX-1005, 143.

Differing Al compositions

	phase number	layer thickness, µm	Al	Fe	Si	Cr	Mn
			~~Volume-%~~ Mass-%				
Layer (a)	1	5 – 9	7,2	89,2	1,9	0,3	1,4
[Layer (a)]	2	< 1µm	unmeasurable				
Layer (b)	3	11 – 18	51,4	45,9	1,9	0,1	0,7
Layer (c)	4	3 – 8	33,9	54,3	10,6	0,3	0,9
Layer (d)	5	5 – 11	53,2	44,1	1,9	0,2	0,6

Al% (layer (b)) > Al% (layer (c))

Annotated Engels Table

[25]: The precoated steel product as recited in claim 24 wherein the fourth mean aluminum composition is less than the second mean aluminum composition.

86. Engels' Table discloses that the fourth Al% is **53.2%**, while the second Al% is **51.4%**. EX-1005, 143.

87. For similar reasons to those discussed for [12] and [23], absent a showing of criticality or unexpected results, the values taught by Engels render obvious the claimed relationship. For example, a 1% increase in Engels' phase 3 Al% and a 1% decrease in Engels' phase 5 Al% would result in layers satisfying claim 25, and this modification would have been obvious, with the change in values within typical manufacturing tolerances and achievable by routine experimentation with a reasonable expectation of success. Further, a POSITA would have known that the recited relationship would not be associated with a qualitative or unexpected change in characteristics compared to the composition

relationship of Engels' Table.

88. *[26]: See* [9] above.

89. *[27]-[30]: See* [11]-[14] above.

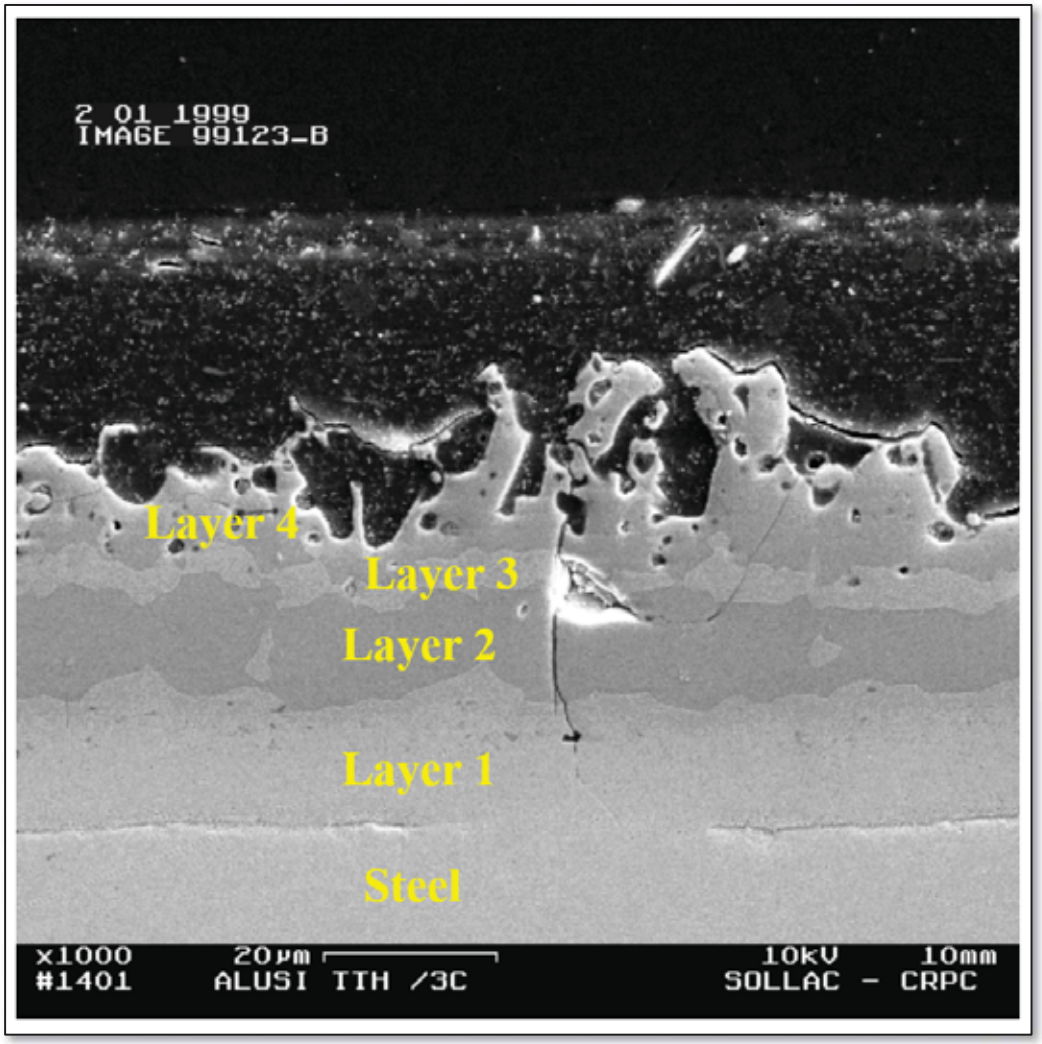
VII. GROUND 1B: Claims 2 and 5-6 are obvious over Engels in view of Cornette

A. Cornette

90. Cornette describes "mechanical testing and different design solutions associated with" certain steel grades. EX-1014, 3. "A specific part of [Cornette] deals with a ultra high tensile strength pre-coated boron steel for hot forming." *Id*. Specifically, Cornette describes the use of "USIBOR 1500" steel in a hot-stamping (or "hot forming") process. *Id*., 9. A "hot dipped" aluminum-silicon pre-coating with average thickness 25 μm is applied to the steel, and the pre-coated steel is heated at "generally 900˚C [for] 5 minutes" and hot-stamped to obtain, as a result of an "alloying reaction between substrate [] and the coating," an "Fe-Al-Si layer [] at the steel surface" that is "typically about 40 μm." *Id*., 9.

91. FIG. 22 of Cornette, reproduced below, shows the coating (a "multiphase alloy layer"), in which four distinct layers are visible. *Id*. It would have been clear to a POSITA that these four layers constitute the Fe-Al-Si coating, with an indicated base steel region underneath. The morphology at the top of the coating (top of indicated layer 4) is representative of a top layer, not of a layer

adjacent to base steel. And the coating forms part of a hot-stamped product, for example, for the reasons discussed in the ’683 Patent’s IPR, in which it was found that these layers and the underlying steel form a “stamped product.” EX-1029, 32-35.



Annotated Cornette FIG. 22

B. Combination of Engels and Cornette

92. It would have been obvious to apply Cornette’s process-related

disclosure to Engels to obtain a coating having layer compositions at least similar to those described by Engels, with the layer thicknesses described by Cornette. Engels describes hot-stamping with heat treatment generally at "temperatures between 900 ˚C and 950 ˚C," and a POSITA would have understood general ranges of other process parameters (e.g., austenitization time, a specific austenitization temperature, and pre-coating thickness) based on general knowledge in the art.

93. To identify specific numerical values of process parameters, a POSITA would have been motivated to consider values used in similar prior art processes such as that of Cornette. It would have been obvious to a POSITA to follow or be generally guided by Cornette's teachings when experimenting with hot-stamping processes, e.g., by using the disclosed "USIBOR 1500" steel and/or by performing a 900˚C austenitization for five minutes using a 25 μm pre-coating. EX-1014, 9-10. As I noted above in Section VI.B, these parameters would have been easily configurable by a POSITA, and a POSITA would have also had access to the disclosed USIBOR 1500, which was commercially available at the time.

94. Moreover, 22MnB5 and USIBOR 1500 have similar compositions, such that the substitution of one for the other would have constituted a minor modification within the general conditions of what was already in use. These compositions are shown in the table below. EX-1037, Table 1; EX-1014, 9. Indeed,

Engels references USIBOR 1500 steel, such that a POSITA would have known that the use of USIBOR 1500 would not represent a notable departure from Engels' teachings. EX-1005, 139.

Element	**22MnB5 Composition (%)**	**USIBOR 1500 Composition (%)**
C	0.233	$0.2 \leq C\% \leq 0.25$
Mn	1.23	$1.1 \leq Mn\% \leq 1.35$
Si	0.24	$0.15 \leq Si\% \leq 0.35$
Cr	0.14	$0.15 \leq Cr\% \leq 0.3$
Ti	0.033	$0.02 \leq Ti\% \leq 0.05$
Al	0.035	$0.02 \leq Al\% \leq 0.06$
P	0.018	--
S	0.001	≤ 0.008
B	0.0022	$0.002 \leq B\% \leq 0.004$
Ni	0.023	--

95. The POSITA would have been further motivated by Cornette's reporting that these parameters provide good results in terms of weldability, corrosion resistance, and mechanical strength. EX-1014, 10.

96. A POSITA would have had a reasonable expectation of success in making the combination. The process parameters noted by Cornette would all have been readily available to a steel metallurgist working on hot-stamping. And the coatings disclosed by Engels and Cornette are quite similar: each includes four primary layers identifiable using electron microscopy (in the case of Engels, five total phases, where the second phase is negligible and/or where the first and second phases together are interpreted as one layer), and each is approximately 40 μm

thick (*see* [1h] above). Moreover, Engels' disclosure of using temperatures "between 900 ˚C and 950 ˚C" suggests that Engels' FIG. 5 coating was processed under conditions generally similar to those of Cornette, which discloses thermal treatment at 900 ˚C. EX-1014, 3.

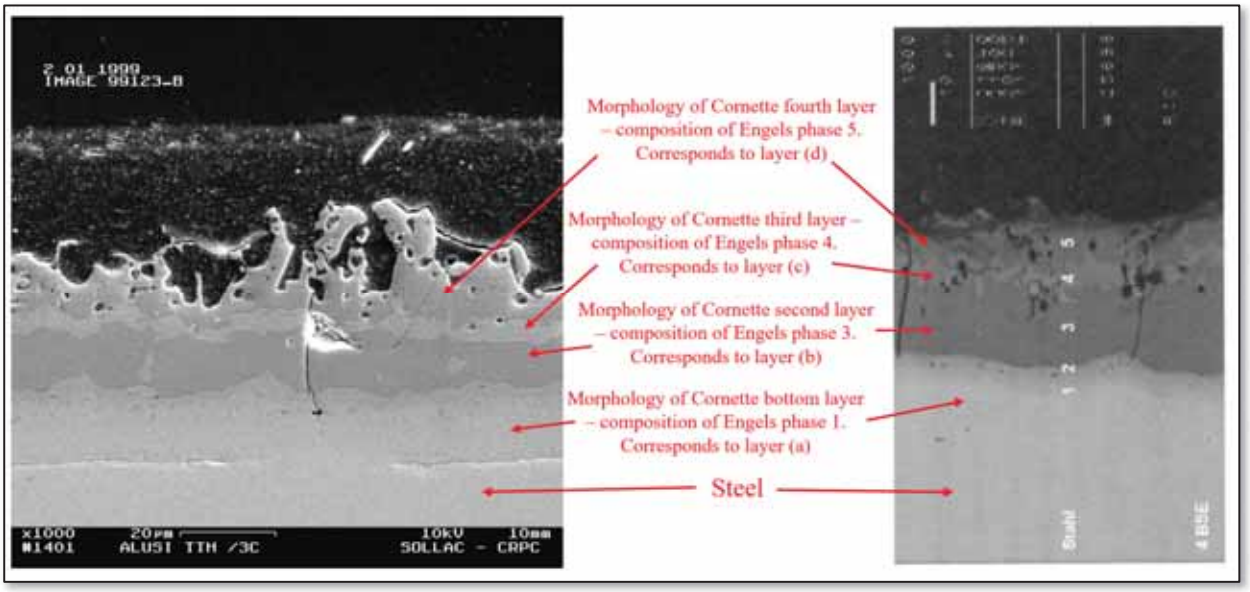
97. And Engels itself provides detailed guidance that "heating rate," "total processing time," "maximum austenitizing temperature," and "material thickness" are all process parameters that can be tuned to achieve a "correctly shaped diffusion layer." EX-1005, 142.

98. Accordingly, it would have been obvious to a POSITA to apply Cornette's teachings to obtain a "**modified Engels coating**" in which the four layers have the thicknesses and morphologies described by Cornette, and compositions like those described by Engels, as shown below. By adjustment of the parameters identified by Engels and guided by Cornette's teachings, a POSITA would have been able to adjust the hot-stamping process to arrive at such a layer as a matter of design choice and routine experimentation, and as an example of a layer that it would have been obvious to try manufacturing and testing, given that there are only a finite number of options for the thicknesses of four layers in the four-primary-layer, approximately 40 μm coating disclosed by both Engels and Cornette.

99. Certainly, layer thickness/morphology and composition may be

associated with one another. For example, based on my experience, a POSITA would expect that a given change to austenitization temperature might affect both coating and/or layer thickness **and** the composition of one or more layers, such that a POSITA would have had to exercise care when performing experimentation, e.g., to generally retain a multi-layer structure with target hardness and corrosion resistance. However, this type of optimization was well-established and would have constituted merely routine optimization in the field. I note, for example, Takagi's clear description of how the high-temperature diffusion process proceeds to form a multi-layer coating. EX-1016, [0019].

100. I also note that, in order to satisfy claim 1, the layers of the modified coating need not have **exactly** the same compositions as those disclosed by Engels but merely satisfy the recited Fe% relationships, which would be satisfied even for moderate deviations from the Fe% in Engels' Table.



<u>Modified Engels coating</u>

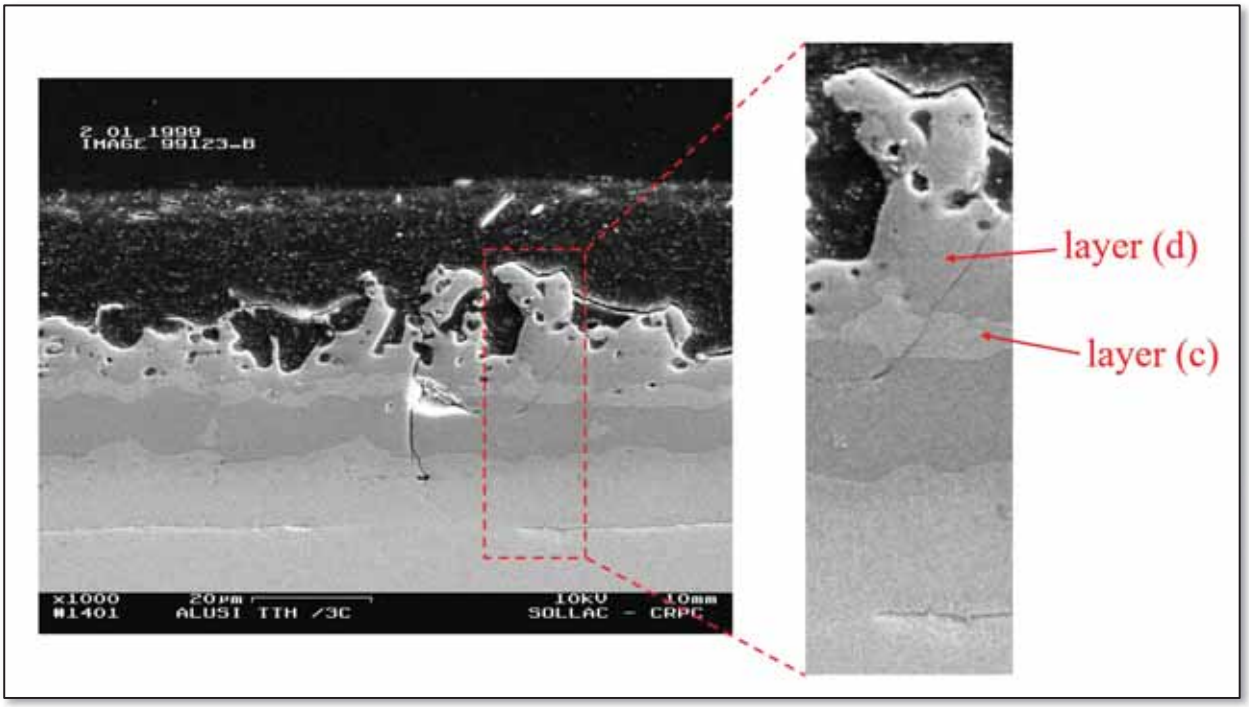
C. Analysis of Claims

[2]: The precoated steel product as recited in claim 1 wherein the layers (c) and (d) are quasi continuous by occupying at least 90% of a level corresponding to each of the layers (c) and (d) and wherein less than 10% of layer (c) is present at an extreme surface of the product.

101. The combination of Engels and Cornette renders obvious claim 2. For "*less than 10% of layer (c) is present at an extreme surface of the product*," Cornette FIG. 22 shows that essentially none of layer (c) of the modified coating is present at the extreme surface of the coating. EX-1014, FIG. 22. In analyzing Cornette FIG. 22, I identified layers based on their relative shading. Layers (c) and (d) were clearly distinguishable from one another and from other layers/materials

shown in FIG. 22.

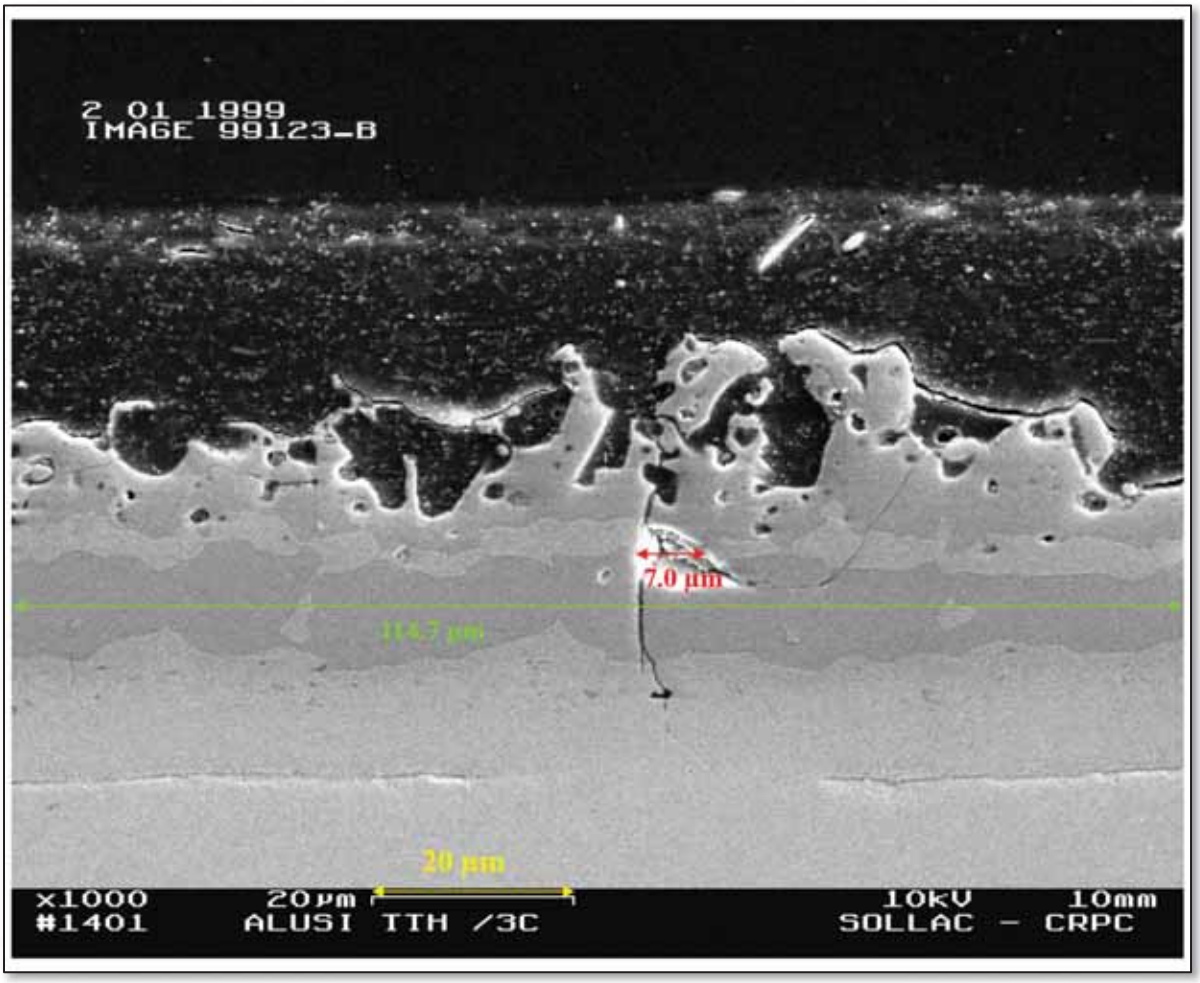
102. With respect to the first element of claim 2, as shown below, Cornette's uppermost two layers (mapped to (c) and (d)) extend continuously or essentially continuously, e.g., as illustrated in the segment of FIG. 22 enlarged below. Claim 2 merely refers to "a level corresponding to each of the layers" and, thus, the enlarged segment of FIG. 22 demonstrates "a level" of layers (c) and (d) that satisfies claim 2.



