

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

GENERAL ELECTRIC COMPANY,
Petitioner,

v.

PRATT AND WHITNEY CANADA CORP.,
Patent Owner.

IPR2020-00083
Patent 9,709,070 B2

Before SCOTT A. DANIELS, MITCHELL G. WEATHERLY, and
SEAN P. O'HANLON, *Administrative Patent Judges*.

DANIELS, *Administrative Patent Judge*.

JUDGMENT
Final Written Decision
Determining All Challenged Claims Unpatentable
35 U.S.C. § 318(a)

I. INTRODUCTION

A. Background

General Electric Company (“Petitioner”) filed a Petition to institute an *inter partes* review, initially, of claims 1–21 of U.S. Patent No. 9,709,070 B2 (“the ’070 patent”). Paper 1 (“Pet.”). Pratt and Whitney Canada Corp. (“Patent Owner”) filed a Preliminary Response. Paper 6 (“Prelim. Resp.”). Contemporaneously with its Preliminary Response, Patent Owner filed a Disclaimer (Ex. 2003) disclaiming claims 1–4, 9–12, 17, 18, 20, and 21. Prelim. Resp. 17–18; Ex. 2003. Therefore, only challenged claims 5–8, 13–16, and 19 remain at issue.¹ We authorized Petitioner to enter an initial Reply to the Preliminary Response. Papers 8–9. We entered a Decision instituting an *inter partes* review of the challenged claims in this proceeding. Paper 11 (“Inst. Dec.”). Patent Owner timely filed a Response. Paper 21 (“PO Resp.”) Petitioner filed a Reply. Paper 26 (“Pet. Reply”). Patent Owner subsequently filed a Sur-Reply. Paper 28 (“PO Sur-Reply”). We heard oral argument on January 21, 2021. A transcript of the argument has been entered into the record. Paper 33 (“Tr.”).

We have jurisdiction under 35 U.S.C. § 6(b). This Final Written Decision is issued pursuant to 35 U.S.C. § 318(a). Petitioner bears the burden of proving unpatentability of the challenged claims, and the burden of persuasion never shifts to Patent Owner. *Dynamic Drinkware, LLC v. Nat’l Graphics, Inc.*, 800 F.3d 1375, 1378 (Fed. Cir. 2015). To prevail, Petitioner must prove unpatentability by a preponderance of the evidence. *See* 35 U.S.C. § 316(e) (2018); 37 C.F.R. § 42.1(d) (2018). Having

¹ The disclaimer leaves only grounds numbered by Petitioner as 8, 10, and 12 at issue in this proceeding. *See* Prelim. Resp. 18.

reviewed the arguments of the parties and the supporting evidence, we find that Petitioner has demonstrated by a preponderance of the evidence that each of the remaining challenged claims—i.e., claims 5–8, 13–16, and 19 of the '070 patent—is unpatentable.

B. Additional Proceedings

Neither party indicates that the '070 patent is involved in a lawsuit or other legal proceeding. Pet. 1; Paper 4.

C. Real Parties in Interest

Petitioner indicates that General Electric Company, Safran Aircraft Engines, CFM International S.A., CFM International, Inc., and Safran S.A. are the real parties-in-interest. Pet. 1.

Patent Owner indicates that United Technologies Corporation and Pratt & Whitney Canada Corp. are the real parties-in-interest. Paper 4, 1.

D. The '070 Patent

The '070 patent (Ex. 1001), titled “Low Hub-to-Tip Ratio Fan for a Turbofan Gas Turbine Engine,” discloses “[a] fan for a turbofan gas turbine engine having a low hub-to-tip ratio.” Ex. 1001, [54], Abstract. Figure 2 of the '070 patent is reproduced below.

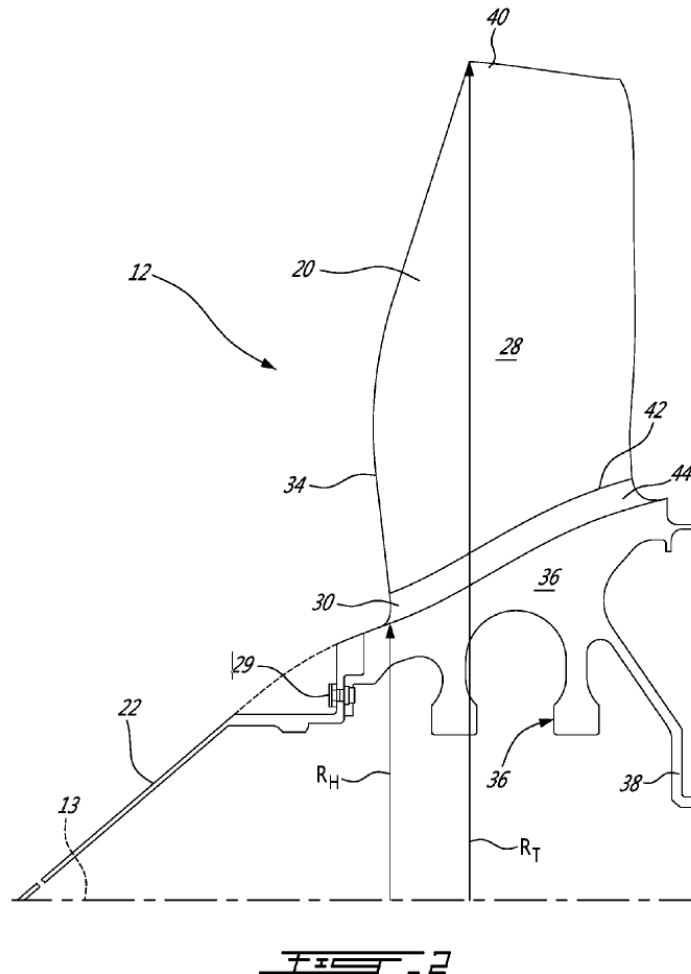


Figure 2 of the '070 patent illustrates in partial cross-section that “fan 12 comprises a plurality of fan blades 20 integrally formed with, and substantially radially extending from, a central fan hub 36.” *Id.* at 3:58–60.

The '070 patent describes various fan embodiments with specific ranges of hub-to-tip ratio, for example, “a ratio of the hub radius to the tip radius, i.e. R_{HUB}/R_{TIP} , which is at least less than 0.29.” Ex. 1001, 4:36–37. In addition, the '070 patent describes that fan 12 is an “integrally bladed rotor (IBR) fan” that has “reduced weight compared to a traditional detachable bladed rotor.” *Id.* at 4:50–52. An IBR fan as described in the '070 patent is fabricated “by first machining a root stub 44 on the hub 36, or

more specifically on a hub preform . . . [t]he blade airfoils 28 may then be fixed to the root stubs 44 of the hub preform [] welded by Linear Friction Welding (LFW).” *Id.* at 4:58–65.