Annotated Cornette FIG. 22 (enlarged view)

103. Even across the entire SEM image in FIG. 22, these layers extend continuously or essentially continuously across the **entire image**, except perhaps for one segment (indicated with red below). A POSITA would have considered the

layer to be continuous or essentially continuous (or quasi continuous) despite this segment. To the extent that this segment is considered to make the layer discontinuous, the segment occupies only about 6% of the total width of FIG. 22. Therefore, layer (c) in Cornette FIG. 22 is "quasi-continuous." Indeed, the red section appears to be damage imparted after cross-sectioning was performed (e.g., an indentation in the coating) and is almost certainly an artifact originating post-processing, such that a correct analysis would include the red section, resulting in layer (c) being fully continuous across FIG. 22.



Annotated Cornette FIG. 22

[5]: The precoated steel product as recited in claim 1 wherein the base steel comprises 20 ppm or less of sulfur.

104. As discussed in Section VII.B, it would have been obvious to use Cornette's USIBOR 1500 steel (also mentioned in Engels) as the base steel. Cornette discloses that this steel has sulfur composition ≤ 0.008%, or ≤ 80 ppm. EX-1014, 9. Given this disclosure, the recited range of "20 ppm or less," which is entirely encompassed by the prior art range, would have been obvious. For

example, it would have been obvious for a steel researcher to seek to optimize the sulfur concentration within Cornette's range, eventually arriving at the recited sulfur concentration.

[6]: The precoated steel product as recited in claim 2 wherein the base steel comprises 20 ppm or less of sulfur.

105. *See* [2] in Sections VI.B and VII.C, and [5] above. [6] is obvious based on the reasoning for [5] and the analysis of either Engels FIG. 5 or Cornette FIG. 22 for [2].

VIII. GROUND 1C: Claims 3-4 and 7-8 are obvious over Engels in view of Laurent

A. Laurent

106. Laurent describes "steel sheet[s]" having compositions that "ensur[e] a very high mechanical resistance after thermal treatment." EX-1023, 1:47-62. In more detail, Laurent discusses various elemental components of the steel and how those components improve performance of the steel. *Id*., 4:18-33. Laurent further notes that components of the steel "allow hardening in the stampers" and that the "mechanical characteristics [] of the sheet [] allow [] a deep stamping." *Id*., 2:50, 4:30. Laurent's references to "stamping," "hardening in the stampers," "hot-shaping," and description of controlled heating and cooling would have suggested to a POSITA that the disclosed steel is well-suited for hot-stamping processes. EX-

1023, 1:45, 3:60-4:9, 4:29, 4:49.

B. Analysis of Claims

[3]: The precoated steel product as recited in claim 1 wherein the base steel includes the following components by weight based on total weight: 0.15%<carbon<0.5%; 0.5%<manganese<3%; 0.1%<silicon<0.5%; 0.01%<chromium<1%; titanium<0.2%; aluminum<0.1%; phosphorus<0.1%; sulfur<0.05%; 0.0005%<boron<0.08%; and further comprises iron and impurities inherent in processing.

[4]: The precoated steel product as recited in claim 1 wherein the base steel comprises the following components by weight based on total weight: 0.20%<carbon<0.5%; 0.8%<manganese<1.5%; 0.1%<silicon<0.35%; 0.01%<chromium<1%; titanium<0.1%; aluminum<0.1%; phosphorus<0.05%; sulfur<0.03%; 0.0005%<boron<0.01%; and further comprises iron and impurities inherent in processing.

107. It would have been obvious to a POSITA to use the steel compositions of Laurent in the hot-stamping process described by Engels. This would have constituted no more than substitution of one element (the Laurent steel) for another (the "22MnB5" steel of Engels) known in the field. EX-1005, 135, 141, 149. A POSITA would have been motivated at least by Laurent's discussion of the

advantages of such a steel and the specific advantages of the particular elements and concentrations of the elements of the steel, as noted in Section VIII.A.

108. As shown in the table below, 22MnB5 and Laurent's steel have generally similar compositions, such that the substitution of one for the other would have constituted a minor modification within the general conditions of what was already in use. EX-1037, Table 1; EX-1023, 1:66-2:10.

Element	**22MnB5 Composition (%)**	**Laurent Composition (%)**
C	0.233	0.20% < C < 0.5%
Mn	1.23	0.8% < Mn < 1.5%
Si	0.24	0.1% < Si < 0.35%
Cr	0.14	0.01% < Cr < 1%
Ti	0.033	Ti < 0.1%
Al	0.035	Al < 0.1%
P	0.018	P < 0.05%
S	0.001	S < 0.03%
B	0.0022	0.0005% < B < 0.01%
Ni	0.023	--

109. The "preferabl[e]" "steel composition by weight" of Laurent satisfies or renders obvious each of the recited compositions of claims 3 and 4, as shown in the below chart, illustrating that there was nothing new about the compositions recited in claims 3 and 4. EX-1023, 1:66-2:10.

Element	**[3] composition**	**[4] composition**	**Laurent composition** (col.2)
C	0.15% < C < 0.5%	0.2% < C < 0.5%	0.20% < C < 0.5%
Mn	0.5% < Mn < 3%	0.8% < Mn < 1.5%	0.8% < Mn < 1.5%
Si	0.1% < Si < 0.5%	0.1% < Si < 0.35%	0.1% < Si < 0.35%
Cr	0.01% < Cr < 1%	0.01% < Cr < 1%	0.01% < Cr < 1%
Ti	Ti < 0.2%	Ti < 0.1%	Ti < 0.1%
Al	Al < 0.1%	Al < 0.1%	Al < 0.1%
P	P < 0.1%	P < 0.05%	P < 0.05%
S	S < 0.05%	S < 0.03%	S < 0.03%
B	0.0005% < B < 0.08%	0.0005% < B < 0.01%	0.0005% < B < 0.01%
Remainder	"iron and impurities inherent in processing"	"iron and impurities inherent in processing"	"iron and impurities inherent in processing"

110. For each element, the Laurent composition either exactly matches, falls fully within, or overlaps substantially with the compositions of claims 3 and 4, thereby rendering obvious those compositions.

[7]: The precoated steel product as recited in claim 1 wherein a ratio of titanium to nitrogen in the base steel in weight % is in excess of 3.42.

[8]: The precoated steel product as recited in claim 2 wherein a ratio of titanium to nitrogen in the base steel in weight % is in excess of 3.42.

111. Engels in view of Laurent renders obvious the recited Ti:N relationship. Laurent discloses "**[t]itanium, the ratio of the content of which with respect to the nitrogen content should be in excess of 3.42**, is introduced in order to prevent combining of the boron with the nitrogen, the nitrogen being combined with titanium." EX-1023, 4:25-28. This is exactly the relationship

recited in claims 7 and 8. It would have been obvious to use this relationship in the base steel of Engels in order to obtain the recited chemical benefit (preventing combining of boron with nitrogen).

112. For [8], *see* [2] in Section VI.B.

IX. GROUND 1D: Claims 3-6 are obvious over Engels in view of Nishibata

A. Nishibata

113. Nishibata describes steel compositions and process parameters for "hot forming" (i.e., hot-stamping) for automotive components. EX-1050, 1. Nishibata describes that the inclusion of certain elements, in certain concentrations, can improve properties of the steel. For example, Nishibata discusses the benefits of certain concentrations of carbon, manganese, silicon, chromium, titanium, aluminum, phosphorous, sulfur, and boron. *Id*., 3-5. Based on the inclusion of these elements, "it is possible to produce hot-formed members that also have stabilized strengths and toughnesses." *Id*., 2.

B. Analysis of Claims

[3]: The precoated steel product as recited in claim 1 wherein the base steel includes the following components by weight based on total weight: 0.15%<carbon<0.5%; 0.5%<manganese<3%; 0.1%<silicon<0.5%; 0.01%<chromium<1%; titanium<0.2%; aluminum<0.1%; phosphorus<0.1%;

sulfur<0.05%; 0.0005%<boron<0.08%; and further comprises iron and impurities inherent in processing.

[4]: The precoated steel product as recited in claim 1 wherein the base steel comprises the following components by weight based on total weight: 0.20%<carbon<0.5%; 0.8%<manganese<1.5%; 0.1%<silicon<0.35%; 0.01%<chromium<1%; titanium<0.1%; aluminum<0.1%; phosphorus<0.05%; sulfur<0.03%; 0.0005%<boron<0.01%; and further comprises iron and impurities inherent in processing.

[5]: The precoated steel product as recited in claim 1 wherein the base steel comprises 20 ppm or less of sulfur.

[6]: The precoated steel product as recited in claim 2 wherein the base steel comprises 20 ppm or less of sulfur.

114. It would have been obvious to use the steel compositions of Nishibata in Engels, including the use of 20 ppm (0.002%) or less of sulfur. This would have constituted no more than substitution of one element (the Nishibata steel) for another (the "22MnB5" steel of Engels) known in the field. EX-1005, 135, 141, 149. A POSITA would have been motivated by Nishibata's discussion of the advantages of such a steel, including that the steel provides "stabilized strengths and toughnesses." EX-1050, 2. For sulfur composition specifically, a POSITA would have been motivated by Nishibata's comment that sulfur is "effective in

raising the hardening ability of the steel plate and raising the stabilizing of its strength after hardening" if included at a sufficiently low concentration. EX-1050, 4.

115. As shown in the table below, 22MnB5 and Nishibata's steel have generally similar compositions, such that the substitution of one for the other would have constituted a minor modification within the general conditions of what was already in use. The Nishibata ranges in the table are derived from the discrete values provided for Nishibata's steels and render obvious the compositions of claims 3 and 4 for reasons discussed in Section VIII.B. The recited compositions are also rendered obvious by the compositions on pg. 3-4.

Element	**22MnB5 Composition (%)**	**Nishibata composition** (Table 1)
C	0.233	0.16% ≤ C ≤ 0.42%
Mn	1.23	1.2% ≤ Mn ≤ 1.53%
Si	0.24	0.02% ≤ Si ≤ 0.25%
Cr	0.14	0.19% ≤ Cr ≤ 0.2%
Ti	0.033	0.02% ≤ Ti ≤ 0.03%
Al	0.035	0.04% ≤ Al ≤ 0.06%
P	0.018	0.001% ≤ P ≤ 0.019%
S	0.001	0.001% ≤ S ≤ 0.004%
B	0.0022	0.0007% ≤ B ≤ 0.0015%
Ni	0.023	--

Element	**[3] composition**	**[4] composition**	**Nishibata composition** (Table 1)
C	0.15% < C < 0.5%	0.2% < C < 0.5%	0.16% ≤ C ≤ 0.42%
Mn	0.5% < Mn < 3%	0.8% < Mn < 1.5%	1.2% ≤ Mn ≤ 1.53%
Si	0.1% < Si < 0.5%	0.1% < Si < 0.35%	0.02% ≤ Si ≤ 0.25%
Cr	0.01% < Cr < 1%	0.01% < Cr < 1%	0.19% ≤ Cr ≤ 0.2%
Ti	Ti < 0.2%	Ti < 0.1%	0.02% ≤ Ti ≤ 0.03%
Al	Al < 0.1%	Al < 0.1%	0.04% ≤ Al ≤ 0.06%
P	P < 0.1%	P < 0.05%	0.001% ≤ P ≤ 0.019%
S	S < 0.05%	S < 0.03%	0.001% ≤ S ≤ 0.004%
B	0.0005% < B < 0.08%	0.0005% < B < 0.01%	0.0007% ≤ B ≤ 0.0015%
Remainder	"iron and impurities inherent in processing"	"iron and impurities inherent in processing"	"essentially Fe"

116. For [5]-[6], Nishibata discloses base steel compositions having sulfur% of 0.002% and 0.001% (20 ppm and 10 ppm), within the claimed range. EX-1050, Table 1. The sulfur% range based on Nishibata's steels in Table 1 also substantially overlaps with the claimed range, and the claimed range is also encompassed by Nishibata's sulfur range of "≤0.05%." EX-1050, 4. As such, the claimed range is obvious.

117. For [6], *see also* [2] in Section VI.B. To expand on the foregoing discussion, there are also other reasons why a POSITA would have been motivated to modify Engels in view of Nishibata. First, Engels and Nishibata are in the same field of endeavor as the '602 Patent (e.g., pre-coated boron steels used for automotive parts). *See* EX-1050 at 2 (disclosing that "[t]his invention provides hot-

formed members which can be produced from high-strength steel plates by using a hot-forming method and which also have stabilized strengths and toughnesses, as well as a hot-forming method for producing them"). Second, a POSITA would have recognized that mechanical properties of a steel can be improved by reducing the steel's sulfur content. It was recognized that the inclusion of sulfur at high concentrations can deteriorate steel formability. EX-1052, [0088]. *See also* EX-1051 at 5 (discussing that, ideally, sulfur would be limited to 10 ppm in steels by 1990). Knowing this, a POSITA would have been motivated to look for a boron steel having a low sulfur content, such as the boron steels described in Nishibata (e.g., boron steels with low sulfur contents, e.g., ≤ 20 ppm). Third, as noted above, the concentrations disclosed for Nishibata's steels are similar to those of Engels' 22MnB5 composition. In light of this, a POSITA would have expected the proposed combination of Engels and Nishibata to yield predictable and successful results (e.g., a coated steel stamped product having the advantages as described by Engels and Nishibata).

X. GROUND 1E: Claim 6 is obvious over Engels in view of Cornette and Nishibata

A. Analysis of [6]

[6]: The precoated steel product as recited in claim 2 wherein the base steel comprises 20 ppm or less of sulfur.

118. For reasons discussed in VII.B and IX.B, it would have been obvious to apply Cornette's process parameters and Nishibata's base steel composition to Engels, to obtain a modified product having Nishibata's base steel and the modified coating of Section VII.B.

119. The coating and steel composition render obvious claim [6] for reasons discussed for [2] and [5] in Sections VII.B and IX.B.

XI. GROUND 1F: Claim 8 is obvious over Engels in view of Cornette and Laurent

A. Analysis of [8]

[8]: The precoated steel product as recited in claim 2 wherein a ratio of titanium to nitrogen in the base steel in weight % is in excess of 3.42.

120. For reasons discussed in VII.B and VIII.B, it would have been obvious to apply Cornette's process parameters and Laurent's base steel composition to Engels, to obtain a modified product having Laurent's base steel and the modified coating of Section VII.B.

121. The coating and steel composition render obvious claim [8] for reasons discussed for [2] and [7] in Sections VII.B and VIII.B.

XII. GROUND 1G: Claims 11-17, 19, 23, 25, and 27-30 are obvious over Engels in view of Takagi

122. An overview of Takagi is provided below in Section XIII.A.

A. Analysis of claims

[11]: The precoated steel product as recited in claim 1 wherein the interdiffusion layer comprises the following components by weight based on total weight: 86 to 95% Fe, 4 to10% Al, and 0 to 5% Si.

[12]: The precoated steel product as recited in claim 1 wherein the intermediate layer comprises the following components by weight based on total weight: 39 to 47% Fe, 53 to 61% Al, and 0 to 2% Si.

[13]: The precoated steel product as recited in claim 1 wherein the intermetallic layer comprises the following components by weight based on total weight: 62 to 67% Fe, 30 to 34% Al, and 2 to 6% Si.

[14]: The precoated steel product as recited in claim 1 wherein the superficial layer comprises the following components by weight based on total weight: 39 to 47% Fe, 53 to 61% Al, and 0 to 2% Si.

[15]: The precoated steel product as recited in claim 11 wherein the intermediate layer comprises the following components by weight based on total weight: 39 to 47% Fe, 53 to 61% Al, and 0 to 2% Si.

[16]: The precoated steel product as recited in claim 15 wherein the intermetallic layer comprises the following components by weight based on total weight: 62 to 67% Fe, 30 to 34% Al, and 2 to 6% Si.

[17]: The precoated steel product as recited in claim 16 wherein the superficial layer comprises the following components by weight based on total

weight: 39 to 47% Fe, 53 to 61% Al, and 0 to 2% Si.

[27]: The precoated steel product as recited in claim 24 wherein the interdiffusion layer comprises the following components by weight based on total weight: 86 to 95% Fe, 4 to 10% Al, and 0 to 5% Si.

[28]: The precoated steel product as recited in claim 24 wherein the intermediate layer comprises the following components by weight based on total weight: 39 to 47% Fe, 53 to 61% Al, and 0 to 2% Si.

[29]: The precoated steel product as recited in claim 24 wherein the intermetallic layer comprises the following components by weight based on total weight: 62 to 67% Fe, 30 to 34% Al, and 2 to 6% Si.

[30]: The precoated steel product as recited in claim 24 wherein the superficial layer comprises the following components by weight based on total weight: 39 to 47% Fe, 53 to 61% Al, and 0 to 2% Si.

123. Engels in view of Takagi renders obvious the layer compositions recited in claims 11-17 and 27-30. As discussed in Section VI.B, Engels' phase 1 and 5 compositions directly teach the recited compositions of the Interdiffusion and Superficial layers, while Engels' phases 3 and 4 render obvious the recited compositions of the Intermediate and Superficial layers.

124. For example, Engels' phase 4, which corresponds to the recited "Intermetallic layer," has weight %, by total weight, of 54.3% Fe, 33.9% Al, and

10.6% Si. EX-1005, 143. Of these, the Al% satisfies claim 20, while the Fe% and Si% are close to, but outside, the recited ranges.

125. Takagi describes that several hot-stamped coatings, including No. 1 and 4, provide desirable formability, corrosion resistance, and weldability. EX-1016, Table 1. Takagi associates these advantages with certain layer characteristics, including innermost layer hardness and thickness, intermediate layer Al%, and outermost layer Fe%. EX-1016, [0017]-[0025].

126. Takagi's Inner, Inter 2, Inter 3, and Outer layers are similar to Engels' phases 1, 3, 4, and 5, respectively, based on layer-by-layer comparisons of Takagi's and Engels' layers, as discussed above in Section VI.B. Each also have the same positioning in a five-layer coating. For example, Engels' phase 4 and Takagi's Inter 3 are each the second-shallowest layer in a five-layer coating. Thus, a POSITA would have applied Takagi's teachings for the Inner, Inter 2, Inter 3, and Outer layers to Engels' phases 1, 3, 4, and 5.

127. For at least these reasons, it would have been obvious to optimize the composition of Engels' phases 1, 3, 4, and/or 5 (that is, to modify one, multiple, or all of those compositions) to that of the corresponding layers of Takagi's Nos. 1 and 4 coatings, to achieve the formability, corrosion resistance, and weldability benefits associated with the No. 1 and 4 coatings. As Takagi notes, these benefits are directly associated with the compositions of the layers of the coatings, such that

a POSITA would have been motivated to obtain the same or similar compositions. EX-1016, [0020]-[0025].

128. Engels and Takagi provide a roadmap for performing this optimization. Engels describes that properties of the "diffusion layer" (coating) depend on the "[t]emperature profile" (e.g., "heating rate," "total processing time," "maximum austenitizing temperature," and "material thickness"), and Takagi describes (i) how target parameters such as layer hardness and corrosion resistance depend on composition and (ii) how composition can be controlled "by controlling the raised temperature of the heating and the holding time at the raised temperature." EX-1005, 141-142; EX-1016, [0019]-[0021]. Given this guidance and similarities between the layer compositions of Engels and Takagi, it would have been obvious and well within the skill of a POSITA to obtain the claimed compositions by routine experimentation, for example, by experimenting with the thermal parameters identified by Engels guided by Takagi's more-specific temperature disclosures.

129. This optimization would have constituted no more than experimentation within the general conditions already disclosed by Engels. For example, as shown in the table below, the layer compositions are similar to one another.

Phase/ Layer	Engels Composition	Takagi No. 1 Composition	Takagi No. 4 Composition
1 / Inner	7.2 Al% 1.9 Si% 89.2 Fe%	7.7 Al% 2.0 Si% 89.6 Fe%	6.0 Al% 1.5 Si% 90.7 Fe%
3 / Inter 2	51.4 Al% 1.9 Si% 45.9 Fe%	48.4 Al% 1.2 Si% 50.1 Fe%	51.9 Al% 0.6 Si% 46.8 Fe%
4 / Inter 3	33.9 Al% 10.6 Si% 54.3 Fe%	31.6 Al% 5.7 Si% 62.0 Fe%	30.4 Al% 5.3 Si% 63.1 Fe%
5 / Outer	53.2 Al% 1.9 Si% 44.1 Fe%	54.8 Al% 0.8 Si% 44.5 Fe%	47.4 Al% 2.2 Si% 49.8 Fe%

130. The resulting modified phases 1, 3, 4, and/or 5 would satisfy or render obvious claims 11-17 and 27-30, as discussed in more detail in Section XIII.E below.

[19]: The precoated steel product as recited in claim 1 wherein the first mean iron composition is 90 percent, the second mean iron composition is 43 percent, the third mean iron composition is 63 percent and the fourth mean iron composition is 45 percent.

131. As discussed for [13] in Section XII.A and in Section VI.B, it would have been obvious to modify the composition of Engels' phase 4 to have a composition of or similar to Takagi's Inter 3 layer . As discussed in Sections VI.B and XIII.E, Engels' phase 1, 3, and 5 compositions, in combination with Takagi's Inter 3 composition, render obvious the claimed iron compositions.

132. In addition, for the reasons provided for [13] in Section XII.A, it would have been obvious to modify the compositions of Engels' phases 1, 3, 4, and 5 to have compositions of or similar to Takagi's Inner, Inter 2, Inter 3, and Outer layers, respectively. The compositions of these layers also render obvious the claimed iron compositions. *See* Section XIII.E.

[23]: The precoated steel product as recited in claim 22 wherein the fourth mean iron composition is higher than the second mean iron composition.

133. As discussed for [13] in Section XII.A, it would have been obvious to modify the compositions of Engels' phases 3 and 5 to have compositions of or similar to Takagi's layers Inter 2 and Outer, respectively. As discussed in Section XIII.E, Takagi's layer compositions for No. 4 satisfy the claimed iron compositions.

[25]: *The precoated steel product as recited in claim 24 wherein the fourth mean aluminum composition is less than the second mean aluminum composition.*

134. As discussed for [13] in Section XII.A and in Section VI.B, it would have been obvious to modify the compositions of Engels' phases 3 and 5 to have compositions of or similar to Takagi's layers Inter 2 and Outer, respectively. As discussed in Section XIII.E, Takagi's layer compositions for No. 4 satisfy the claimed aluminum compositions.

XIII. GROUND 2A: Claims 1-30 are obvious over Takagi in view of Hein and GMW14400

A. Takagi

135. Takagi is a patent application publication directed to steel parts with "Al-Si-Fe alloy layer[s]." EX-1016, [0005]. As described by Takagi, "a heat resisting hot-dip aluminum-coated steel sheet containing Si in a coating layer is heated at a rate of 1-10° C./sec to a temperature in the temperature range of 900-950° C., and held at that raised temperature for a holding time (or duration) of 2-8 minutes." *Id*., [0026]. "After the heat treatment for holding in the abovementioned temperature range, the steel sheet is carried from a heating furnace to a forming press." *Id*., [0027]. "The forming operation into a desired shape is started in the temperature range of 700-800° C. After the forming operation, the shaped sheet is cooled rapidly." *Id*., [0028]. A POSITA would have understood that this process – heating, forming while hot, and rapid cooling – is a hot-stamping process as disclosed in the '602 Patent.

136. Takagi describes that "[d]uring the growth of the Al-Si-Fe alloy layer by the heat treatment, mutual diffusion between Al coating and steel substrate layer produces various Al-Si-Fe ternary intermetallic compounds []. The Al-Si-Fe alloy layer formed by the heat treatment has a layered structure made up of these intermetallic compounds, and offers advantages of formability, corrosion

resistance and weldability." EX-1016, [0016]. Table 1 of Takagi provides manufacturing methods, compositions, and hardness values for multiple layers of coatings obtained using five different combinations of temperature and hold time. Nos. 1 and 4 in Table 1 are coatings having five distinct layers.

Coatings with five layers

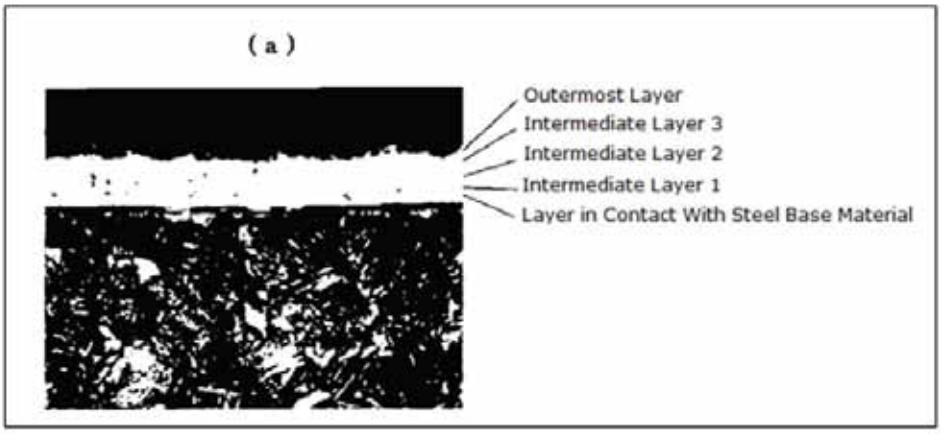
TABLE 1

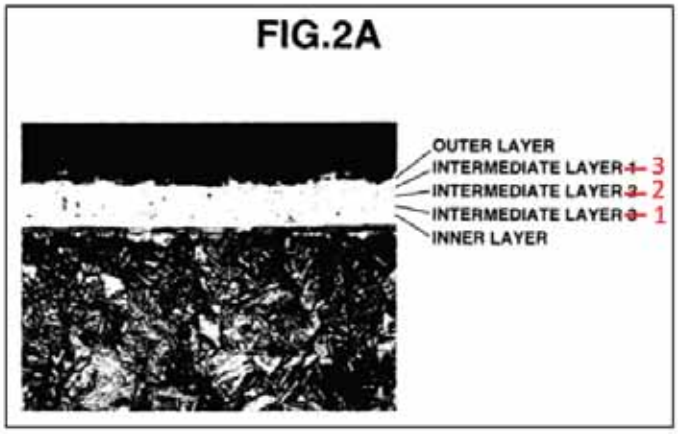
No.	PRODUCTION		COATING LAYER STRUCTURE & COMPOSITION (%)						STEEL BASE HARDNESS (Hv)	COATING LAYER HARDNESS (Hv)			OXIDE WEIGHT (mg/dm²)	FORMABILITY	CORROSION RESISTANCE	WELDABILITY
	RAISED TEMPERATURE (°C)	HOLD TIME (min.)	COMPONENT & HARDNESS	INNER	INTER 1	INTER 2	INTER 3	OUTER		SOFTEST	AVERAGE	SOFTER RANGE (%)				
1	920	3	Al	7.7	31.0	48.4	31.6	54.8	450	310	415	51	300	○	○	○
			Si	2.0	3.9	1.2	5.7	0.8								
			Fe	89.6	65.9	50.1	62.0	44.5								
			Hv	310	360	750	700	800								
2	900	2	Al	27.2	48.4	31.6	—	54.9	415	380	455	22	275	×	○	○
			Si	4.1	1.2	5.7		0.8								
			Fe	67.2	50.1	61.9		44.1								
			Hv	380	760	720	—	810								
3	930	10	Al	9.4	—	—	—	11.6	400	305	385	78	550	○	×	×
			Si	1.3				1.8								
			Fe	88.4				85.7								
			Hv	305	—	—	—	410								
4	950	5	Al	6.0	27.8	51.9	30.4	47.4	440	280	400	59	385	○	○	○
			Si	1.5	4.3	0.6	5.3	2.2								
			Fe	90.7	66.7	46.8	63.1	49.8								
			Hv	280	340	720	690	800								
5	900	4	Al	3.2	54.5	33.4	—	54.5	440	300	410	56	335	○	○	○
			Si	0.4	2.5	15.3		6.8								
			Fe	94.3	42.7	51.4		38.4								
			Hv	300	740	700	—	810								

Annotated Takagi Table 1

137. In Table 1, layers Inner, Inter 1, Inter 2, Inter 3, and Outer are arranged from the base steel outwards in that order. Takagi FIG. 2A erroneously shows the opposite order for intermediate layers 1, 2, and 3. FIG. 2(a) of the original Japanese patent filing, JP3738754, shows the correct order, which accords with the order in which the layers are presented in Table 1 and with Takagi's discussion of the soft inner layer. EX-1018. Especially in view of the descriptions relating to the soft inner layer, a POSITA would have recognized that Takagi's

FIG. 2A represents a clear error. The translated drawing from the JP filing, along with a corrected version of the US publication, are shown below.





<u>Top: translation of FIG. 2(a) of JP3738754</u>
<u>Bottom: corrected FIG. 2A of Takagi</u>

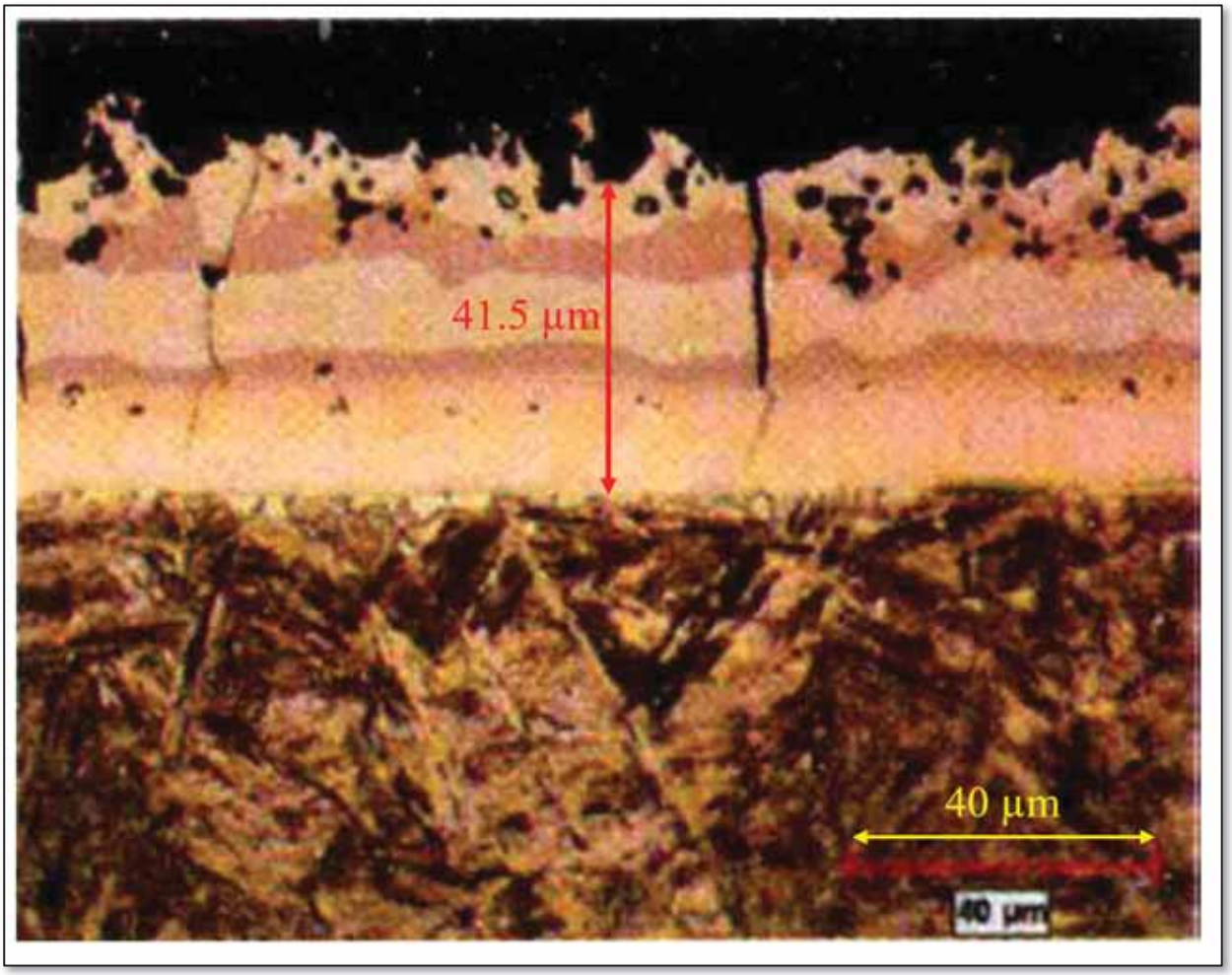
B. Hein

138. Hein is an article titled "Hot Stamping of USIBOR 1500 P: Part and Process Analysis Based on Numerical Simulation." Hein describes the use of "Usibor 1500 P," a "precoated boron steel, with a metallic coating of aluminium-silicon [] of approximately 25 μm/side." EX-1019, 164. The steel is "hot-

stamp[ed]" by "heating blanks until complete austenitization (900°C to 950°C, during 4 to 10 minutes)" and "transferr[ing] very quickly on a press for the stamping." *Id*., 163. "The quenching [] is carried out just after the forming, the heat being absorbed by the closed die (cooling speed between 50°C/s and 100°C/s). The total cycle time (transfer + stamping+ cooling in the die) lies today between 15 s and 25 s." *Id*., 164. "During the heat treatment in the furnaces, this protective coating is transformed into an alloyed layer made of Fe-Al-Si, [] highly adherent on the substrate and with good corrosion properties." *Id*., 165.

139. Hein FIG. 4 shows the "[s]tructure of the alloyed layer Al-Fe-Si after hot-stamping." EX-1019, 165.[2] Five layers can be distinguished based on comparison of shading and tone. The included 40 μm scale in this figure permits the calculation of exact thicknesses for the coating as a whole and for each layer. For example, my measurements indicate, for at least one possible measurement point, a total coating thickness of 41.5 μm.

[2] Measurements and depictions of Hein FIG. 4 in this Declaration are drawn from EX-1020, a higher-resolution color version of EX-1019, in German.



Annotated Hein FIG. 4

C. GMW14400

140. GMW14400 is a material specification published by General Motors and designed to inform steel makers of the requirements of steel to be used in GM vehicles. Steel manufacturers were required to follow this specification to supply vehicle parts to GM. The specification "covers the requirements for low carbon, heat-treatable boron steel used in the manufacture of structural parts requiring heat treatments to achieve high strength." EX-1026, 1. "Part sections [] supplied under

this standard shall be made by austenitizing a pre cut blank, hot stamping the heated blank and rapid cooling (quenching) the stamped part in the die or via water quenching." *Id*.

141. GMW14400 requires that the Al-Si pre-coating "[p]rior to hot-stamping" have a thickness of "20 to 33" μm, and that the coating thickness "[f]ollowing hot-stamping" be ">35" μm. EX-1026, 7. I note that this pre-coating thickness range **exactly matches** the target pre-coating thickness range disclosed by the '602 Patent. EX-1001, 5:12-19. GMW14400 also requires a certain chemical composition of the base steel. *Id*., 2.

D. Combination of Takagi, Hein, and GMW14400

142. Takagi describes a pre-coating thickness of 10-20 μm. EX-1016, [0035]. A POSITA would have expected a thickness increase with heat treatment on the order of about "50%." EX-1025, 5:17-20. As a result, using a 20 μm pre-coating a POSITA would have expected Takagi to obtain a coating of 30 μm or more. GMW14400 corroborates this analysis, with GMW14400 using a 20-33 μm pre-coating to obtain a coating > 35 μm. EX-1026, 7. Takagi does not disclose a specific numerical value for thickness after heat treatment.

143. Given GMW1400's disclosure, and motivated at least by market demand, a POSITA would have found it obvious to implement Takagi's coating thickness to meet GMW1400's specification, adjusting parameters (e.g., pre-

coating thickness and heat treatment parameters) as needed. Such adjustments would have been well within the skill of POSITA and would have been achievable with a reasonable expectation of success.

144. It would have been typical for a researcher in industry or academia to review standards such as GMW14400 to learn about industrial objectives and steel processing, for example, in order to guide internal design and research. Based on GMW14400's requirements, a POSITA would have sought to form a hot-stamped coating with a thickness greater than 35 μm.

145. In pursuit of this goal, the POSITA would have identified Hein as teaching process parameters that, when employed in hot-stamping, produce a coating having a thickness of approximately 40 μm, satisfying the > 35 μm requirement of GMW14400. And, based on this disclosure, the POSITA would have found it obvious to try modifying Takagi's processes based on Hein's and/or GMW1440's process parameters in order to obtain such a coating. In addition, independent of the teachings of GMW14400, a POSITA would have been motivated by Hein's disclosure that Hein's steel and process parameters provide benefits including high tensile strength and yield strength, a lack of springback, and a "highly adherent" coating with "good corrosion properties." EX-1019, 164-165. Such modifications would have entailed nothing more than applying Hein's and GMW14400's known techniques and parameters to Takagi to obtain a

predictable result.