According to the ’070 patent fabricating an IBR fan is not straightforward. *See id.* at 1:35–39 (“Attempts to manufacture an integrated bladed rotor (IBR) fan with a low hub to tip ratio have not been successful because of the lack of space for machine tools between the roots of the blades when the hub is also reduced in size.”). The ’070 patent explains that “[t]he machining of an IBR fan 12 with such a low hub/tip ratio is made difficult by the lack of space between the blades 20, particularly at the blade roots 30 since the gap between the blades is much narrower the smaller the radius of the fan.” *Id.* at 4:52–56. To account for the lack of space between blades at the connection of the blade root and hub, the ’070 patent describes a method of “machining a root stub 44 on the hub 36” where “[t]he blade airfoils 28 may then be fixed to the root stubs 44 of the hub preform . . . by Linear Friction Welding (LFW), for example, along the joint line 42 as shown on the blade 20 in FIG. 2.” *Id.* at 4:59–66. According to the ’070 patent the height of the root stubs 44 beyond the hub facilitates machining of an IBR fan with low hub/tip ratios “because it is easier to access the radial gap between adjacent blades 20 with machine tools.” *Id.* at 4:62–63.

E. Illustrative Claims

The remaining challenged claims 5–8, 13–16, and 19, are dependent either directly or indirectly upon independent claims 1, 12, and 17. Dependent claim 5, along with base independent claim 1 and intervening dependent claim 4 (both disclaimed), illustrate the claimed subject matter and are reproduced below:

1. (*Disclaimed*) A fan for a turbofan gas turbine engine, the fan defining a fan centerline and comprising a rotor hub and a plurality of fan blades adapted to rotate about the fan centerline, the fan blades extending radially from the rotor hub to outer tips thereof, the fan blades circumferentially spaced apart about the rotor hub in a single axial blade row, each of the fan blades having a leading edge, a hub radius (R_{HUB}) and a tip radius (R_{TIP}), wherein the hub radius (R_{HUB}) is the radius of the leading edge at the hub relative to the fan centerline, and the tip radius (R_{TIP}), is the radius of the leading edge at the outer tip relative to the fan centerline, and wherein the ratio of the hub radius to the tip radius (R_{HUB}/R_{TIP}) is less than 0.29.
4. (*Disclaimed*) The fan as defined in claim 1, wherein the fan is an integrally bladed rotor, the fan blades being integrally formed with the rotor hub.
5. The fan as defined in claim 4, wherein the rotor hub of the integrally bladed rotor includes a preform having root stubs disposed on the rotor hub at circumferential positions corresponding to at least alternate ones of said fan blades in the single axial blade row, the root stubs being formed on the rotor hub prior to the fan blades being fastened thereto.

Ex. 1001, 5:18–44.

F. The Alleged Grounds of Unpatentability

Based on Patent Owner's disclaimer and Petitioner's challenges to the '070 patent only three specific grounds remain at issue in this proceeding.²

² Petitioner supports its challenge with Declarations of Reza Abhari, Ph.D (Ex. 1003) and Ingrid Hsieh-Yee, Ph.D (Ex. 1021). Patent Owner relies on Declarations of Ernesto Benini, Ph.D (Exs. 2001, 2009) and Steven Schmid, Ph.D (Ex. 2010). *See infra*.

Claims Challenged	35 U.S.C. §	References
5–8, 13–16, 19	103	Kaplan, ³ Brownell ⁴
5–8, 13–16, 19	103	Gray, ⁵ Brownell
5–8, 13–16, 19	103	Kodama, ⁶ Brownell

G. The Level of Ordinary Skill in the Art

Factors pertinent to a determination of the level of ordinary skill in the art include: “(1) educational level of the inventor; (2) type of problems encountered in the art; (3) prior art solutions to those problems; (4) rapidity with which innovations are made; (5) sophistication of the technology, and (6) educational level of workers active in the field.” *Envtl. Designs, Ltd. v. Union Oil Co.*, 713 F.2d 693, 696–697 (Fed. Cir. 1983) (citing *Orthopedic Equip. Co. v. All Orthopedic Appliances, Inc.*, 707 F.2d 1376, 1381–82 (Fed. Cir. 1983)). Not all such factors may be present in every case, and one or more of these or other factors may predominate in a particular case. *Id.* Moreover, these factors are not exhaustive but are merely a guide to determining the level of ordinary skill in the art. *Daiichi Sankyo Co. Ltd, Inc. v. Apotex, Inc.*, 501 F.3d 1254, 1256 (Fed. Cir. 2007).

In determining a level of ordinary skill, we also may look to the prior art, which may reflect an appropriate skill level. *Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001). Additionally, the Supreme Court informs

³ Ex. 1005, B. Kaplan, E. Nicke, C. Voss, *Design of a Highly Efficient Low-Noise Fan for Ultra-High Bypass Engines*, Proceedings of GT2006, ASME Turbo Expo 2006: Power for Land, Sea and Air (May 8–11, 2006).

⁴ Ex. 1008, US Patent No. 6,524,072 B1 (Feb. 25, 2003).

⁵ Ex. 1019, D.E. Gray, W.B. Gardner, *Energy Efficient Engine Program—Technology Benefit/Cost Study*, Vol. II, United Technologies Corp., Pratt & Whitney Engineering Division, NASA Contract NAS3-20646 (Oct. 1983).

⁶ Ex. 1006, US Patent Appl’n No. 12/307,535, Pub. No. 2009/0304518 A1 (Dec. 10, 2009).

us that “[a] person of ordinary skill is also a person of ordinary creativity, not an automaton.” *KSR Int’l v. Teleflex Inc.*, 550 U.S. 398, 421 (2007).

Petitioner contends a person of ordinary skill in the art “would include someone who has a M.S. degree in Mechanical Engineering or Aerospace Engineering as well as at least 3-5 years of experience in the field of gas turbine engine design and analysis.” Pet. 15 (citing Ex. 1003 ¶ 4). Initially Patent Owner demurred, asserting that a person with such a level of skill and experience “would have considered it obvious to make these complex fan assemblies with the claimed low hub-to-tip ratios by linear friction welding to root stubs.” Prelim. Resp. 4. Now, in its Response, Patent Owner does not expressly dispute Petitioner’s proposed level of ordinary skill in the art.