146. For example, while Takagi describes a pre-coating thickness of 10-20 μm, the POSITA would have found it obvious to try a pre-coating thickness of "25 μm/side" as described by Hein, and to try a pre-coating thickness range of "20 to 33" μm as described by GMW14400. EX-1019, 164; EX-1026, 7. The POSITA would have also been aware of a direct correlation between pre-coating thickness and coating thickness, e.g., as indicated by FR2833504's disclosure that alloying of a pre-coating "generally corresponds to a 50% increase" in thickness for the resulting coating. EX-1025, 5:17-20. And the POSITA would have recognized that pre-coating and coating thickness were result-effective variables, e.g., as taught by Engels, by GMW14400, and by JP2004244704's disclosure that "[a] thickness of 20 μm or more [of pre-coating] is preferred because a thicker layer responsible for corrosion resistance results in greater overall corrosion resistance and a longer material life." EX-1005, 142; EX-1034, [0013].

147. The POSITA would also have found it obvious to try varying the pre-coating composition, e.g., by trying the 90 Al% aluminum-silicon pre-coating described by Hein and the 85-95 Al% aluminum-silicon coating bath described by GMW14400. EX-1019, 164; EX-1026, 6. The POSITA would have been motivated at least by Takagi's disclosure that the silicon proportion in the pre-coating can be varied over a range of 3% to 11% (such that the POSITA would

have been motivated to identify the optimum Si% within that range), and Takagi's disclosure that the Al% in the resulting coating is highly determinative of the coating's adhesion and corrosion resistance. EX-1016, [0013], [0021].

148. The POSITA would also have found it obvious to try varying the base steel, e.g., by trying a steel having the compositions disclosed by GMW1440 and by trying the USIBOR 1500 steel disclosed by Hein, which satisfies or approximately satisfies the steel compositions required by GMW14400. EX-1019, 164; EX-1026, 2.

149. In addition, the POSITA would have found it obvious to try varying the various heating parameters described by Takagi, e.g., within the thermal process windows described by Hein. EX-1019, 163-164. All of these parameters – heating rate, heating temperature, rate of primary cooling, forming temperature, and quenching rate – were recognized by Takagi as result-effective. EX-1016, [0019], [0026]-[0037]. Moreover, the corresponding experimentation was well within the reach and skill of a POSITA, e.g., by appropriately configuring the austenitization furnace and quenching die.

150. Moreover, a POSITA would have had high confidence that the modifications would be successful: the heating profiles used for Takagi's parts are all within or close to the temperature and time ranges disclosed by Hein, and a modified pre-coating thickness of, for example, 25 μm represents a small

modification compared to the 10-20 μm range disclosed by Takagi. EX-1016, FIG. 4, [0035]; EX-1019, 163. For example, Hein discloses austenitization at "900°C to 950°C, during 4 to 10 minutes," while Takagi discloses a heating temperature of "900~950° C" with a holding time of "2~10 min." EX-1016; [0047]; EX-1019, 163.

151. As a result, based on the foregoing routine experimentation, a POSITA would have arrived at various coatings with layers having various thicknesses and compositions. For example, a POSITA would have arrived at "**modified Takagi coatings No. 1 and No. 4**" having, for each of their five layers, the layer composition described for Takagi's No. 1 and No. 4 coatings (or similar composition), and having the layer thickness and morphology shown in Hein FIG. 4 (or similar thickness and morphology). It is true that obtaining those compositions and thicknesses would require experimentation and some degree of trial and error, within the finite number of possible experimental values for some or all of the foregoing thermal treatment parameters. However, given (i) the knowledge that both Takagi's and Hein's processes result in the formation of five-layer coatings, (ii) the relatively small increase in pre-coating thickness associated with a modification of Takagi based on Hein's pre-coating thickness (only from 20 μm to 25 μm), (iii) the art's recognition that layer characteristics (e.g., hardness and corrosion resistance) depend directly on layer composition, and (iv) the art's

clear recognition of the most relevant process parameters for modifying layer compositions and thicknesses, the manufacture of the modified coatings would have been obvious. EX-1016, [0019]-[0026].

152. As a result, the modified Takagi coatings No. 1 and No. 4 are members of a wide class of coatings that are, in my opinion, rendered obvious by Takagi, Hein, and GMW14400. For example, insofar as any aspects of the coating layers described in the ’602 Patent may be the result of specific heating parameters or pre-coating parameters, a POSITA would have arrived at such layers by routine experimentation. I base this opinion at least on a comparison between the values disclosed in the ’602 Patent and those in Takagi, Hein, and GMW14400. The values are generally identical or very similar, and the ’602 Patent includes no disclosure to suggest an unexpected criticality in any of these parameters that would place any of the claimed layer parameters outside the bounds of routine experimentation. When comparing the ’602 Patent to the prior art, a POSITA would have seen very similar processes being applied to very similar steel parts.

Parameter	’602 Patent	’602 Patent Example 2	Takagi	Hein	GMW14400
Pre-coating thickness (μm)	20 – 30	---	10 – 20	25	20 - 33
Heating rate (˚C/s)	4 - 12	10	8; 1-10	---	---
Temperature (˚C)	880 - 940	920	920, 950	900 - 950	---
Hold time (min)	< 3 – 13	< 6	3, 5	<[3] 4 – 10	
Cooling rate (˚C/s)	> 30, or > 50		20 – 100	50 – 100	

153. From my experience during IPR proceedings for the ’683 Patent, I am aware that the heating rates disclosed in the ’602 Patent were a focus of some discussion. Heating rates were also discussed in detail during prosecution of the ’602 Patent. EX-1002, 16-20. With respect to the heating rates, I will briefly note that the disclosed preferential heating rate range of “4 [to] 12°C./s” encompasses Takagi’s disclosed heating rates of 8˚C/s and 1-10˚C/s; encompasses the heating rate range of 5-10˚C/s disclosed by WO02/103073; and encompasses the heating rates from 20˚C to 700˚C disclosed in FIG. 2 of EX-1039, which I measure to be

[3] “<” here indicates that the disclosed time includes both the heating ramp-up time and the hold time.

5.2 °C/s and 8°C/s.[4] EX-1001, 7:13-24; EX-1016, [0026], [0037]; EX-1035, 57:1; EX-1039, FIG. 2. I can find no evidence that any of the foregoing temperature or coating parameters disclosed by the ’602 Patent represented an invention or novel insight. These parameter ranges described by the ’602 Patent were general in view of the prior art, and it would have been well within the skill of a POSITA to arrive at the claimed coatings as a result of routine experimentation within the conditions of the prior art.

E. Analysis of Claims

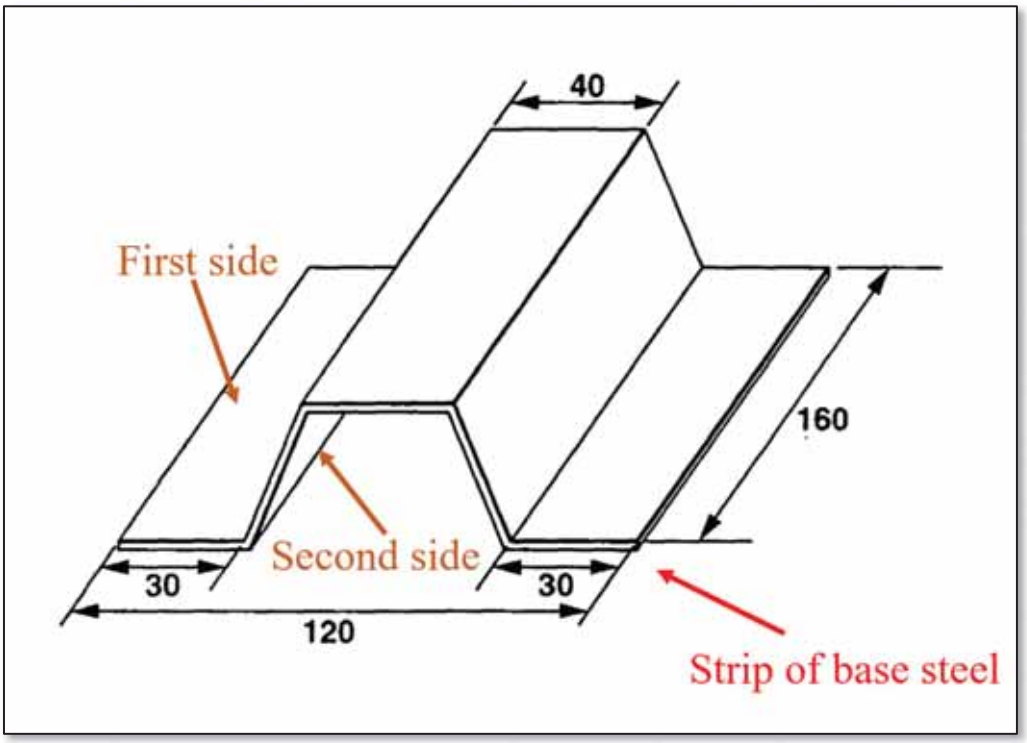
[1pre]: A precoated steel product comprising:

154. The modified Takagi parts are “precoated steel product[s]” or “precoated steel stamped blanks.” Takagi describes that, in the “[t]est [p]rocedure” used for producing the Nos. 1 and 4, “[f]rom the [] hot-dip aluminum-coated steel sheet, a flat plate [] was cut out, heat-treated [] and **formed into a shape** shown in FIG. 1.” EX-1016, [0036]. “Form[ing]” refers to stamping. Further, Hein FIG. 4 shows a “[s]tructure of the alloyed layer Al-Fe-Si **after hot-stamping**.” EX-1019, 165. Hein also clarifies that the precoated part can be referred to as a “**blank**.” EX-1019, 163, 166-167.

[4] For the EX-1039 value, I measured the average heating rate over the 20˚C to 700˚C range based on the curves in FIG. 2.

[1a]: a strip of base steel having a first side and a second side; and

155. The modified Takagi parts comprise a strip of base steel having a first side and a second side. These sides are shown, for example, in Takagi FIG. 1, which illustrates the "shape" of the hot-stamped parts of Takagi Nos. 1 and 4. This shape is obtained by "form[ing]" a "**flat plate**." EX-1016, [0036]. The "base steel" of the FIG. 1 part, and its two sides, would be underneath a coating. That is, in FIG. 1, the visible surfaces are surfaces of the coating, but a POSITA would have understood that a strip of base steel with two sides was under the coating.

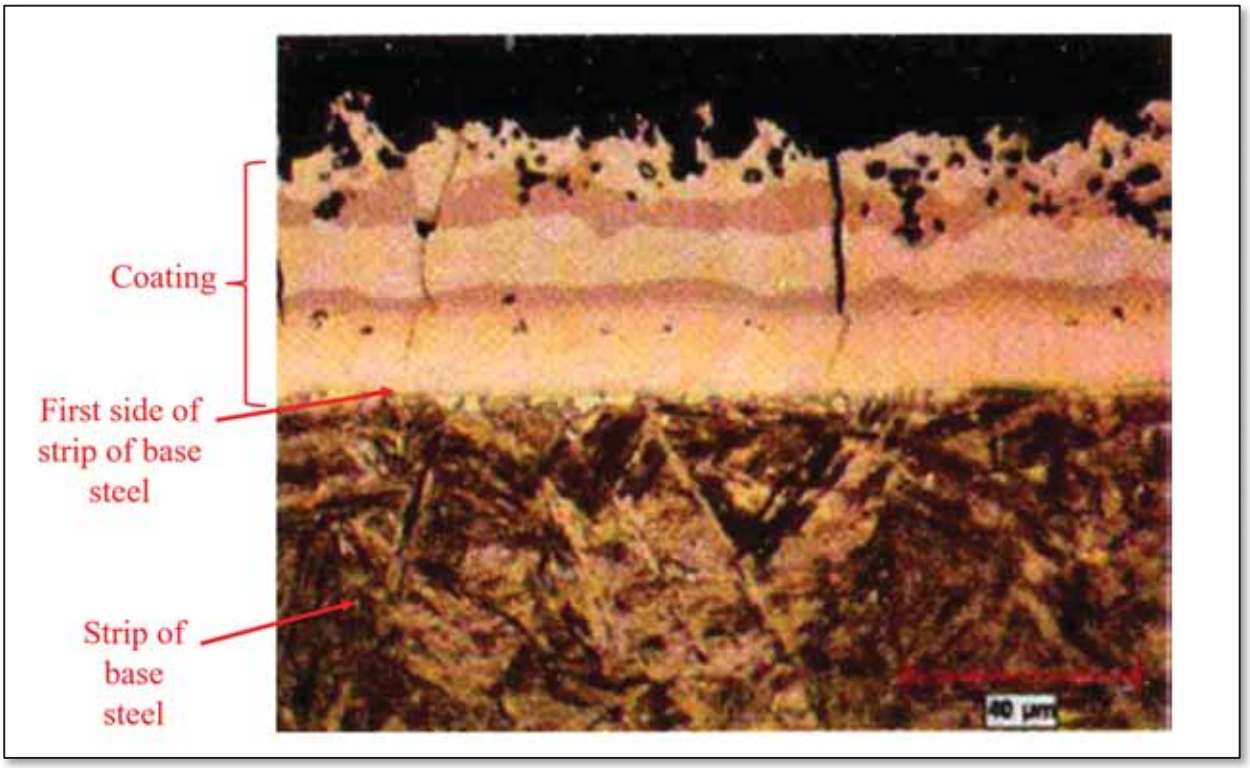


Annotated Takagi FIG. 1

[1b]: a coating on at least one of the first side of the strip of base steel and

the second side of the strip of base steel,

156. The modified Takagi parts comprise a coating on at least one of the first side of the strip of base steel and the second side of the strip of base steel. Hein FIG. 4 shows an example of such a coating which, as discussed in Section XIII.D, corresponds to the modified Takagi coatings Nos. 1 and 4.



Annotated Hein FIG. 4

[1c]: wherein the coating results from interdiffusion between the base steel, and an aluminum or aluminum alloy pre-coating,

157. The modified Takagi coatings result from interdiffusion between the base steel and the aluminum or aluminum alloy pre-coating. Takagi describes that

"[d]uring the growth of the Al-Si-Fe alloy layer by the heat treatment, **mutual diffusion between Al coating and steel substrate layer** produces various Al-Si-Fe ternary intermetallic compounds." EX-1016, [0016].

[1d]: and wherein the coating includes, proceeding from the base steel outwards: (a) an interdiffusion layer having a first mean iron composition,

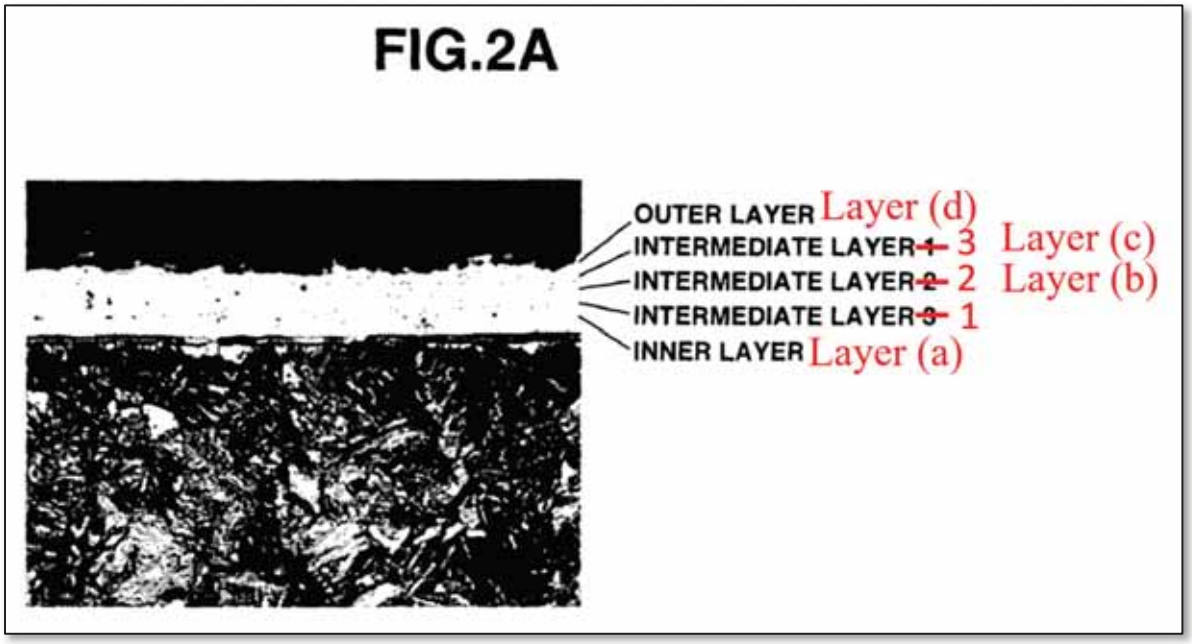
[1e]: (b) an intermediate layer having a second mean iron composition different from the first mean iron composition,

[1f]: (c) an intermetallic layer having a third mean iron composition different from the first and second mean iron compositions, the third mean iron composition being higher than the second mean iron composition; and

[1g]: (d) a superficial layer having a fourth mean iron composition different from the third mean iron composition,

158. The modified Takagi coatings have the foregoing recited layers. For example, the modified Takagi coatings include five layers corresponding to the Inner, Inter 1, Inter 2, Inter 3, and Outer layers of Takagi Table 1. At least the **Inner, Inter 2, Inter 3, and Outer layers** of each of the modified Takagi Nos. 1 and 4 coatings teach the recited layers (a), (b), (c), and (d), respectively. The Inner, Inter 2, Inter 3, and Outer layers proceed "from the base steel outwards," as shown in Takagi FIG. 2A. These layers also satisfy the meanings of "Interdiffusion," "Intermediate," "Intermetallic," and "Superficial" proposed by Petitioner during

IPR proceedings for the ’683 Patent. EX-1031, 22-24.



Annotated Takagi FIG. 2A

159. The compositions and thickness/morphology of the modified Takagi coatings’ layers, in association with the corresponding layers of the ’602 Patent, are shown in the annotated Takagi Table 1 and Hein FIG. 4 below.