Petitioner’s proposed level of ordinary skill in the art is consistent with our review of the ’070 patent and the background and descriptions of the prior art asserted in this proceeding. For example, U.S. Patent No. 6,524,072 to Brownell explains that it was known at least by 1998 that “[t]he two most commonly used methods for manufacturing BLISKS are machining from solid and attaching separately made blades onto a disk by friction welding.”⁷ Ex. 1008, 1:17–20. In its Background section, the ’070 patent describes that it was known in the art that reducing the hub-to-tip ratio of turbine engine fans was beneficial for fan efficiency and explained that “[a]ttempts to manufacture an integrated bladed rotor (IBR) fan with a low hub-to-tip ratio have not been successful because of the lack of space for machine tools between the roots of the blades.” Ex. 1001, 1:35–39. Thus, before the filing of the application that became the ’070 patent a person of

⁷ An integrally bladed rotor, “IBR,” is also referred to in the prior art as a “blisk.” See Ex. 1013, 1:7–10.

ordinary skill in the art would have been aware of friction welding techniques for IBR's, that a low hub-to-tip ratio for gas turbine fan blades was desirable for efficiency, and also that friction welding techniques for low hub-to-tip ratio fans required consideration of the physical spacing between the blades for machine tools.

Based on the complete record now before us, we adopt Petitioner's definition of the level of ordinary skill in the art for this Decision.

H. Claim Construction

In an *inter partes* review based on a petition filed after November 13, 2018, the claims are construed

using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. [§] 282(b), including construing the claim in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent.

See 37 C.F.R. § 42.100(b) (2019)); *see Phillips v. AWH Corp.*, 415 F.3d 1303, 1312–13 (Fed. Cir. 2005) (setting forth claim construction standard in civil actions). Any special definitions for claim terms must be set forth in the specification with reasonable clarity, deliberateness, and precision. *See In re Paulsen*, 30 F.3d 1475, 1480 (Fed. Cir. 1994).

Neither party identifies any claim term for express interpretation. Based on our review of the complete record and a reasonable reading of the claims we do not perceive the need to interpret any claim term. In this proceeding we can determine patentability of the challenged claims without expressly interpreting any claim terms.

II. ANALYSIS

We turn now to Petitioner’s asserted grounds of unpatentability and Patent Owner’s arguments in its Response to determine whether Petitioner has met its burden under 35 U.S.C. § 316(e).

A. The Legal Constructs of Obviousness

Section 103(a) forbids issuance of a patent when “the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains.” *KSR*, 550 U.S. at 406.

The question of obviousness is resolved on the basis of underlying factual determinations, including: (1) the scope and content of the prior art; (2) any differences between the claimed subject matter and the prior art; (3) the level of ordinary skill in the art; and (4) when available, evidence such as commercial success, long-felt but unsolved needs, and failure of others. *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966); *see KSR*, 550 U.S. at 407 (“While the sequence of these questions might be reordered in any particular case, the [Graham] factors continue to define the inquiry that controls.”). The Court in *Graham* explained that these factual inquiries promote “uniformity and definiteness,” for “[w]hat is obvious is not a question upon which there is likely to be uniformity of thought in every given factual context.” *Graham*, 383 U.S. at 18.

The Supreme Court made clear that we apply “an expansive and flexible approach” to the question of obviousness. *KSR*, 550 U.S. at 415. Whether a patent claiming the combination of prior art elements would have been obvious is determined by whether the improvement is more than the

predictable use of prior art elements according to their established functions. *Id.* at 417. To reach this conclusion, however, it is not enough to show merely that the prior art includes separate references covering each separate limitation in a challenged claim. *Unigene Labs., Inc. v. Apotex, Inc.*, 655 F.3d 1352, 1360 (Fed. Cir. 2011). Rather, obviousness additionally requires that a person of ordinary skill at the time of the invention “would have selected and combined those prior art elements in the normal course of research and development to yield the claimed invention.” *Id.*

Moreover, in determining the differences between the prior art and the claims, the question under 35 U.S.C. § 103 is not whether the differences themselves would have been obvious, but whether the claimed invention as a whole would have been obvious. *Litton Indus. Prods., Inc. v. Solid State Sys. Corp.*, 755 F.2d 158, 164 (Fed. Cir. 1985) (“It is elementary that the claimed invention must be considered as a whole in deciding the question of obviousness.”) (citation omitted); *see also Stratoflex, Inc. v. Aeroquip Corp.*, 713 F.2d 1530, 1537 (Fed. Cir. 1983) (“[T]he question under 35 U.S.C. § 103 is not whether the differences themselves would have been obvious. Consideration of differences, like each of the findings set forth in *Graham*, is but an aid in reaching the ultimate determination of whether the claimed invention as a whole would have been obvious.”) (citation omitted).

As a fact finder, we also must be aware “of the distortion caused by hindsight bias and must be cautious of arguments reliant upon *ex post* reasoning.” *KSR*, 550 U.S. at 421. This does not deny us, however, “recourse to common sense” or to that which the prior art teaches. *Id.*

Against this general background, we consider the references, other evidence, and arguments on which the parties rely.

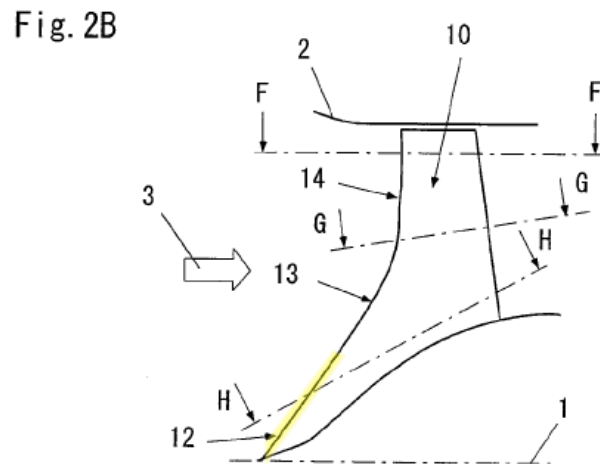
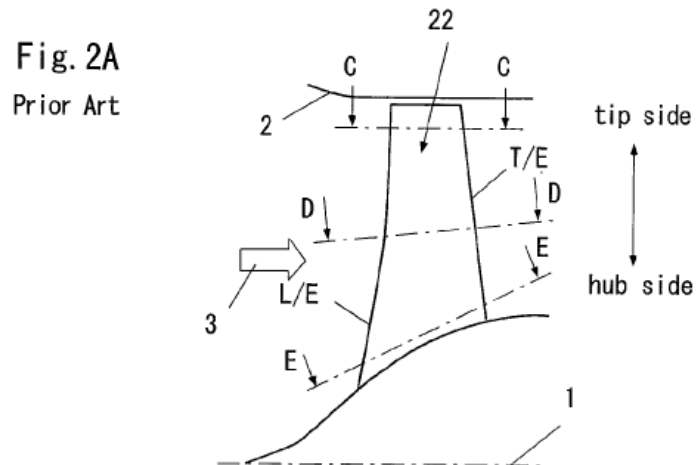
B. Claims 5–8, 13–16, and 19 — Obviousness over Kodama and Brownell

Petitioner asserts that claims 5–8, 13–16, 19 would have been obvious over Kodama and Brownell. Pet. 28–53. We first describe the prior art that Petitioner combines to show that these claims are obvious, and then turn to the merits of the combination. For the reasons explained below, we determine that Petitioner has established by a preponderance of the evidence that claims 5–8, 13–16, and 19 would have been obvious over Kodama and Brownell.

1. Kodama

Kodama is titled “Turbofan Engine” and was published December 19, 2009. Petitioner contends Kodama is prior art under 35 U.S.C. § 102(b). Pet. 18. Patent Owner does not dispute the prior-art status of Kodama. *See generally* PO Resp. 63–68.

Kodama describes an improvement in a first stage fan for a turbofan engine where “a hub-side leading edge part 12 of a fan first-stage rotating blade 10 for taking an air there into [extends] more in a forward direction than a tip-side leading edge part 14 and a mid-span leading edge part 13.” Ex. 1006 ¶ 44. Kodama’s improved blade 10 shown below in Figure 2B, as annotated by the Board, is presented in contrast with prior art blade 22 shown in Figure 2A, labeled “Prior Art.”



Kodama's Figure 2A, above labelled "Prior Art," and annotated Figure 2B, below it, contrast the hub-side leading edge of prior art blade 22 in Figure 2A with the improved blade 10 having hub-side leading edge 12, annotated in yellow, extending more forward on the hub as illustrated in Figure 2B. Kodama explains that due to improved blade 10 "it is possible to realize the same total flow rate by using the fan rotating blade having a smaller diameter than that of the fan rotating blade according to the conventional art." *Id.* ¶ 67.

Kodama also illustrates in Figure 4A, below, several embodiments of blade 10 with leading edge 12 extending forward along the hub by different amounts a–d.

Fig.4A

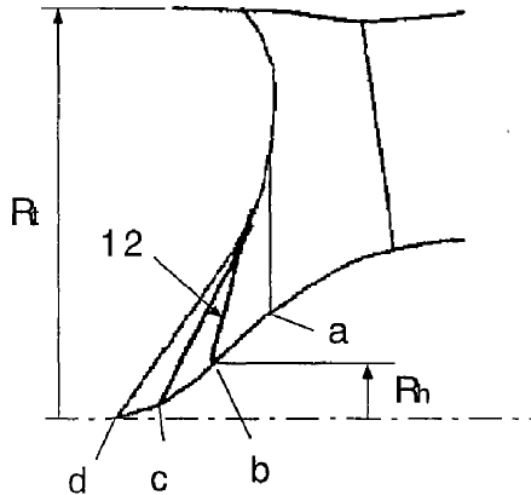
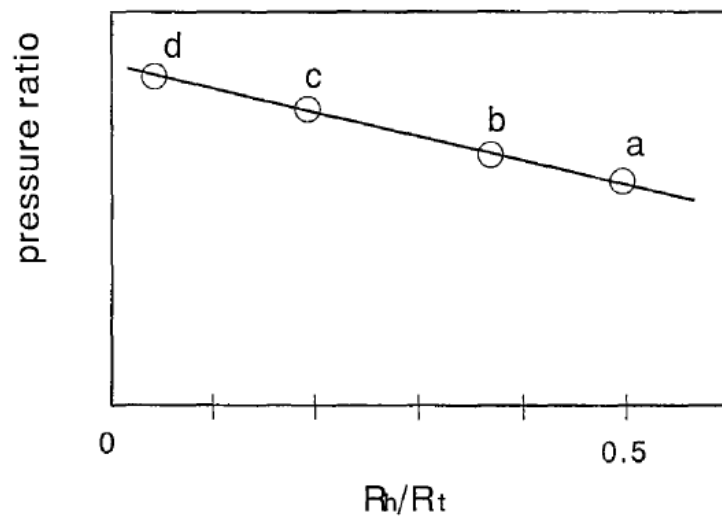


Figure 4A, above, illustrates different embodiments a–d of leading edge 12. Embodiment a corresponds to the prior art, and embodiments b, c, and d correspond to desirable hub-to-tip ratios, R_{HUB}/R_{TIP} , within the range of 0–0.4 as shown for example in Figure 4B below.⁸ *Id.* ¶ 51.

⁸ Dr. Abhari explains that Kodama refers to hub to tip ratio as a “boss ratio.” Ex. 1003 ¶ 119 (citing Ex. 1006 ¶¶ 16, 49).

Fig.4B



Kodama's Figure 4 B, above, is used to explain that it is possible to obtain beneficial pressure ratios for the first stage fan compared to prior art embodiment a, using the hub to tip ratios, R_{HUB}/R_{TIP} , of embodiments b, c, and d between 0 and 0.4. *Id.* ¶¶ 52–53.

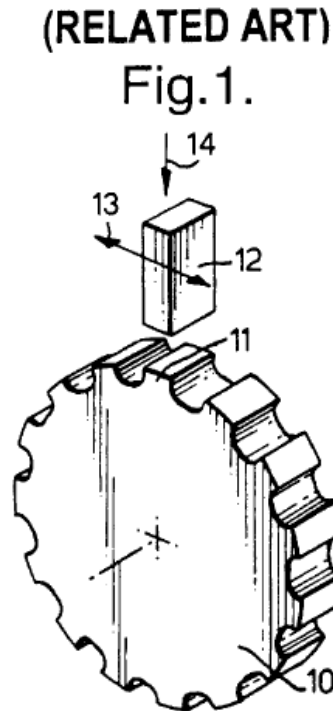
2. Brownell

Brownell is titled “Disk for a Blisk Rotary Stage of a Gas Turbine Engine.” Ex. 1008, [54]. Brownell describes

[a] disk for a BLISK rotary stage of a gas turbine engine includes a stub on the tapered circumferential surface of a turbine disk, the stub defining a weld joint surface . . . [a] blade is applied radially to the stub and linear friction welding of the blade to the stub is effected by oscillating the blade.