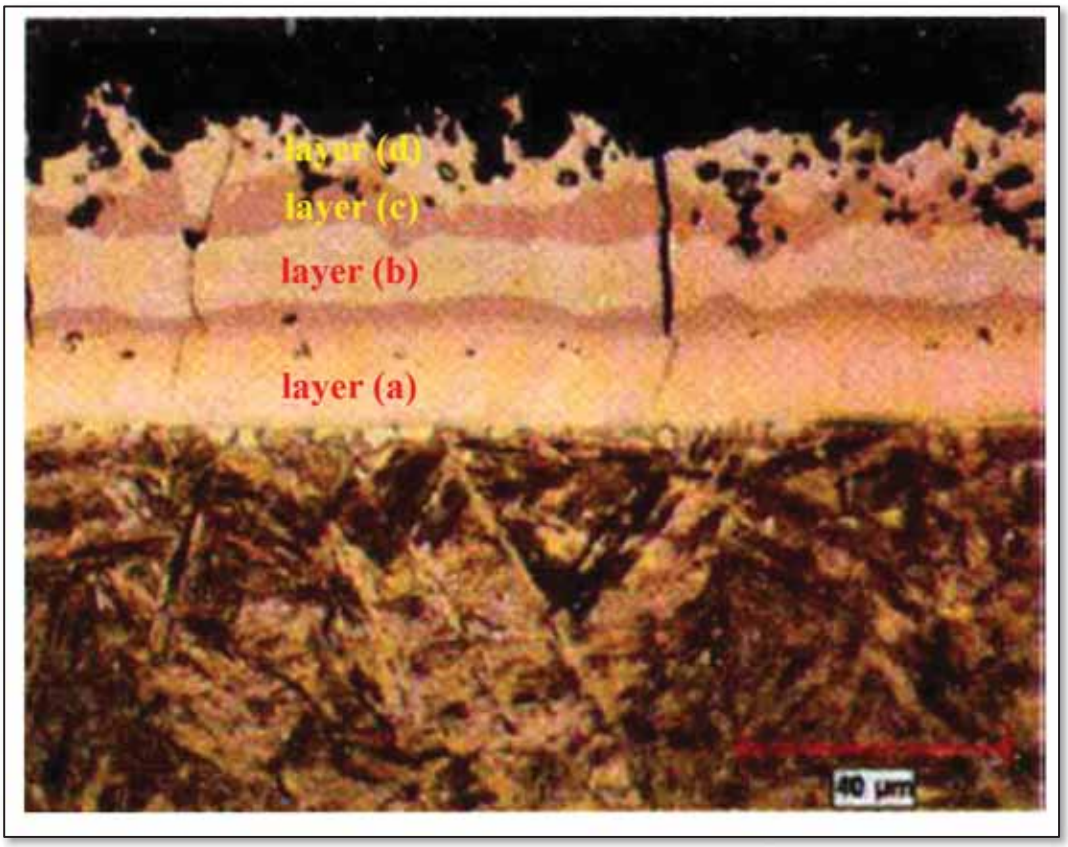
Corresponding layers of '227 Patent

TABLE 1

(a) (b) (c) (d)

No.	PRODUCTION		COATING LAYER STRUCTURE & COMPOSITION (%)						STEEL BASE HARDNESS (Hv)	COATING LAYER HARDNESS (Hv)			OXIDE WEIGHT (mg/dm²)	FORMABILITY	CORROSION RESISTANCE	WELDABILITY
	RAISED TEMPERATURE (°C)	HOLD TIME (min.)	COMPONENT & HARDNESS	INNER	INTER 1	INTER 2	INTER 3	OUTER		SOFTEST	AVERAGE	SOFTER RANGE (%)				
1	920	3	Al	7.7	31.0	48.4	31.6	54.8	450	310	415	51	300	○	○	○
			Si	2.0	3.9	1.2	5.7	0.8								
			Fe	89.6	65.9	50.1	62.0	44.5								
			Hv	310	360	750	700	800								
2	900	2	Al	27.2	48.4	31.6	—	54.9	415	380	455	22	275	×	○	○
			Si	4.1	1.2	5.7		0.8								
			Fe	67.2	50.1	61.9		44.1								
			Hv	380	760	720	—	810								
3	930	10	Al	9.4	—	—	—	11.6	400	305	385	78	550	○	×	×
			Si	1.3				1.8								
			Fe	88.4				85.7								
			Hv	305	—	—	—	410								
4	950	5	Al	6.0	27.8	51.9	30.4	47.4	440	280	400	59	385	○	○	○
			Si	1.5	4.3	0.6	5.3	2.2								
			Fe	90.7	66.7	46.8	63.1	49.8								
			Hv	280	340	720	690	800								
5	900	4	Al	3.2	54.5	33.4	—	54.5	440	300	410	56	335	○	○	○
			Si	0.4	2.5	15.3		6.8								
			Fe	94.3	42.7	51.4		38.4								
			Hv	300	740	700	—	810								

Annotated Takagi Table 1



Annotated Hein FIG. 4

160. The Inner, Inter 2, Inter 3, and Outer layers of the modified Takagi coatings satisfy the recited mean iron compositions. Takagi Table 1 shows the compositions of each of the layers of Nos. 1 and 4, illustrating that (i) in each sample, these layers have different mean iron compositions, and (ii) the iron composition in layer Inter 3 (corresponding to layer (c)) is greater than the iron composition in layer Inter 2 (corresponding to layer (b)) in each sample. As discussed in Section XIII.D, the layers of the modified Takagi coatings have compositions the same as or similar to these compositions. *See* Section VI.B for a discussion of why a POSITA would have interpreted Takagi's "percent by mass" to be a "mean" composition. EX-1016, [0020].

Corresponding layers of '602 Patent - Iron compositions different for each layer

TABLE 1

(a) (b) (c) (d)

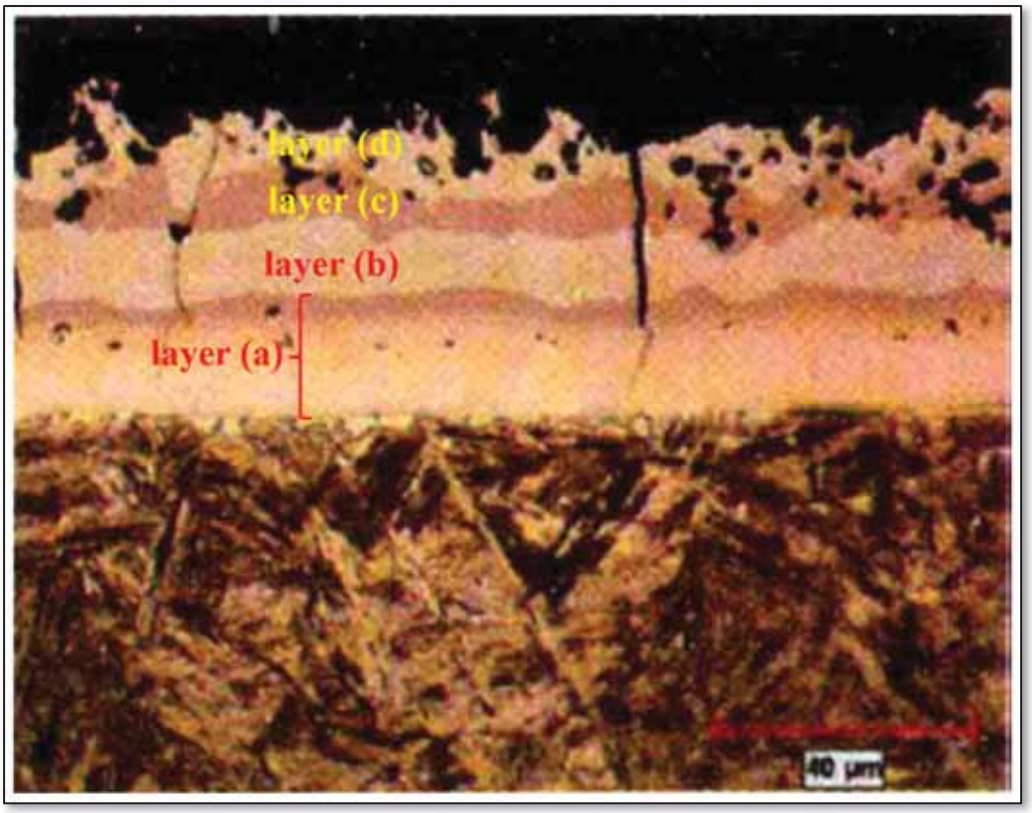
No.	PRODUCTION		COATING LAYER STRUCTURE & COMPOSITION (%)						STEEL BASE HARDNESS (Hv)	COATING LAYER HARDNESS (Hv)			OXIDE WEIGHT (mg/dm²)	FORMABILITY	CORROSION RESISTANCE	WELDABILITY
	RAISED TEMPERATURE (°C)	HOLD TIME (min.)	COMPONENT & HARDNESS	INNER	INTER 1	INTER 2	INTER 3	OUTER		SOFTEST	AVERAGE	SOFTER RANGE (%)				
1	920	3	Al	7.7	31.0	48.4	31.6	54.8	450	310	415	51	300	○	○	○
			Si	2.0	3.9	1.2	5.7	0.8								
			Fe	89.6	65.9	50.1	62.0	44.5								
			Hv	310	360	750	700	800								
2	900	2	Al	27.2	48.4	31.6	–	54.9	415	380	455	22	275	×	○	○
			Si	4.1	1.2	5.7		0.8								
			Fe	67.2	50.1	61.9		44.1								
			Hv	380	760	720	–	810								
3	930	10	Al	9.4	–	–	–	11.6	400	305	385	78	550	○	×	×
			Si	1.3				1.8								
			Fe	88.4				85.7								
			Hv	305	–	–	–	410								
4	950	5	Al	6.0	27.8	51.9	30.4	47.4	440	280	400	59	385	○	○	○
			Si	1.5	4.3	0.6	5.3	2.2								
			Fe	90.7	66.7	46.8	53.1	49.8								
			Hv	280	340	720	690	800								
5	900	4	Al	3.2	54.5	33.4	–	54.5	440	300	410	56	335	○	○	○
			Si	0.4	2.5	15.3		6.8								
			Fe	94.3	42.7	51.4		38.4								
			Hv	300	740	700	–	810								

Fe%(layer (b)) < Fe%(layer (c))

Annotated Takagi Table 1

161. In addition, the **Inner and Inter 1** layers of the modified Takagi Nos.

1 and 4 coatings **together** teach the Interdiffusion layer (layer (a)). This mapping, reflected in the annotated Hein FIG. 4 below, would be consistent with one example of the ’602 Patent’s disclosure for the reasons discussed in Section VI.B.



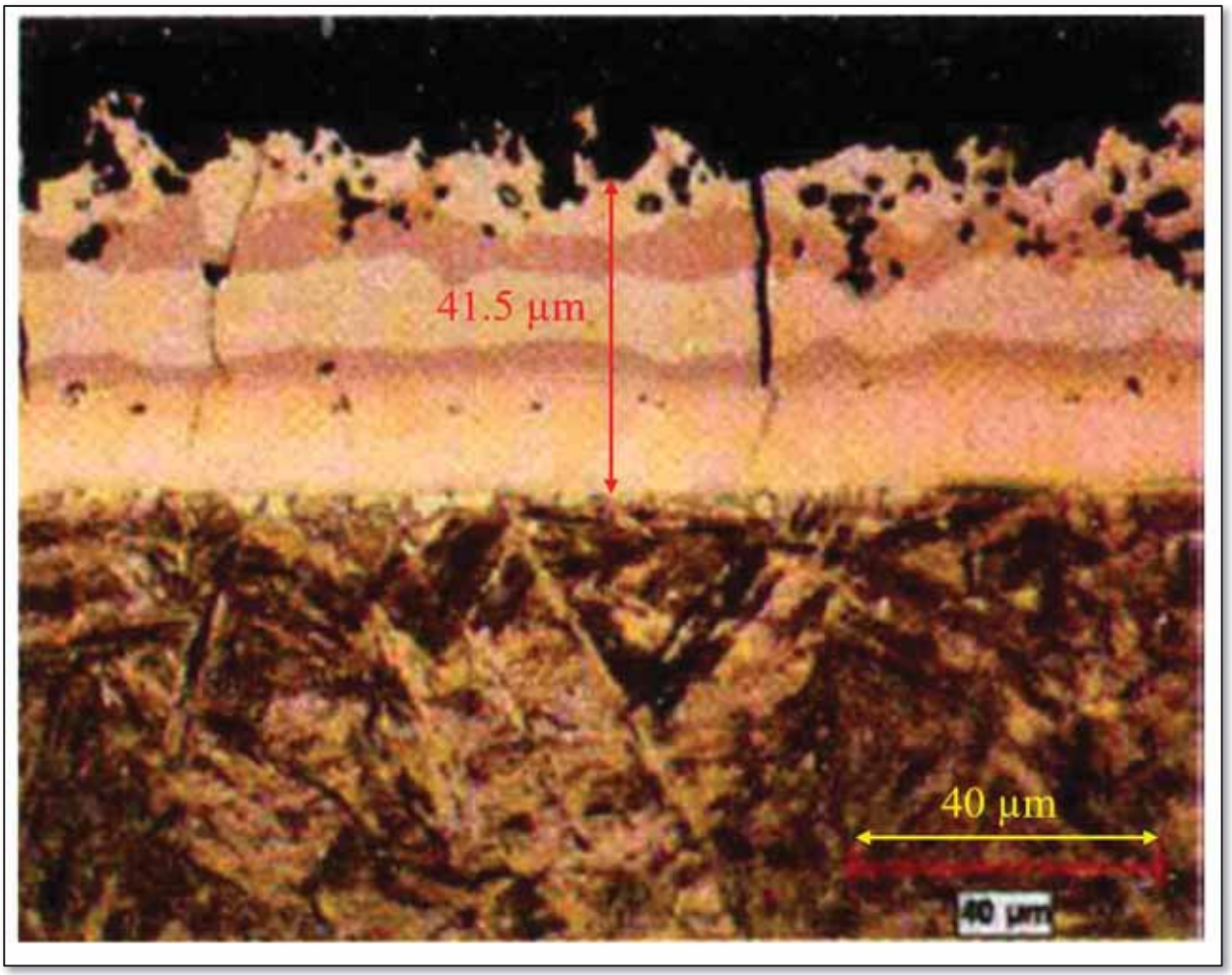
Annotated Hein FIG. 4

162. All arguments provided herein that rely on associating the Inner layer with layer (a) apply equally to this composite layer of the Inner and Inter 1 layers, and that alternative mapping should be understood as being included in the discussions below.

[1h]: wherein the coating has a thickness greater than 30 micrometers.

163. The modified Takagi coatings have thicknesses greater than 30 µm.

As discussed in Section XIII.D, the modified Takagi coatings have thicknesses the same as or similar to that of Hein FIG. 4. My measurements indicate that the Hein FIG. 4 coating has a thickness of 41.5 μm, satisfying this claim element.



Annotated Hein FIG. 4

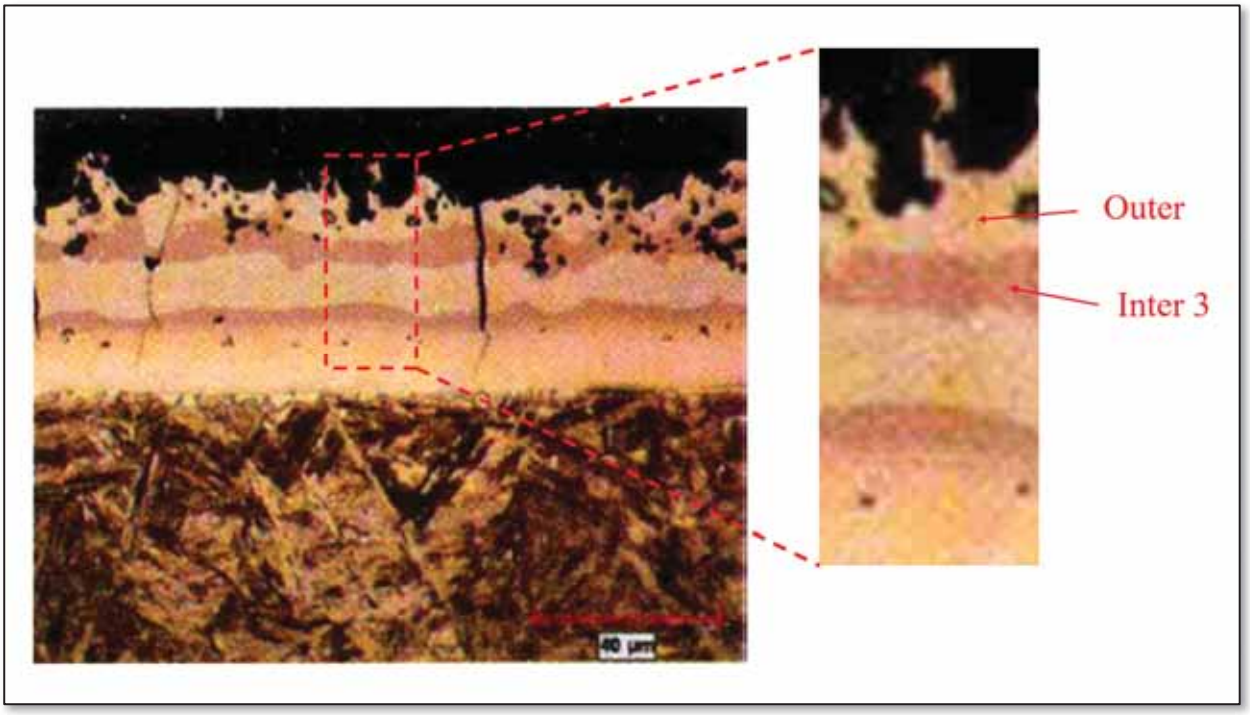
[2]: The precoated steel product as recited in claim 1 wherein the layers (c) and (d) are quasi continuous by occupying at least 90% of a level corresponding to

each of the layers (c) and (d) and wherein less than 10% of layer (c) is present at an extreme surface of the product.

164. I conducted an analysis as noted above in Section VI.B, based on observations of the shading of the different layers of Hein's coating in EX-1020.

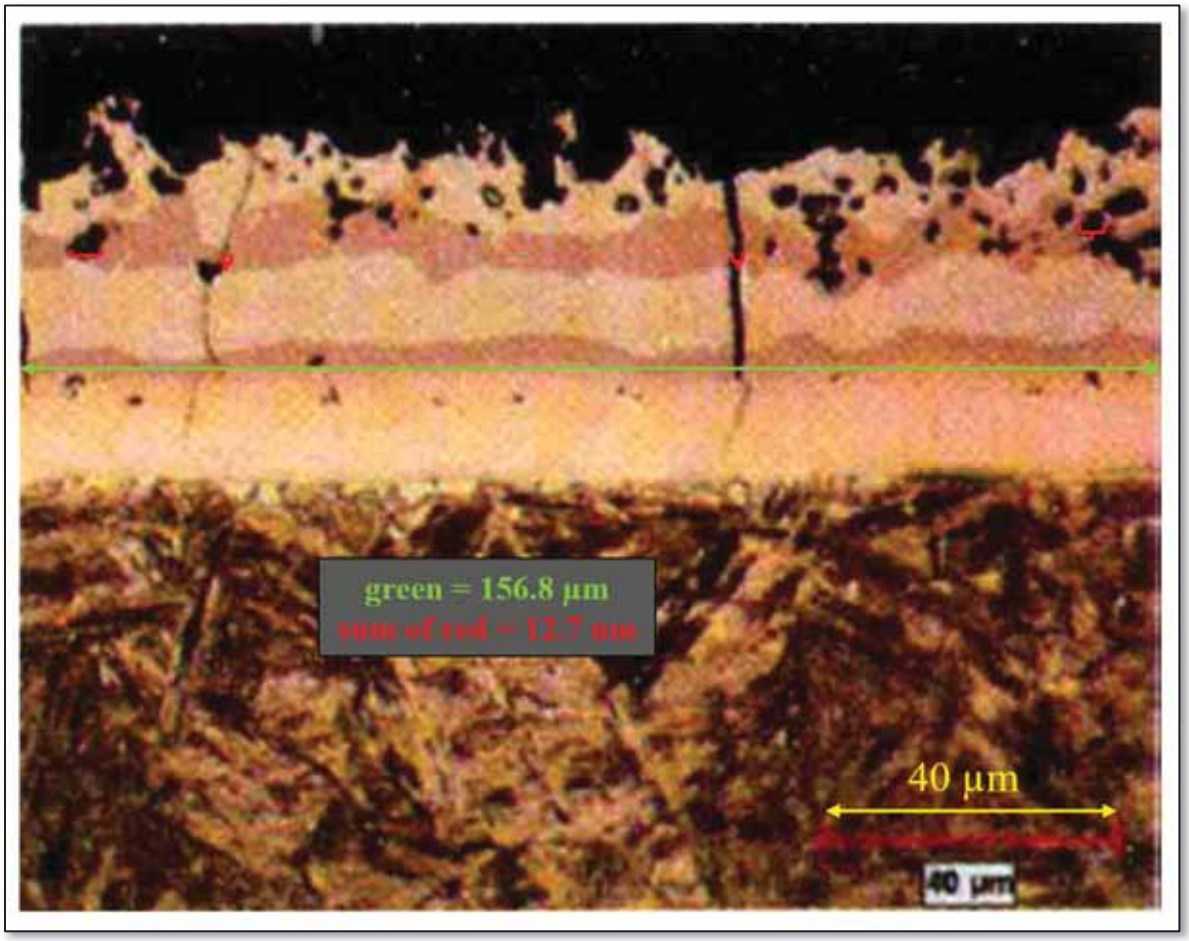
165. The combination of Takagi, Hein, and GMW14400 renders obvious claim 2. For "*less than 10% of layer (c) is present at an extreme surface of the product*," Hein FIG. 4 shows that essentially none of the Inter 3 layer (corresponding to layer (c) of Takagi-Hein-GMW14400 coating) is present at the extreme surface of the coating. EX-1019, FIG. 4.

166. With respect to the first element of claim 2, as shown below, the Inter 3 and Outer layers of the modified coating extend continuously or essentially continuously, e.g., as illustrated in the segment of Hein FIG. 4 enlarged below. Claim 2 merely refers to "a level corresponding to each of the layers" and, thus, the enlarged segment of FIG. 4 demonstrates "a level" of layers (c) and (d) that satisfies claim 2.



Annotated Hein FIG. 4 (enlarged view)

167. Even across the entire SEM image in FIG. 4, these layers extend continuously or essentially continuously across the **entire image**, except perhaps for (i) one or two apparent cracks extending through the Inter 3 and Outer layers and (ii) voids at the left and right edges of the Inter 3 layer. The Inter 3 and Outer layers appear to extend continuously around other voids present in FIG. 4. A POSITA would have considered the layer to be continuous or essentially continuous (or quasi continuous) despite these segments. To the extent that these segments are considered to make the layer discontinuous, the segments (indicated in red below) occupy only about 8% of the total width of FIG. 4. Therefore, the Inter 3 and Outer layers are "quasi-continuous."



Annotated Hein FIG. 4

[3]: The precoated steel product as recited in claim 1 wherein the base steel includes the following components by weight based on total weight: 0.15%<carbon<0.5%; 0.5%<manganese<3%; 0.1%<silicon<0.5%; 0.01%<chromium<1%; titanium<0.2%; aluminum<0.1%; phosphorus<0.1%; sulfur<0.05%; 0.0005%<boron<0.08%; and further comprises iron and impurities inherent in processing.

[4]: The precoated steel product as recited in claim 1 wherein the base steel comprises the following components by weight based on total weight: 0.20%<carbon<0.5%; 0.8%<manganese<1.5%; 0.1%<silicon<0.35%; 0.01%<chromium<1%; titanium<0.1%; aluminum<0.1%; phosphorus<0.05%; sulfur<0.03%; 0.0005%<boron<0.01%; and further comprises iron and impurities inherent in processing.

168. GMW14400's steel compositions satisfy or overlap all composition ranges in [3]-[4]. EX-1026, 2. A comparison between the compositions is shown in the table below. It would have been obvious to use these steel compositions to satisfy General Motors' requirements. The POSITA would have been further motivated by the recognition that the values in GMW1400 are in agreement with the "Maximum-%" for C, Mn, Si, Cr, Ti, and B described by Hein for USIBOR 1500 steel, which provides "numerous" "technical and economic advantages [] for the manufacturers and the hot-stampers." EX-1019, 164, 165.

169. The "0.010 max. %" nitrogen disclosed by GMW14400 would have been understood by a POSITA as an "impurit[y] inherent in processing." If too much nitrogen is present, the nitrogen will bond with boron, which is a critical element needed to increase hardenability. In the art, we generally seek to minimize the amount of nitrogen, which is considered to be an impurity. Further, the

disclosure of "steel" in GMW14400 would have been understood by a POSITA as disclosing that the remainder of the material would be composed of iron and any trace impurities, iron being the primary component of steel.

170. Further, GMW1440's lack of disclosure of a Ti% range would have suggested to a POSITA that Ti would be present in small quantities if at all, such that this disclosure teaches a steel with Ti% of less than 0.1%. For example, because GMW14400 does not teach the inclusion of Ti and [16]-[17] recite ranges that include 0% Ti, GMW14400 teaches a Ti% within the claimed range.

Element	**[3] composition**	**[4] composition**	**GMW14400 composition**
C	0.15% < C < 0.5%	0.2% < C < 0.5%	0.20 to 0.25% C
Mn	0.5% < Mn < 3%	0.8% < Mn < 1.5%	1.00 to 1.35% Mn
Si	0.1% < Si < 0.5%	0.1% < Si < 0.35%	0.15 to 0.35% Si
Cr	0.01% < Cr < 1%	0.01% < Cr < 1%	0.11 to 0.35% Cr
Ti	Ti < 0.2%	Ti < 0.1%	[none (satisfied)]
Al	Al < 0.1%	Al < 0.1%	0.010 min. % Al
P	P < 0.1%	P < 0.05%	0.025 max. %
S	S < 0.05%	S < 0.03%	0.010 max. %
B	0.0005% < B < 0.08%	0.0005% < B < 0.01%	0.0015 to 0.005 wt. %
Remainder	"iron and impurities inherent in processing"	"iron and impurities inherent in processing"	iron (implicit); 0.010 max. % N

[5]: The precoated steel product as recited in claim 1 wherein the base steel comprises 20 ppm or less of sulfur.

[6]: The precoated steel product as recited in claim 2 wherein the base steel

comprises 20 ppm or less of sulfur.

171. As discussed for [3], it would have been obvious to use the steel compositions of GMW14400 to satisfy General Motors' requirements. GMW14400 discloses a sulfur composition ≤ 0.01% (≤ 100 ppm). EX-1026, 2. Given this disclosure, the recited range of "20 ppm or less," which is entirely encompassed by the prior art range, is obvious. It would have been obvious for a POSITA to experiment to optimize sulfur content within this range, e.g., to determine a narrower range that provides effective results. As a result, it would have been obvious to arrive at the claimed range by routine experimentation.

172. For [6], *see also* [2] above.

[7]: The precoated steel product as recited in claim 1 wherein a ratio of titanium to nitrogen in the base steel in weight % is in excess of 3.42.

[8]: The precoated steel product as recited in claim 2 wherein a ratio of titanium to nitrogen in the base steel in weight % is in excess of 3.42.

173. It would have been obvious to try varying the composition of the base steel based on Hein's description of USIBOR 1500 steel and based on GMW14400's requirements. EX-1019, 164. For example, because GMW1400 is silent as to a titanium concentration, it would have been obvious to a POSITA to try varying the Ti% within the range disclosed by Hein, for example, based on Hein's description that USIBOR 1500 steel is particularly advantageous for hot-

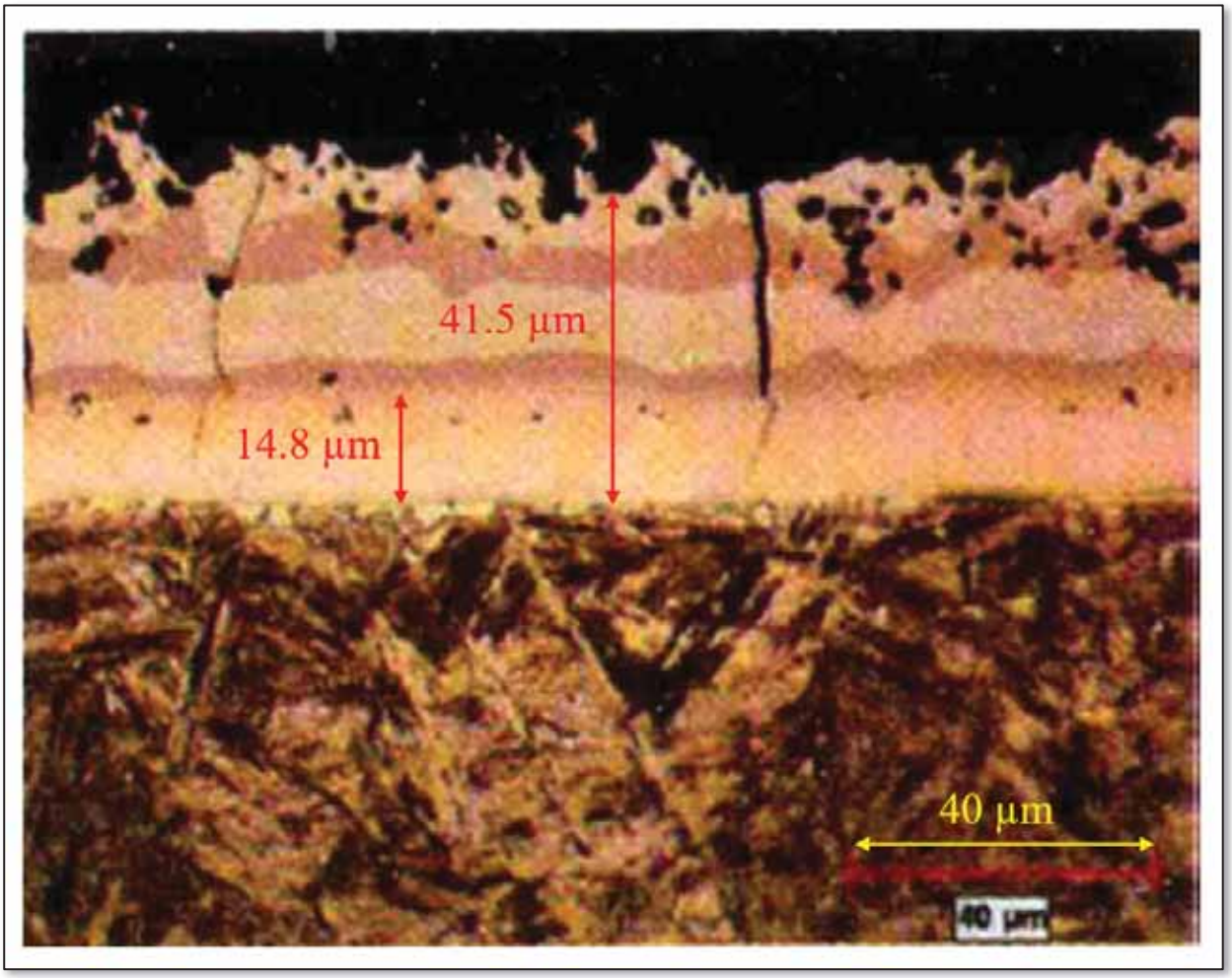
stamping. EX-1026, 2; EX-1019, 164-165. As a result of this routine experimentation, it would have been obvious for a POSITA to arrive at the disclosed **0.05%** upper limit for Ti% disclosed by Hein, in combination with the **0.01%** upper limit for N% disclosed by GMW14400. EX-1019, 164; EX-1026, 2. These two compositions satisfy the ratio "in excess of 3.42" recited in claims 7-8.

174. For [8], *see also* [2] above.

[9]: The precoated steel product as recited in claim 1 wherein the layer (a) has a thickness less than 15 micrometers.

[10]: The precoated steel product as recited in claim 1 wherein the layer (a) has a thickness less than 10 micrometers.

175. As discussed in Section XIII.D, the layers of the modified Takagi coatings have thicknesses the same as or similar to those of Hein FIG. 4. My measurements indicate that the deepest layer of the Hein FIG. 4 coating (which corresponds to layer (a)) has a thickness of **14.8 µm**.



Annotated Hein FIG. 4

176. This thickness satisfies [9]. To the extent it is argued that the thickness is not explicitly disclosed, it would have been obvious to try varying the thickness of the layer to obtain a slightly thinner layer, thereby satisfying the claimed thickness ranges.

177. For [10], it would have been obvious to experiment with the coating thickness to arrive at the claimed less than 10 µm. The claimed range would represent a decrease in thickness for the Inner layer of only several µm, and the

’602 Patent does not describe any criticality or unexpected results for “less than 10 micrometers” compared to 14.8 μm in the modified Takagi coating. Nor would a POSITA have expected there to be such a qualitative or critical difference, in view of well-understood principles of metallurgy.

178. Indeed, the ’602 Patent does not appear to specifically disclose the claimed range of [10] at all. The range is at most **indirectly** indicated by boilerplate language referring to “all whole numbers, ranges and subranges” between 1 and 15 μm. EX-1001, 6:44-49. The closest description to an actual coating satisfying [10] is that a certain tested part (“ii”) has a “10 micrometers thick” interdiffusion layer, and the ’602 Patent discusses no benefits associated with that thickness. EX-1011, 12:61-13:6. That same part exhibits an “extremely small” weldability range, which is an undesirable feature in hot-stamped steel parts. The weldability range indicates a range of currents over which which a satisfactory weld can be produced. High weldability corresponds to more reliable joints and manufacturing processes. A small weldability range would be difficult to manage in production environments, in which variation in parameters is usually greater than in the lab. As such, a POSITA would not have recognized the “10 micrometers thick” characteristic as providing any notable benefit.

179. The ’602 Patent notes that FIG. 2 illustrates a coating “which does not correspond to the invention” and which “yields inferior results in resistance spot

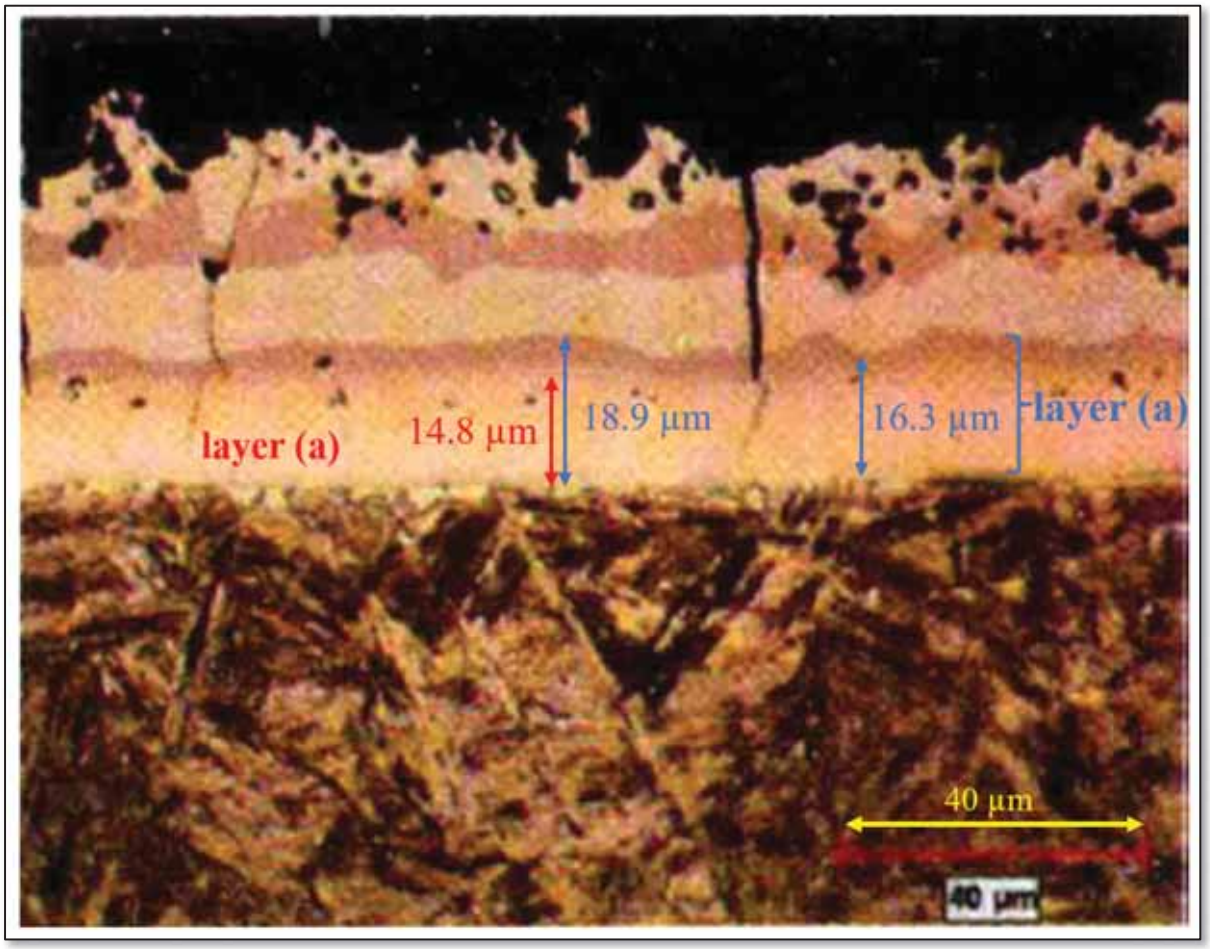
welding." EX-1001, 3:57-61. The '602 Patent does not otherwise appear to discuss this figure. However, from context, a POSITA would have understood that FIG. 2 might correspond to the "ii" coating, given that this is the only coating described in the '602 Patent as exhibiting poor welding characteristics. But the FIG. 2 coating is not described by the '602 Patent as including a superficial layer, which would be required in order to satisfy claim 1. In general, the '602 Patent's teachings for claim 10 are unclear and not well established.

180. A POSITA would have been motivated to experiment with the Inner layer thickness to arrive at the claimed thickness range with a reasonable expectation of success. Takagi explicitly recognizes this thickness as a result-effective variable, noting the thickness' relationship to crack prevention and corrosion resistance. EX-1016, [0017]. To be sure, Takagi generally suggests that the Inner layer should be thicker rather than thinner. EX-1016, [0017]. However, Takagi's recognition of the Inner layer thickness as a relevant parameter would have led a POSITA to try reducing its thickness as a matter of routine optimization.

181. Takagi also describes the physical mechanism behind layer formation and how the layer can be tuned "by controlling the raised temperature of the heating and the holding time at the raised temperature." EX-1016, [0019]. By varying these parameters and the other parameters noted by Takagi and Hein (e.g., heating rate), it would have been obvious for a POSITA to arrive at the claimed

thickness.

182. In the case where the Inner and Inter 1 layers are together applied as layer (a), the composite layer has a measured thickness of **18.9 µm** or **16.3 µm**, which renders obvious the claimed thicknesses absent evidence of criticality or unexpected results, for the reasons discussed above.



<u>Annotated Hein FIG. 4</u>

[11]: The precoated steel product as recited in claim 1 wherein the interdiffusion layer comprises the following components by weight based on total

weight: 86 to 95% Fe, 4 to 10% Al, and 0 to 5% Si.

183. The Inner layers of the modified Takagi coatings, which correspond to the interdiffusion layer, have or at least render obvious the recited compositions. Specifically, as taught in Takagi Table 1, the Inner layers of modified Takagi coating Nos. 1 and 4 have compositions of, or similar to, **89.6% Fe, 7.7% Al, 2.0% Si**, and **90.7% Fe, 6.0% Al, 1.5% Si**, respectively. All of these values are within the recited ranges.

184. Further, Takagi's % are "mass %," which is equivalent to weight %. EX-1016, [0020]. *See* Section VI.A above. And, for reasons similar to those provided above with respect to [11] in Section VI.B, a POSITA would have understood the disclosed mass/weight % to be based on **total** mass/weight and to correspond to **mean** compositions. For example, the disclosed Al%/Si%/Fe% for each layer of Takagi do not sum to 100%, suggesting the consideration of other elements when calculating the mass/weight %.