Id. at Abstract. Referring to Figure 1, Brownell explains that in a conventional planar friction weld joint interface, “[t]ypically, a blade 12 is urged in contact with the stub 11 by a force 14 and oscillated to and fro in the directions of arrows 13 over a range of linear movement in a range from

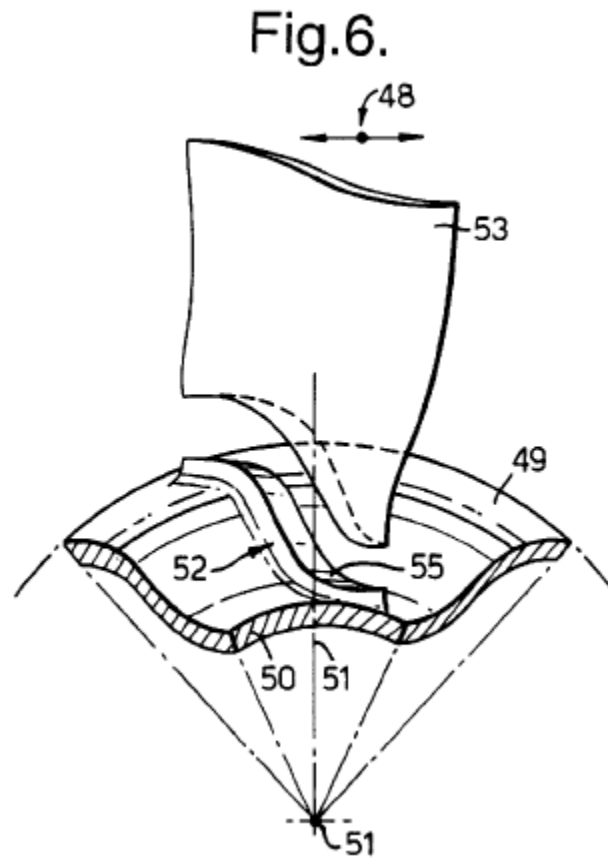
± 1 mm to ± 13 mm.” *Id.* at 3:31–34. Brownell’s Figure 1 is reproduced below.



Brownell’s Figure 1 “illustrates the principle of a known linear friction welding method using a planar weld joint and tangential motion.” *Id.* at 2:65–67.

Brownell teaches that known 2-dimensional planar linear weld joint surfaces are not desirable in more complex disc curvatures and blade chord dimensions. Ex. 1008, 4:1–31 (explaining that planar linear weld joints are disfavored “even more so when considering the manufacture of BLISKS having high hade angles and annulus curvature, coupled with large blade stagger and twist.”).

Figure 6 of Brownell, depicting a non-planar stub 52 and upper surface 55, is reproduced below.



Brownell's Figure 6 illustrates a perspective view of fan blade 53 aligned above (but not yet joined) with non-planar upper surface 55 of stub 52 formed on, and matching, the curved annulus of periphery 49 of disk 50. Ex. 1008, 4:60–63.

Brownell explains with respect to Figure 6 that in the case of upper surface 55 that is not planar, because stub 52 follows the contoured annulus of disk 49, upper surface 55 “is flat in the direction of welding oscillation.” Ex. 1008, 5:11–12. The direction of blade oscillation 48 is shown in Brownell's Figure 6 as “tangential” to the disk annulus. In other words, Brownell states “[t]he direction of oscillation 48 is then perpendicular, or parallel to such a perpendicular, to the disk axis 51.” *Id.* at 5:26–28.

Brownell describes in relation to Figure 9, reproduced below, that besides tangential oscillation “the direction of welding oscillation may be given a significant axial component as shown at 60 in FIGS. 9 and 10.” *Id.* at 5:41–43.

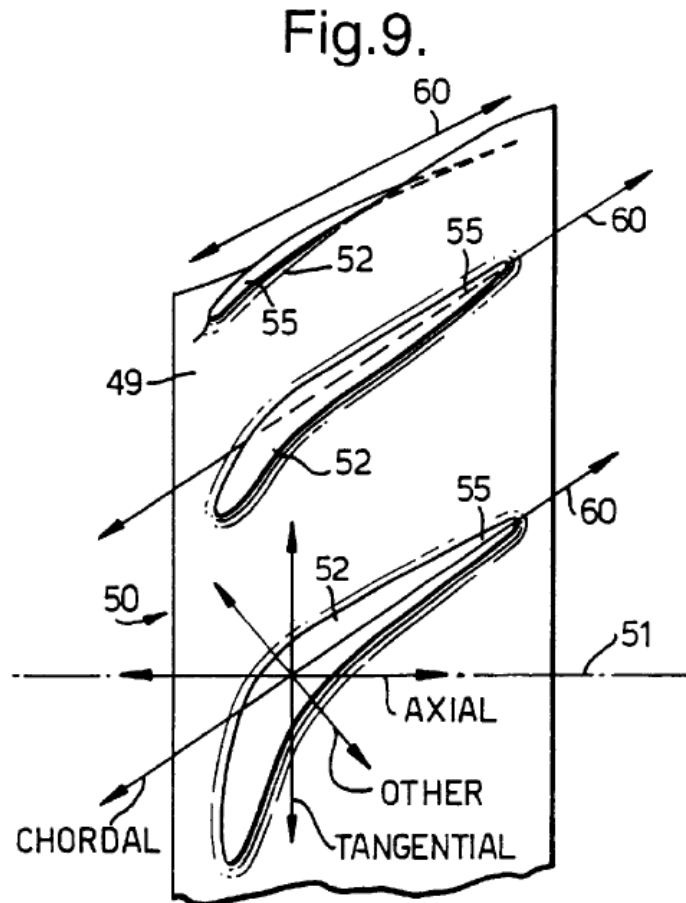


Figure 9 of Brownell, above, illustrates axial, tangential, chordal and other oscillation directions.

3. Claim 1 (disclaimed)

Because claim 5 depends directly from dependent claim 4, which in turn depends directly from independent claim 1, and keeping in mind that claims 1 and 4 are now disclaimed, we also address to the extent necessary

the relevant limitations of intervening claims 1 and 4 as part of our analysis of claim 5.

Petitioner argues that Kodama discloses all the limitations of disclaimed claim 1 including a first stage rotating fan for a gas turbine engine having blades with a hub-to-tip ratio between 0 and 0.4, thus encompassing the limitation, “wherein the ratio of the hub radius to the tip radius (R_{HUB}/R_{TIP}) is less than 0.29,” as recited in claim 1. *See* Pet. 70 (stating that “Figure 4A of Kodama discloses two embodiments (c and d) that have a hub/tip ratio of less than 0.29”) (citing Ex. 1006 ¶ 51).

We find Petitioner’s evidence persuasive that Kodama discloses the elements of claim 1 including a fan for a turbofan gas turbine engine having circumferentially spaced apart fan blades around a rotor hub for rotation about a fan center line. Pet. 59–65 (citing Ex. 1006 ¶¶ 13–14, 16, 49, Fig. 2B; Ex. 1003 ¶¶ 119, 122–123). We also find persuasive Petitioner’s evidence that Kodama discloses two embodiments, specifically embodiments c and d shown in Figures 4a and 4b, having a hub-to-tip ratio of less than 0.29 as recited in claim 1. Pet. 68–78 (citing Ex. 1003 ¶¶ 126, 128; Ex. 1006 ¶¶ 44, 49, 51, Figs. 4A–B).

4. Claim 4 (disclaimed)

Depending from claim 1, claim 4 recites the additional limitation “wherein the fan is an integrally bladed rotor, the fan blades being integrally formed with the rotor hub.” Ex. 1001, 5:36–38. Petitioner relies on Brownell for this limitation arguing that “Brownell discloses a method of fabricating a blisk (i.e., an IBR) for a gas turbine engine via linear friction welding.” Pet. 87 (citing Ex. 1008, 1:14–16, 2:19–22, 4:32–36).

As set forth in greater detail below, we disagree that a person of ordinary skill in the art would not have been motivated to combine Kodama and Brownell. For the purposes of addressing the limitations of claim 4, we find Petitioner's evidence persuasive as to an "integrally bladed rotor," noting that Brownell explains that "the invention concerns a method for the manufacture or repair of a BLISK by linear friction welding." Ex. 1008, 1:14–15. Our finding as to the specific limitations of claim 4 is consistent with Dr. Abhari's unrebutted testimony that in Brownell "the blisk, [] refers to a rotor disk that is integrally formed with the blades." Ex. 1003 ¶ 37 (citing Ex. 1013, 1:7–10).

5. Claim 5

Claim 5 includes the additional limitations "wherein the rotor hub of the integrally bladed rotor includes a preform having root stubs disposed on the rotor hub at circumferential positions corresponding to at least alternate ones of said fan blades in a single axial blade row." Ex. 1001, 5:39–41.

a. Petitioner's Arguments

Petitioner argues that Brownell discloses a "preform," understood by those of ordinary skill in the art as a rotor hub having root stubs formed prior to fabricating the complete integrally bladed rotor. Pet. 94 (citing Ex. 1003 ¶ 101). Petitioner refers specifically to the illustration in Brownell's Figure 6 showing the preform, root stub 52 and unattached airfoil blade 53. *Id.* at 95 (citing Ex. 1008, 2:49–53). Claim 5 also requires "having root stubs disposed on the rotor hub at circumferential positions corresponding to at least alternate ones of said fan blades." Ex. 1001, 5:40–42. One reason for this limitation, the '070 patent explains, is that

[i]t has been contemplated that alternative methods may also be used, such as forming a root stub 44 only for every alternate

blade, while machining the full blade 20 between each alternate root stub. This would allow sufficient access for machine tools between two alternate full blades, to machine [] around the remaining root stub.

Id. at 4:67–5:5. Petitioner argues that Brownell’s Figure 9 “shows a portion of a rotor hub, including stubs disposed on the rotor hub at circumferential positions that correspond to each of the fan blades in the single axial blade row.” Pet. 96 (citing Ex. 1003 ¶103). Petitioner notes, and Patent Owner does not contest, that “having a root stub for each blade encompasses at least alternate blades, as required by Claim 5.” *Id.* at 95–96; *see also* PO Resp. 63–69 (not contesting whether prior art describes “having root stubs . . . corresponding to at least alternate blades”).

Petitioner reasons that one of ordinary skill in the art would have fabricated Kodama’s fan as a blisk as taught by Brownell because it was well “known that manufacturing a fan as a blisk would provide numerous advantages, including improved aerodynamic performance (*i.e.*, improved efficiency), improved structural integrity, and reduced weight.” Pet. 89 (citing Ex. 1017, 1:15–18; Ex. 1003 ¶¶ 91–97). Petitioner argues that a person of ordinary skill in the art would have been motivated to manufacture the blisk using linear friction welding, for example, “because it allows for separate manufacturing of the rotor disk and blades. Thus, each portion of the blisk can be made from the optimal material and manufacturing process.” *Id.* at 90 (citation omitted) (citing Ex. 1008 1:17–30). Petitioner also argues that Brownell confirms that a person of ordinary skill in the art would have had a reasonable expectation of success because Brownell expressly describes that gas turbine fans and compressor disks can be made by linear friction welding. Pet. 92 (citing Ex. 1008, 4:32–33).

b. Patent Owner's Arguments

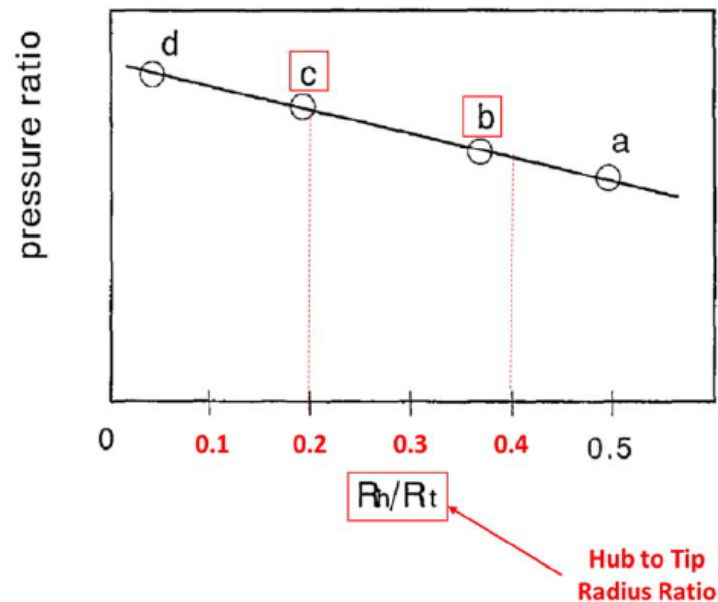
Patent Owner's main argument is that a person of ordinary skill in the art would specifically *not* have been motivated to use Brownell's linear friction welded blisk and the use of root stubs for manufacturing an integrally bladed rotor fan to achieve the low hub-to-tip ratio fan disclosed by Kodama. PO Resp. 63. That is, according to Patent Owner the combination is inoperable, specifically that "it would be ***impossible*** to manufacture *Kodama's* fan assembly using linear friction welding." *Id.* at 65 (citing Ex. 2001 ¶ 86; Ex. 2010 ¶ 104) (emphasis in original). Pointing to the cross-examination testimony of Dr. Abhari, Patent Owner argues specifically that a person of ordinary skill in the art would "know that embodiment D, which includes a hub-to-tip ratio that approaches zero, ***could not be made using linear friction welding***, because 'a person skilled in the art would recognize [(the hub-to-tip ratio)] is at zero and this is what D in figure 4A is showing.'" *Id.* at 66 (citing Ex. 2025, 111:12–16, 117:20–118:4) (emphasis in original). Based on embodiment d in Figures 4A–B above, and the cited testimony by Dr. Abhari, Patent Owner argues "that Kodama's disclosure readily shows that its fan blades converge to the centerline, making linear friction welding not possible." *Id.* Along with inoperability, Patent Owner presents several other related arguments which we address below under separate heading.