[12]: The precoated steel product as recited in claim 1 wherein the intermediate layer comprises the following components by weight based on total weight: 39 to 47% Fe, 53 to 61% Al, and 0 to 2% Si.

185. The Inter 2 layers of the modified Takagi coatings, which correspond to the intermediate layer, render obvious the recited compositions. Specifically, as taught in Takagi Table 1, the Inter 2 layers of modified Takagi coating Nos. 1 and

4 have compositions of, or similar to, **50.1% Fe, 48.4% Al, 1.2% Si**, and **46.8% Fe, 51.9% Al, 0.6% Si**, respectively. These values are within the recited ranges except for No. 1 Al% (deviation of 4.6%), No. 1 Fe% (deviation of 3.1%), and No. 4 Al% (deviation of 1.1%).

186. For reasons similar to those discussed with respect to [12] and [13] in Section VI.B, the disclosed compositions render obvious the claimed compositions. Takagi describes both Fe% and Al% as result-effective, noting specifically Fe%'s relationship to hardness and Al%'s relationship to corrosion resistance. EX-1016, [0020]-[0021]. Takagi also describes the physical mechanism behind layer formation and how " the diffusion quantity of Fe [can be] varied" (which would correspond to control of Al% and Fe%) "by controlling the raised temperature of the heating and the holding time at the raised temperature." EX-1016, [0019]. By varying these parameters and the other parameters noted by Takagi and Hein (e.g., heating rate), it would have been obvious for a POSITA to arrive at the claimed compositions as a result of routine experimentation.

187. In addition, there is no criticality or unexpected behavior associated with the very small deviations noted above. Based on a POSITA's understanding of steel characteristics, the deviations would be associated with no qualitative differences and, indeed, would fall within manufacturing tolerances for the micron-scale layers under consideration, as discussed in Section VI.B.

[13]: The precoated steel product as recited in claim 1 wherein the intermetallic layer comprises the following components by weight based on total weight: 62 to 67% Fe, 30 to 34% Al, and 2 to 6% Si.

188. The Inter 3 layers of the modified Takagi coatings, which correspond to the intermetallic layer, have or at least render obvious the recited compositions. Specifically, as taught in Takagi Table 1, the Inter 3 layers of modified Takagi coating Nos. 1 and 4 have compositions of, or similar to, **62.0% Fe, 31.6% Al, 5.7% Si**, and **63.1% Fe, 30.4% Al, 5.3% Si**, respectively. All of these values are within the recited ranges.

[14]: The precoated steel product as recited in claim 1 wherein the superficial layer comprises the following components by weight based on total weight: 39 to 47% Fe, 53 to 61% Al, and 0 to 2% Si.

189. The Superficial layers of modified Takagi coating Nos. 1 and 4 have compositions of, or similar to, **44.5% Fe, 54.8% Al, 0.8% Si**, and **49.8% Fe, 47.4% Al, 2.2% Si**, respectively. All of the No.1 values are within the recited ranges, directly teaching the elements of claim 14. The No. 4 values deviate from the recited ranges by 2.8%, 5.6%, and 0.2% for Fe%, Al%, and Si%, respectively. Absent evidence of criticality or unexpected results, these values render obvious the claimed ranges for the reasons discussed with respect to [12] and [13] in Section VI.B and [12] in Section XIII.E.

[15]: See [12] above.

[16]: See [13] above.

[17]: See [14] above.

[18]: The precoated steel product as recited in claim 1 wherein the interdiffusion layer has a thickness of from 1 micron to 15 microns.

190. *See* [9]. The modified Takagi coating has an Inner layer with thickness **14.8 µm**, as disclosed in Hein FIG. 4, based on my pixel measurements. This discloses or renders obvious claim 18. In the case where the Inner and Inter 1 layers are together applied as layer (a), the composite layer has a measured thickness of **18.9 µm** or **16.3 µm**, which renders obvious the claimed thicknesses absent evidence of criticality or unexpected results.

[19]: The precoated steel product as recited in claim 1 wherein the first mean iron composition is 90 percent, the second mean iron composition is 43 percent, the third mean iron composition is 63 percent and the fourth mean iron composition is 45 percent.

191. The modified Takagi coatings No. 1 and 4 have layer-wise Fe% of or similar to **89.6, 50.1, 62.0, 44.5** and **90.7, 46.8, 63.1, 49.8**, all similar to the claimed Fe%. For similar reasons to those discussed for [12] in Section VI.B, absent a showing of criticality or unexpected results, the values taught by Takagi render obvious the claimed values. It would have been obvious for a POSITA to

arrive at these values as the result of routine experimentation with a reasonable expectation of success, as discussed with respect to [12] and [13] in Section VI.B and [12] in Section XIII.E

192. Further, the ’602 Patent fails to describe a “difference in kind and not of degree” associated with the differences between claim 19’s Fe% and Takagi’s, which are similar, as shown in the table below. For example, the Takagi No. 4 coating deviates from the claimed coating by 0.7%, 3.8%, 0.1%, and 4.8%, respectively, for the four layers of the coating. These differences would likely fall within manufacturing tolerances for micron-scale layers in a hot-stamped coating.

Layer	Claimed Fe%	Takagi No. 1 Fe%	Takagi No. 4 Fe%
(a)	90	89.6	90.7
(b)	43	50.1	46.8
(c)	63	62.0	63.1
(d)	45	44.5	49.8

[20]: The precoated steel product as recited in claim 1 wherein the fourth mean iron composition is lower than the third mean iron composition.

193. The modified Takagi coatings have Fe% for Inter 3 and Outer layers of **62.0%** and **44.5%** for No. 1 and **63.1% and 49.8%** for No. 4, respectively, based on Takagi Table 1. These pairs of values both satisfy claim 20, with Inter 3 corresponding to layer (c) and Outer corresponding to layer (d).

[21]: A precoated steel product comprising:

a strip of base steel having a first side and a second side; and a coating on

at least one of the first side of the strip of base steel and the second side of the strip of base steel, wherein the coating results from interdiffusion between the base steel, and an aluminum or aluminum alloy pre-coating, and wherein the coating includes, proceeding from the base steel outwards:

(a) an interdiffusion layer having a first mean iron composition,

(b) an intermediate layer having a second mean iron composition different from the first mean iron composition,

(c) an intermetallic layer having a third mean iron composition different from the first and second mean iron compositions, the third mean iron concentration being higher than the second mean iron composition, and

(d) a superficial layer having a fourth mean iron composition different from the first, second and third mean iron compositions,

wherein the coating has a thickness greater than 30 micrometers.

194. *See* claim 1 above. Claim 21 is identical to claim 1 except for additionally reciting that the fourth mean composition is different from the first and second mean iron compositions. This element is disclosed in Takagi Table 1 for each of the modified Nos. 1 and 4.

Corresponding layers of '602 Patent

TABLE 1

(a) (b) (c) (d)

No.	PRODUCTION		COATING LAYER STRUCTURE & COMPOSITION (%)						STEEL BASE HARDNESS (Hv)	COATING LAYER HARDNESS (Hv)			OXIDE WEIGHT (mg/dm²)	FORMABILITY	CORROSION RESISTANCE	WELDABILITY
	RAISED TEMPERATURE (°C)	HOLD TIME (min.)	COMPONENT & HARDNESS	INNER	INTER 1	INTER 2	INTER 3	OUTER		SOFTEST	AVERAGE	SOFTER RANGE (%)				
1	920	3	Al	7.7	31.0	48.4	31.6	54.8	450	310	415	51	300	○	○	○
			Si	2.0	3.9	1.2	5.7	0.8								
			Fe	89.6	65.9	50.1	62.0	44.5								
			Hv	310	360	750	700	800								
2	900	2	Al	27.2	48.4	31.6	—	54.9	415	380	455	22	275	×	○	○
			Si	4.1	1.2	5.7		0.8								
			Fe	67.2	50.1	61.9		44.1								
			Hv	380	760	720	—	810								
3	930	10	Al	9.4	—	—	—	11.6	400	305	385	78	550	○	×	×
			Si	1.3				1.8								
			Fe	88.4				85.7								
			Hv	305	—	—	—	410								
4	950	5	Al	6.0	27.8	51.9	30.4	47.4	440	280	400	59	385	○	○	○
			Si	1.5	4.3	0.6	5.3	2.2								
			Fe	90.7	66.7	46.8	63.1	49.8								
			Hv	280	340	720	690	800								
5	900	4	Al	3.2	54.5	33.4	—	54.5	440	300	410	56	335	○	○	○
			Si	0.4	2.5	15.3		6.8								
			Fe	94.3	42.7	51.4		38.4								
			Hv	300	740	700	—	810								

Different Fe% in each layer

Annotated Takagi Table 1

[22]: See [20].

[23]: The precoated steel product as recited in claim 22 wherein the fourth mean iron composition is higher than the second mean iron composition.

195. The claimed Fe% relationship is satisfied for the modified No. 4 coating based on Takagi Table 1 (**46.8%** for Inter 2 (layer (b)) and **49.8%** for Outer (layer (d))).

196. The modified No. 1 coating (**50.1%** for Inter 2 (layer (b)) and **44.5%** for Outer (layer (d))) renders obvious [23] for reasons discussed for [23] in Section III.B and for [12] in Section XIII.E.

[24]: A precoated steel product comprising:

a strip of base steel having a first side and a second side; and

a coating on at least one of the first side of the strip of base steel and the second side of the strip of base steel, wherein the coating results from interdiffusion between the base steel, and an aluminum or aluminum alloy pre-coating, and wherein the coating includes, proceeding from the base steel outwards:

(a) an interdiffusion layer having a first mean aluminum composition,

(b) an intermediate layer having a second mean aluminum composition different from the first mean aluminum composition,

(c) an intermetallic layer having a third mean aluminum composition different from the first and second mean aluminum compositions, and

(d) a superficial layer having a fourth mean aluminum composition different from the first, second and third mean aluminum compositions, the second mean aluminum composition being greater than the third mean aluminum composition;

wherein the coating has a thickness greater than 30 micrometers.

197. *See* claim 1 above. Claim 24 is identical to claim 1 except that (i) mean **aluminum** compositions are recited instead of mean iron compositions, (ii) the fourth mean Al% is "different from the first, second and third mean" Al%, and (iii) "the second mean aluminum composition [is] greater than the third mean aluminum composition." These elements are disclosed for the modified Nos. 1 and

4 coatings in Takagi Table 1, which discloses Inter 2/Inter 3 Al% of **48.4/31.6** and **51.9/30.4** for Nos. 1 and 4, respectively.

[25]: The precoated steel product as recited in claim 24 wherein the fourth mean aluminum composition is less than the second mean aluminum composition.

198. The claimed Al% relationship is satisfied for the modified No. 4 coating based on Takagi Table 1 (fourth Al% **47.4%**, second Al% **51.9%**). The modified No. 1 coating (fourth Al% **54.8%**, second Al% **48.4%**) renders obvious [25] for reasons discussed for [25] in Section III.B and for [12] in Section XIII.E.

[26]: See [9] above.

[27]-[30]: See [11]-[14] above.

XIV. GROUND 2B: Claims 3-4 and 7-8 are obvious over Takagi in view of Hein, GMW14400, and Laurent

A. Analysis of Claims

[3]: The precoated steel product as recited in claim 1 wherein the base steel includes the following components by weight based on total weight: 0.15%<carbon<0.5%; 0.5%<manganese<3%; 0.1%<silicon<0.5%; 0.01%<chromium<1%; titanium<0.2%; aluminum<0.1%; phosphorus<0.1%; sulfur<0.05%; 0.0005%<boron<0.08%; and further comprises iron and impurities inherent in processing.

[4]: The precoated steel product as recited in claim 1 wherein the base steel comprises the following components by weight based on total weight: 0.20%<carbon<0.5%; 0.8%<manganese<1.5%; 0.1%<silicon<0.35%; 0.01%<chromium<1%; titanium<0.1%; aluminum<0.1%; phosphorus<0.05%; sulfur<0.03%; 0.0005%<boron<0.01%; and further comprises iron and impurities inherent in processing.

[7]: The precoated steel product as recited in claim 1 wherein a ratio of titanium to nitrogen in the base steel in weight % is in excess of 3.42.

[8]: The precoated steel product as recited in claim 2 wherein a ratio of titanium to nitrogen in the base steel in weight % is in excess of 3.42.

199. As discussed in Section VIII.B, a POSITA would have found it obvious to try using a steel as disclosed by Laurent to realize "very high mechanical resistance after thermal treatment." EX-1023, 1:47-62. The "preferabl[e]" "composition by weight" of Laurent's steel, including the disclosed ratio of Ti to N, satisfies or renders obvious [3]-[4] and [7]-[8]. EX-1023, 1:66-2:14. For [3]-[4], the relevant compositions are shown in the table below. For [7]-[8], Laurent describes that "in the composition by weight of the sheet, the titanium content with respect to the nitrogen content is in excess of 3.42." EX-1023, 2:11-14. This modification would have represented only a minor change from the steel composition already taught by GMW14400.

Element	[3] composition	[4] composition	GMW1440 composition	Laurent composition (col.2)
C	0.15% < C < 0.5%	0.2% < C < 0.5%	0.20 to 0.25% C	0.20% < C < 0.5%
Mn	0.5% < Mn < 3%	0.8% < Mn < 1.5%	1.00 to 1.35% Mn	0.8% < Mn < 1.5%
Si	0.1% < Si < 0.5%	0.1% < Si < 0.35%	0.15 to 0.35% Si	0.1% < Si < 0.35%
Cr	0.01% < Cr < 1%	0.01% < Cr < 1%	0.11 to 0.35% Cr	0.01% < Cr < 1%
Ti	Ti < 0.2%	Ti < 0.1%	[none (satisfied)]	Ti < 0.1%
Al	Al < 0.1%	Al < 0.1%	0.010 min. % Al	Al < 0.1%
P	P < 0.1%	P < 0.05%	0.025 max. %	P < 0.05%
S	S < 0.05%	S < 0.03%	0.010 max. %	S < 0.03%
B	0.0005% < B < 0.08%	0.0005% < B < 0.01%	0.0015 to 0.005 wt. %	0.0015% < B < 0.01%
Remainder	"iron and impurities inherent in processing"	"iron and impurities inherent in processing"	iron (implicit); 0.010 max. % N	"iron and impurities inherent in processing"

XV. Ground 2C: Claims 3-6 are obvious over Takagi in view of Hein, GMW14400, and Nishibata

A. Analysis of Claims

[3]: The precoated steel product as recited in claim 1 wherein the base steel includes the following components by weight based on total weight:

0.15%<carbon<0.5%; 0.5%<manganese<3%; 0.1%<silicon<0.5%;

0.01%<chromium<1%; titanium<0.2%; aluminum<0.1%; phosphorus<0.1%;

sulfur<0.05%; 0.0005%<boron<0.08%; and further comprises iron and impurities inherent in processing.

[4]: The precoated steel product as recited in claim 1 wherein the base steel comprises the following components by weight based on total weight: 0.20%<carbon<0.5%; 0.8%<manganese<1.5%; 0.1%<silicon<0.35%; 0.01%<chromium<1%; titanium<0.1%; aluminum<0.1%; phosphorus<0.05%; sulfur<0.03%; 0.0005%<boron<0.01%; and further comprises iron and impurities inherent in processing.

[5]: The precoated steel product as recited in claim 1 wherein the base steel comprises 20 ppm or less of sulfur.

[6]: The precoated steel product as recited in claim 2 wherein the base steel comprises 20 ppm or less of sulfur.

200. As discussed in Section IX.B, a POSITA would have found it obvious to try using the steel compositions of Nishibata to obtain "stabilized strengths and toughnesses" in a hot-stamped part. EX-1050, 2. Nishibata's base steel compositions having sulfur% of 0.002% and 0.001% (20 ppm and 10 ppm) satisfy or render obvious [5]-[6]. EX-1050, Table 1. Nishibata's steel compositions in Table 1 and pg. 3-4 also render obvious [3]-[6]. *See* Section IX.B.

201. For [6], *see also* [2] in Section XIII.E. The proposed use of Nishibata's steel with the process and coatings of the Takagi+Hein+GMW14400

combination is further obvious for reasons discussed in Section IX.B. For example, Takagi, Hein, GMW14400, and Nishibata are all in the same field of pre-coated boron steels used for automotive parts. Also, as discussed in Section IX.B, a POSITA would have recognized that Nishibata provides steel with advantageously low sulfur concentrations. Further, as demonstrated in the table below, Nishibata's steels satisfy the elemental concentrations described for Hein's steel, such that (i) the proposed combination would be expected to yield predictable and successful results and (ii) a POSITA would have reduced their time experimenting within the ranges disclosed by Hein by using Nishibata's specific values, e.g., the values for Nishibata's No. 2 steel.

Element	**Hein composition** (Figure 1)	**Nishibata composition** (Table 1)
C	C ≤ 0.25%	0.16% ≤ C ≤ 0.42%
Mn	Mn ≤ 1.4%	1.2% ≤ Mn ≤ 1.53%
Si	Si ≤ 0.35%	0.02% ≤ Si ≤ 0.25%
Cr	Cr ≤ 0.3%	0.19% ≤ Cr ≤ 0.2%
Ti	Ti ≤ 0.05%	0.02% ≤ Ti ≤ 0.03%
B	B ≤ 0.005%	0.0007% ≤ B ≤ 0.0015%

XVI. CONCLUSION

202. The findings and opinions set forth in this declaration are based on my work and examinations to date.

203. I may continue my examinations. I may also receive additional documentation and other factual evidence over the course of this IPR that will allow me to supplement and/or refine my opinions. I reserve the right to add to, alter, or delete my opinions and my declaration upon discovery of any additional information. I reserve the right to make such changes as may be deemed necessary.

204. In signing this declaration, I recognize that the declaration will be filed as evidence in an IPR before the PTAB. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

205. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: 9/6/2024

By:

Dr. Michael Miles
Springville, UT

Appendix A

Michael Miles

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Experience

9/19 – Present	Brigham Young University - Provo, UT Professor, Manufacturing Engineering Department
9/13 – 8/19	Brigham Young University - Provo, UT Professor, Manufacturing Engineering Technology Program
9/09 – 12/16	Brigham Young University - Provo, UT Program Chair/Coordinator, Manufacturing Engineering Technology Program
9/07 – 8/13	Brigham Young University - Provo, UT Associate Professor, Manufacturing Engineering Technology Program
7/01 – 8/07	Brigham Young University - Provo, UT Assistant Professor, Manufacturing Engineering Technology Program
1/00 – 7/01	Assistant Plant Manager, Rexam, PLC - Whitehouse, OH
12/98 – 12/99	Engineering Manager, American National Can - Whitehouse, OH
5/98 – 12/98	Senior Project Engineer, American National Can – Elk Grove Village, IL
1/96 – 4/98	Tooling Engineer, American National Can – Elk Grove Village, IL
2/95 – 1/96	Project Engineer, Pechiney Research Center - Voreppe, France

Education

1995, Ph.D. Materials Science and Engineering, Ecole des Mines de Paris

1991, M.S. Metallurgical Engineering, Ohio State University

1989, B.S. Metallurgical Engineering (French minor), University of Idaho

Professional Activities and Awards

2022 - 2025	Melvin and Maxine Chabries Professorship, BYU Ira A. Fulton College of Engineering
2021	American Welding Society, Adams Memorial Membership Award
2018	Excellence in Scholarship Award, BYU Ira A. Fulton College of Engineering
2011-2013	Nominating committee, The Minerals, Metals, and Materials Society (TMS)
2010	Outstanding Faculty Award, BYU School of Technology
2007- 2010	Chair, The Minerals, Metals, and Materials Society (TMS) Shaping and Forming Committee
2009 – 2011	Faculty advisor, Society of Manufacturing Engineers (SME)
2006	First place award in Society of Manufacturing Engineers (SME) manufacturing challenge competition (faculty team advisor)
2004- 2014	Treasurer and Board Member, Society for the Advancement of Materials and Process Engineering (SAMPE) - Utah Chapter
2003-2007	Faculty advisor for BYU chapter of the Society for Advancement of Materials and Process Engineering (SAMPE)
2003	First place award in Society of Manufacturing Engineers (SME) manufacturing challenge competition (faculty team advisor)
1997	Young Leader Intern for The Minerals, Metals, and Materials Society (TMS)

1990-91	Forming Limit Diagram User's Group, North American Deep Drawing Research Group (NADDRG)
1989-91	Parson's Foundation Fellow, National Science Foundation (NSF) Engineering Research Center for Net Shape Manufacturing, Ohio State University
1988	Member of Tau Beta Pi

Program Director - Asia Manufacturing Engineering Study Abroad Program

Began mentored internship study abroad in 2006 with one company in Shanghai, China. By summer of 2019, approximately 100 students had participated in this program at 13 different companies and three countries (China, Taiwan, Vietnam). Manufacturing engineering technology students were the primary participants, but students from mechanical engineering, chemical engineering, construction management, and nursing were also involved in this 6 week program.