⁹ Patent Owner uses upper case "D" to refer to Kodama's embodiment referenced as lower case "d" in the graph of Figure 4B.

c. Whether Petitioner's Arguments and Evidence are Limited to Kodama's Embodiment d

Patent Owner's main argument is partly premised on the assertion that Petitioner relied initially on Kodama's embodiment D, i.e., embodiment d in Figures 4A–B above, and cannot now rely on other embodiments such as embodiment c. *See* PO Resp. 67 (Patent Owner essentially arguing that Petitioner's reliance on any embodiment other than d would be a new argument.). We disagree with this premise. In the Petition, Petitioner explains that “Kodama discloses several fan designs having hub/tip ratios between less than 0.1 and 0.5 in figures 4A and 4B.” Pet. 60. Petitioner reproduced Kodama's Figure 4A illustrating embodiments a–d, and annotated the figure to highlight leading edge hub radius R_h for embodiment b, for example. *Id.* at 69. The Petition further explains, “Figure 4A of Kodama discloses two embodiment[s] (c and d) that have a hub/tip ratio of less than 0.29.” *Id.* at 70. In the Petition, Petitioner provided Kodama's Figure 4B, reproduced below, with annotations emphasizing for example embodiment c, having a hub-to-tip ratio of about 0.2, which is less than 0.29 as required by claim 1 and having a leading edge that does not extend as far axially forward on the hub as embodiment d. Pet. 73–74.

Fig.4B



Kodama's Figure 4B, above, as annotated by Petitioner emphasizing embodiments b and c of Kodama. *Id.* at 73.

Patent Owner's citations to selected deposition testimony of Dr. Abhari relating to embodiment d and linear friction welding does not paint a complete picture of his testimony, or of Petitioner's arguments. During his cross-examination Dr. Abhari was asked at length what embodiments he relied on and he was consistent that his analysis included embodiment c:

Q. And then, you refer below the figure, then, Kodama discloses that the embodiment D has a hub to tip ratio[] of less than [0].1. While embodiment C has a hub to tip ratio of approximately [0].2. Do you see that, sir?

A. Yes. I do.

Q. Is it your testimony you're not relying on embodiment D at all?

A. Well, I'm relying by saying that between D and C is feasible to use Brownell. But D specifically, at that one point, I'm not relying, but I'm saying between D and C, it is possible to use friction, linear friction row.

Q. So it's not -- go ahead, finish.

A: So you have D to C. C is possible and in between D and C, it would also be possible. But D by itself would not be possible to do friction welding and then you have friction welding as described.

...

Q. You also relied on D, too, for the purposes of your opinions in Kodama, correct?

A. In between C and D. That's what I refer.

Ex. 2025, 110:2–112:3. Dr. Abhari's deposition testimony is consistent with his original declaration stating that "a POSITA would understand that a hub-to-tip ratio between 0.25 and 0.29 would be achieved by positioning the hub side leading edge of the fan blade between points b and c in Figure 4A of Kodama." Ex. 1003 ¶ 131. Overall, this is compelling evidentiary support that Petitioner considered in the Petition all the embodiments of Kodama, including embodiment c for which Dr. Abhari testified that friction welding was possible:

Q. And can you describe how the person of ordinary skill would use linear friction welding Kodama's blade with Brownell's method.

A. Well, there are four geometries that are shown. A, B, C, and D. A, B, and C, there is room in front that allows you to move. [D], on the other hand, as you go to zero, that would not be possible to build with in friction welding. But I did not really consider D as the key disclosure the teaching. If you look at C, which is the primary, discussed so far. Effectively making a

tooling and weld the blade on to the hub tangentially vibrating it, but it does require special attachment.

Ex. 2025, 108:9–22. Accordingly, we are persuaded that it is not a new argument for Petitioner and Dr. Abhari to rely on Kodama’s embodiments b and c with respect to the challenges before us.

d. Whether It Would Have Been Impossible to Combine Kodama and Brownell

We note that Patent Owner’s main argument and supporting testimony from Dr. Benini and Dr. Schmid focus sharply on why Kodama’s embodiment d cannot be friction welded. For example, Dr. Benini testifies that “a person of ordinary skill understands that the maximum benefit in terms of increasing the mass flow and increasing the hub pressure ratio is to extend the hub leading edge down to the centerline, . . . [t]hus, the hub/tip ratio of zero is essential to the purposes of Kodama.” Ex. 2009 ¶ 84. Although this is an apt description of embodiment d as shown in Kodama’s Figures 4A–B, Dr. Benini does not address whether embodiment c, for example, having a hub-to-tip ratio of around 0.2 could not be linear friction welded.

Specifically for Kodama’s embodiments a, b, and c, Patent Owner’s Declarant, Dr. Benini, states, without analysis, that “Kodama’s alternate embodiments also fail to establish obviousness.” *Id.* ¶ 87. Dr. Benini’s testimony as to embodiments a, b, and c, is mainly conclusory and unsupported. We acknowledge Dr. Benini’s testimony regarding Kodama that “[t]here is no space between adjacent blades at this point, *making it impossible* to oscillate the blade during the linear friction welding process.” *Id.* ¶ 86 (emphasis added). This testimony, again, is relevant to Kodama’s embodiment d and Dr. Benini provides no basis for reaching this conclusion

with respect to alternative embodiments a, b, and c. *Elbit Sys. Of America, LLC v. Thales Visionix, Inc.*, 881 F.3d 1354, 1358 (Fed. Cir. 2018) (“The PTAB [i]s entitled to weigh the credibility of the witnesses.”; *quoting Trs. of Columbia Univ. v. Illumina, Inc.*, 620 F. App’x 916, 922 (Fed. Cir. 2015)). Dr. Schmid’s testimony fares no better and is also not compelling when he testifies that linear friction welding “would have been impossible with the blade *shown in Kodama’s Figure 2* because each of the blades converge at the tip of the hub, leaving no space between adjacent blades.” Ex. 2010 ¶ 105 (emphasis added). We give little weight to Dr. Schmid’s testimony because Kodama’s Figure 2B is directed to embodiment d. *Compare* Ex. 1006, Fig. 2B, *with id.* Fig. 4A; *see also id.* ¶ 51 (Kodama explaining that in “FIG. 4A, [embodiment] a denotes an example of the hub-side leading edge part according to the conventional art and b, c, and d denote the positions according to the invention.”).