Patents

T. Turner, R. Forrest, M. Miles: End Closure with Improved Openability, 2/15/2000, number 6,024,239.

S. Packer, R. Steel, J. Babb, M. Miles, K. Kohkonen: Three-body joining using friction stir processing techniques, 12/7/2010, number 7,845,545.

M. Miles, R. Fleck, R. Steel: Friction bit joining using a friction rivet, 9/19/2017, number 9,764,375.

M.P. Miles and T.W. Nelson: Friction stir additive processing, BYU disclosure 2016-017, 3/28/2016.

Michael P Miles, Rodney Dale Fleck, Russell J Steel, Kevin Alexander Shirley and Shane Forrest Wood: Systems and methods for friction bit joining, 7/11/2023, number 11,697,173.

Expert Witness

Expert for Freshfields, Bruckhaus, Deringer in patent infringement lawsuit, London, England, September 2008 – January 2009.

Expert for Foley & Lardner LLP in patent infringement lawsuit, Washington, DC, July 2008 – October 2009.

Expert for Reed Smith LLP in personal injury lawsuit, Los Angeles, CA, January 2010 – March 2010.

Expert for Lewis and Rocca LLP in breach of contract lawsuit, Albuquerque, NM, January 2011 – July 2011.

Expert for Burr & Forman LLP, Inter Partes Review, March 2015 – May 2015.

Expert for Covington & Burling LLP in trade secret lawsuit, Washington, D.C., December 2016.

Expert for Morgan, Lewis & Bockius, Inter Partes Review, March 2019 – June 2020.

Expert for Dinsmore & Shohl, patent infringement lawsuit, April 2023 – August 2023.

External Funding

PI: "Development of a finite element model to predict bending limits of thick plate AA 2519", Rockwell Scientific (DARPA subcontract), February 2003 ($15K).

PI: "Formability of Friction Stir Welded High Strength Steel Sheet", Society of Manufacturing Engineers Education Foundation, May 2005 ($15K).

PI (with Co-PI Kent Kohkonen): "SGER: Friction Bit Joining - A New Solid State Spot Joining Process", National Science Foundation, July 2008 ($99,435)

Co-PI (with PI David Fullwood and Co-PI Brent Adams): "GOALI: Defect Detection Microscopy: Microstructure Design for Formability of Wrought Magnesium Alloys", National Science Foundation, August 2009 ($319,937)

PI: "Impact of PCBN tool design performance and tool life for DP 980 steel", DOE PNNL subcontract, March 2010 ($36,864)

PI: "Tool life and joint performance for friction stir spot welding of ultra high strength steel using reduced vertical welding loads", DOE PNNL subcontract, July 2011 ($37,616)

PI: "Solid state spot joining of cast iron and aluminum", RE-EV Program, subcontract through Ulsan University, South Korea, August 2011 ($20K)

PI: "High speed friction stir spot welding: A new method for spot joining of ultra high strength steel", National Science Foundation, August 2011 ($260,000)

PI (with Co-PI Paul Higgins): "Friction Bit Joining: A Novel Solution to Dissimilar Metals Joining", TCIP State of Utah, with Megastir Technologies, January 2012 ($40,000)

Co-PI (with PI Zhili Feng): "Body-in-White Joining of Aluminum to Advanced High Strength Steel at Prototype Scale", DOE, with Oak Ridge National Lab and Honda, September 2013 ($240,000)

PI (with Co-PI David Fullwood): "Microscopic Fracture Mechanisms Evaluation for Advanced High Strength Steel", Auto/Steel Partnership, October 2013 ($35,000)

PI (with Co-PI Tracy Nelson): "GOALI: Crack Repair of Irradiated Stainless Steel by Friction Stir Processing", National Science Foundation, March 2014 ($304,999)

Co-PI (with PI David Fullwood): "Microstructural Foundations of Magnesium Performance: A Data Mining Approach to High-Throughput HREBSD", National Science Foundation, September 2014 ($346,362)

PI (with Co-PI David Fullwood): "Microscopic Fracture Mechanisms Evaluation for AHSS", Auto/Steel Partnership, October 2014 ($30,000)

Co-PI (with PI David Fullwood and Co-PI Eric Homer): "GOALI: Deformation Microscopy of Retained Austenite Transformation in TRIP Steels", National Science Foundation, July 2015 ($455,515)

PI (with Co-PIs Tracy Nelson and Carl Sorensen): "Development of a methodology for characterizing the tool/part interface in friction stir welding for improvement of predictive modeling in aluminum alloys" NASA, January 2019 ($500,000)

PI: "Solid-State Body-in-White Spot Joining of Al to AHSS at Prototype Scale (Phase III)", Department of Energy, March 2019 ($200,021)

PI (with Co-PI David Fullwood): “GOALI/Collaborative Research: Strain Gradient Plasticity Modeling to Link Microstructural Non-Local Effects of Dislocation/Interface Interactions with Ductility and Springback”, National Science Foundation, August 2019 ($299,855)

Co-PI (with PI Troy Munro): “Improvement of Modeling Predictions in Friction Stir Welding by More Accurate Measurement of Heat Transfer Between Tooling and Workpiece”, National Science Foundation, December 2019 ($348,402)

Co-PI (with PI Tracy Nelson and Co-PI Yuri Hovanski): “Investigation of friction stir additive repair techniques of AA 7050 for naval application”, Office of Naval Research, July 2020 ($494,916)

Co-PI (with PI David Fullwood): “Collaborative Research: GOALI: Understanding multiscale mechanics of cyclic bending under tension to improve elongation-to-fracture of hexagonal metals”, National Science Foundation, September 2022 ($314,745).

Co-PI (with PI Tracy Nelson): “A study on methods for obtaining materials flow data for the next generation inertia weld parameter optimization model”, General Electric Research Center, July 2023 ($90,000).

Co-PI (with PI Tracy Nelson): “Morphogenic Interfaces”, DARPA/MINT, April 2023 ($160,000).

PI: “Complex Internal Structures in Castings for Extreme Environmental Conditions”, Idaho National Laboratory, October 2023 ($29,545)

Peer-reviewed journal papers (2014-2024): BYU student co-authors underlined

Sajjad Izadpanah Najmabad, David Fullwood, Tristan Russell, Marko Knezevic, Michael Miles (2024). Interpretation of the stress dip test as a means of characterizing backstress: Experiments and backstress-aided crystal plasticity modeling of polycrystalline tantalum, International Journal of Plasticity, Volume 181, pp. 104089.

Nathan Miller, Nicholas Pitkin, Talukder Musfika Tasnim Oishi, Desmond Mensah, Marko Knezevic, Michael Miles, David Fullwood (2024). Multiscale characterization of dislocation development during cyclic bending under tension in commercially pure titanium, Journal of Materials Research and Technology, Volume 32, pp. 2513-2527.

Talukder Musfika Tasnim Oishi, Nick Pitkin, Nathan Miller, Desmond Mensah, David T. Fullwood, Michael P. Miles, Brad L. Kinsey, Marko Knezevic (2024). Influence of specimen width on the elongation-to-fracture in cyclic-bending-under-tension of commercially pure titanium sheets. International Journal of Mechanical Sciences, Volume 278, pp.109447.

Matthew Goodson, Ryan Melander, Michael P. Miles, Troy Munro (2023). Effect of workpiece/tool heat transfer and friction coefficients on accuracy of simulated temperatures and torques in a friction stir welding plunge. Materials 2024, 17, pp. 198

Dane Sargeant, Md Zahidul Sarkar, Rishabh Sharma, Marko Knezevic, David T. Fullwood, Michael P. Miles (2023). Effect of pre-strain on springback behavior after bending in AA 6016-T4: Experiments and crystal plasticity modeling. International Journal of Solids and Structures, Volume 283, pp. 112485.

Derrik Adams, Marcus Behling, Michael P. Miles, Eric R. Homer, Anil K. Sachdev, Emily V. White, David T. Fullwood (2023). Characterization of the Factors Influencing Retained Austenite Stability in Q&P Steels via In Situ EBSD. Metall Mater Trans A 54, pp. 1355–1363.

Rishabh Sharma, Dane Sargeant, Sowmya Daroju, Marko Knezevic, Michael P. Miles, David T. Fullwood (2022). Multi-strain path deformation behavior of AA6016-T4: Experiments and crystal plasticity modeling, International Journal of Solids and Structures, Volumes 244–245, pp.111536.

Sowmya Daroju, Toshihiko Kuwabara, Rishabh Sharma, David T. Fullwood, Michael P. Miles, Marko Knezevic (2022). Experimental characterization and crystal plasticity modeling for predicting load reversals in AA6016-T4 and AA7021-T79, International Journal of Plasticity, Volume 153, pp.103292.

Evan Berger, Michael Miles, Andrew Curtis, Paul Blackhurst, and Yuri Hovanski (2022). 2D Axisymmetric Modeling of Refill Friction Stir Spot Welding and Experimental Validation, Journal of Manufacturing and Materials Processing, 6(4) pp. 89.

Jie Wu, Yuri Hovanski, and Michael Miles (2022). Digital Image Correlation Characterization and Formability Analysis of Aluminum Alloy TWB during Forming, Materials 15(15), pp. 5291.

David Prymak, Michael Miles, Tracy Nelson, Fredrick Michael (2021). A High-Pressure Shear Testing Approach to Measure Flow Stresses Near a Friction Stir Welding Tool, Materials Performance and Characterization, 10(1), pp. 727-738.

Jie Wu, Yuri Hovanski, Michael Miles (2021). Investigation of the Thickness Differential on the Formability of Aluminum Tailor Welded Blanks, Metals, 11(6), pp. 875.

Rishabh Sharma, Camille M Poulin, Marko Knezevic, Michael P Miles, David T Fullwood (2021). Micromechanical origins of remarkable elongation-to-fracture in AHSS TRIP steels via continuous bending under tension, Materials Science and Engineering A, 825, pp. 141876.

Derrik Adams, Michael P Miles, Eric R Homer, Tyson Brown, Raj K Mishra, David T Fullwood (2021). Phase determination in dual phase steels via HREBSD-based tetragonality mapping, Journal of Microscopy, 282(1), pp. 60-72.

Daniel Ellis, Matthew Goodson, Michael Miles, Troy Munro (2021). Optimized Design for a Device to Measure Thermal Contact Conductance During Friction Stir Welding, International Journal of Thermophysics, 42(1), pp. 1-24.

Jason Weaver, John Linn, Michael Miles (2021). Interface Joint Strength between SS316L Wrought Substrate and Powder Bed Fusion Built Parts, Materials, 14(11), p. 3041.

Stephen Cluff, Marko Knezevic, Michael P Miles, David T Fullwood, Raja K Mishra, Anil K Sachdev, Tyson Brown, Eric R Homer (2021). Coupling kinetic Monte Carlo and finite element methods to model the strain path sensitivity of the isothermal stress-assisted martensite nucleation in TRIP-assisted steels, Mechanics of Materials, 154, pp. 1-14.

Derrik Adams, Shamoon Irfan, Jeff Cramer, Michael P Miles, Eric R Homer, Tyson Brown, Raj K Mishra, David T Fullwood (2020). Digital Image Correlation of Forescatter Detector Images for Simultaneous Strain and Orientation Mapping, Microscopy and Microanalysis, 26(4), pp. 641-652.

Isaac Chelladurai, Devin Adams, David T Fullwood, Michael P Miles, Stephen Niezgoda, Irene J Beyerlein, Marko Knezevic (2019). Modeling of trans-grain twin transmission in AZ31 via a neighborhood-based viscoplastic self-consistent model, International Journal of Plasticity, 117, pp. 21-32.

Jason M Weaver, TJ Barton, John Linn, Derrik Jenkins, Michael P Miles, Robert Smith (2019). Quantifying accuracy of a concept laser metal additive machine through the NIST test artifact, Rapid Prototyping Journal, 25(2), pp. 221-231.

M.P. Miles, T.W. Nelson, C. Gunter, F.C. Liu, L. Fourment, T. Mathis (2019). Predicting recrystallized grain size in friction stir processed 304L stainless steel, Journal of Materials Science & Technology, 35(4), pp. 491-498.

T.M. Rampton, S.I. Wright, M.P. Miles, E.R. Homer, R.H. Wagoner, D.T. Fullwood (2018). Improved twin detection via tracking of individual Kikuchi band intensity of EBSD patterns, Ultramicroscopy, 185, 5-14.

J. Cramer, D. Adams, M.P. Miles, D.T. Fullwood, E.R. Homer, T. Brown, R.K. Mishra, A. Sachdev (2018). Effect of strain path on forming limits and retained austenite transformation in Q&P 1180 steel. Materials Science and Engineering A, 734, pp. 192-199.

A. Orme, D.T. Fullwood, M.P. Miles (2018). Evolution of Mg AZ31 twin activation with strain: a machine learning study. Materials Discovery, 12, 20-29.

R. Sharma, I. Chelladurai, A.D. Orme, M.P. Miles, C.G. Giraud-Carrier, D.T. Fullwood (2018). A Step Towards Intelligent EBSD Microscopy: Machine Learning Prediction of Twin Activity in MgAZ31. Journal of Microscopy, 272(1), 67-78.

C.Gunter, M.P. Miles, F.C.Liu, T.W. Nelson (2018). Solid state crack repair by friction stir processing in 304L stainless steel, Journal of Materials Science & Technology, 34(1) 140-147.

F.C.Liu, Y.Hovanski, M.P.Miles, C.D.Sorensen, T.W.Nelson (2018). A review of friction stir welding of steels: Tool, material flow, microstructure, and properties. Journal of Materials Science & Technology, 34(1), 39-57.

Eun-Yeong Ahn, Hrishikesh Das, Sung-Tae Hong, Kyung-Sik Han, Michael Miles, Kwang-Jin Lee, Ju-Won Park, Heung Nam Ha (2017). Process responses and resultant joint properties of friction stir welding of dissimilar 5083 and 6061 aluminum alloys, Journal of Mechanical Science and Technology, 31(8), 3955-3960.

I. Chelladuari, M.P. Miles, D.T. Fullwood, J.E. Carsley, R.K. Mishra, I.J. Beyerlein, and M. Knezevic (2017). Microstructure Correlation with Formability for Biaxial Stretching of Magnesium Alloy AZ31B at Mildly Elevated Temperatures. JOM, 69(5), 907-914.

J-R. Kim, E-Y. Ahn, H. Das, Y-H. Jeong, S-T. Hong, M.P. Miles, and K-J. Lee (2017). Effect of tool geometry and process parameters on mechanical properties of friction stir spot welded dissimilar aluminum alloys, International Journal of Precision Engineering and Manufacturing 18, 445-452.

Y. C. Lim, L. Squires, T.-Y. Pan, M. P. Miles, J. K. Keum, G.-L. Song, Y. Wang, Z. Feng (2017). Corrosion behaviour of friction-bit-joined and weld-bonded AA7075-T6/galvannealed DP980. Science and Technology of Welding and Joining, 22(6), 455-464.

A. D. Orme, I. Chelladurai, T. M. Rampton, D. T. Fullwood, A. Khosravani, M. P. Miles, R. K. Mishra (2016). Insights into twinning in Mg AZ31: A combined EBSD and machine learning study. Computational Materials Science, 124, 353-363.

T. Ruggles, S. Cluff, M.P. Miles, D.T. Fullwood, C. Daniels, A. Avila, M. Chen (2016). Ductility of Advanced High-Strength Steel in the Presence of a Sheared Edge. JOM, 68(7), 1839-1849.

L. Squires, Y.C. Lim, M.P. Miles, Z. Feng (2015). Mechanical properties of dissimilar metal joints composed of DP 980 steel and AA 7075-T6. Science and Technology of Welding and Joining, 20(3), pp. 242-248.

Y.C. Lim, L. Squires, T.-Y. Pan, M.P. Miles, G.-L. Song, Y. Wang, Z. Feng (2015). Study of mechanical joint strength of aluminum alloy 7075-T6 and dual phase steel 980 welded by friction bit joining and weld-bonding under corrosion medium. Materials & Design, 69(15), pp. 37-43.

T. Hartman, M.P. Miles, S.-T. Hong, R. Steel, S. Kelly (2015). Effect of PCBN tool grade on joint strength and tool life in friction stir spot welded DP 980 steel. Wear, 328-329, pp. 531-536.

D.T. Fullwood, A. Khosravani, J. Scott, M.P. Miles, R. Mishra (2015). Nucleation and propagation of twins in AZ31 magnesium alloy. Acta Materialia, 100, pp. 202-214.

M.P. Miles, U. Karki, and Y. Hovanski (2014). Temperature and Material Flow Prediction in Friction Stir Spot Welding of Advanced High Strength Steel. JOM, 66 (10), pp. 2130-2136.

N. Saunders, M. Miles, T. Hartman, Y. Hovanski, S.T. Hong, R. Steel (2014). Joint Strength in High Speed Friction Stir Spot Welded DP 980 Steel. International Journal of Precision Engineering and Manufacturing, 15(5), pp. 841-848.

Md. Abu Mowazzem Hossain, Md. Tariqul Hasan, Sung-Tae Hong, Michael Miles, Hoon-Hwe Cho, Heung Name Han (2014). Mechanical Behaviors of Friction Stir Spot Welded Joints of Dissimilar Ferrous Alloys under Opening-Dominant Combined Loads. Advances in Materials Science and Engineering, pp. 179-193.

Md. Abu Mowazzem Hossain, Md. Tariqul Hasan, Sung-Tae Hong, Michael Miles, Hoon-Hwe Cho, Heung Name Han (2014). Failure Behaviors of Friction Stir Spot Welded Joints of Dissimilar Ferrous Alloys under Quasi-Static Shear Loads. International Journal of Materials and Product Technology, 48 (1-4), pp. 179-193.

Book Chapters with Peer Review

M. Miles: Formability Testing of Sheet Metals, ASM Handbook, vol. 14B, pp. 673-696 (2006). (Chapter was revised and updated)