Patent Owner makes the ancillary argument that Dr. Abhari has not done any calculations to determine whether *Brownell’s* teachings would work for *Kodama’s* fan.” PO Resp. 68 (citing Ex. 2025 99:11–101:20). As discussed above, Dr. Abhari has opined that a person of ordinary skill in the art would have understood that Kodama’s embodiment c can be friction welded, as well as the points between embodiments c and d. Ex. 2025, 109:11–17. This testimony, although challenged with respect to embodiment d, is materially un rebutted by Dr. Benini and Dr. Schmid as to embodiment c.

To the extent that Dr. Abhari did not present detailed technical calculations, the obviousness inquiry does not ask “whether the references could be physically combined but whether the claimed inventions are

rendered obvious by the teachings of the prior art as a whole.” *In re Etter*, 756 F.2d 852, 859 (Fed. Cir. 1985) (en banc); *see also In re Keller*, 642 F.2d 413, 425 (CCPA 1981) (“The test for obviousness is not whether the features of a secondary reference may be bodily incorporated into the structure of the primary reference; . . . Rather, the test is what the combined teachings of the references would have suggested to those of ordinary skill in the art.”). Our rules also do not require an instruction manual on how to physically incorporate or combine the disclosures of two references. As *KSR* informs us, “in many cases a person of ordinary skill will be able to fit the teachings of multiple patents together like pieces of a puzzle.” *KSR*, 550 U.S. at 420. The rationale of *KSR* does not support a theory that a person of ordinary skill can “only perform combinations of a puzzle element A with a perfectly fitting puzzle element B.” *ClassCo, Inc. v. Apple, Inc.*, 838 F.3d 1214, 1219 (Fed. Cir. 2016). “A person of ordinary skill is also a person of ordinary creativity, not an automaton.” *KSR*, 550 U.S. at 421.

Patent Owner argues further that the collars and clamps used in linear friction welding cannot be used to manufacture Kodama’s blade “because the blade is already too close to the centerline.” PO Resp. 67 (citing Ex. 2001 ¶ 87; Ex. 2010 ¶ 106). Patent Owner argues that “*Brownell* oscillates the blades toward one another, in a tangential direction [], reducing the available space between blades to accommodate this oscillation.” *Id.* (citing Ex. 2001 ¶ 87; Ex. 2010 ¶ 106).

The contention of allegedly insufficient spacing between blades is not persuasive for two reasons. On one hand, Dr. Benini and Dr. Schmid are again premising their arguments on their review of embodiment d and provide no persuasive analysis or technical explanation that the spacing

between blades of embodiments a, b, and c could not be linear friction welded. *See, e.g.*, Ex. 2001 ¶ 72 (Dr. Benini stating “*Brownell*’s method would not have worked with *Kodama*’s unique geometry in which the blades extend down to the centerline on the hub.”). On the other hand, Petitioner’s Declarant, Dr. Abhari, was consistent in his testimony that in Kodama

there are four geometries that are shown. A, B, C, and D. A, B, and C, there is room in front that allows you to move. [D], on the other hand, as you go to zero, that would not be possible to build with [linear] friction welding. But I did not really consider D as the key disclosure.

Ex. 2025, 108:12–28. Dr. Abhari did discuss during his deposition that friction welding “requires a lot of tooling and process development.” *Id.* at 107:3–4. And, Dr. Abhari explained that a person of ordinary skill in the art would have to make an “economic assessment” as to which manufacturing technique to employ in fabricating a fan blade. *Id.* at 107:5–10. There is in the record, however, no persuasive evidence that Kodama’s embodiments a, b, and c, could not have been manufactured by linear friction welding with the necessary tooling or even that doing so was economically unfeasible. Overall, we credit Dr. Abhari’s materially un rebutted testimony to establish that a person of ordinary skill in the art would have understood that embodiments a, b, and c of Kodama would have been candidates for linear friction welding as suggested by Brownell.

Although there is evidence in this proceeding that a person of ordinary skill in the art would not have manufactured Kodama’s embodiment d by linear friction welding, Petitioner has provided persuasive evidence that the blade spacing drawbacks pertinent to embodiment d do not apply to embodiments a, b, and c. We are not persuaded that linear friction welding is inoperable in the context of *all* Kodama’s embodiments, or that it would

have been impossible for a person of ordinary skill in the art, considering the level of ordinary skill in the art and well-known fabrication process of linear friction welding, to manufacture Kodama's a, b, and c fan embodiments by linear friction welding as taught by Brownell.

e. Motivation to Combine

Patent Owner's assertion of a lack of motivation to combine rests mainly on the argument that "substantial evidence demonstrates that the combination is inoperable." PO Resp. 63 (citing Ex. 2009 ¶¶ 82–88; Ex. 2010 ¶¶ 103–108). For the reasons discussed above at least as to Kodama's embodiments b and c we do not find that particular argument persuasive. As set forth below, we determine that Petitioner has provided persuasive reasons and evidence explaining why one of ordinary skill in the art would have looked to Brownell's blisk teachings when considering how to manufacture Kodama's gas turbine fan.

Petitioner argues that at the time of filing the application that became the '070 patent a person of ordinary skill in the art was well aware of blisk technology and manufacturing techniques. Pet. 89 (citing Ex. 1003 ¶¶ 91–97; Ex. 1017, 1:15–18). Petitioner argues that a person of ordinary skill in the art "would have known that manufacturing a fan as a blisk would provide numerous advantages, including improved aerodynamic performance (i.e., improved efficiency), improved structural integrity, and reduced weight." *Id.* Petitioner argues persuasively that a person of ordinary skill in the art would have been motivated to manufacture a turbine fan as a blisk using linear friction welding as taught by Brownell because "linear friction welding enables optimization of the fan because it allows for separate manufacturing of the rotor disk and blades. Thus, each portion of

the blisk can be made from the optimal material and manufacturing process.” *Id.* at 90 (citation omitted) (citing Ex. 1008, 1:17–30; Ex. 1003 ¶ 95). Petitioner argues that Brownell specifically teaches a hub with root stubs and that “its linear friction welding method is suitable for complex geometries, such as fans having tapered disks” as taught by Kodama. *Id.* (citing Ex. 1008, 4:1–5); *see also* Ex. 1008, 1:31–35 (Brownell explaining that “[m]ethods for fabrication or repair of integrally bladed rotor assemblies involving providing a projection stubs on the disk periphery are described in EP 376,874 (equivalent U.S. Pat. No. 4,873,751, and GB 2,218,016 (equivalent U.S. Pat. No. 4,883,216).”).

On the complete record now before us, we credit Dr. Abhari’s testimony that “Brownell describes several advantages of its linear friction welding method, including the use of stubs.” Ex. 1003 ¶ 96. Dr. Abhari testifies that a person of ordinary skill in the art would have understood that “Brownell describes that its method of linear friction welding is ideal for blades on tapered disks.” *Id.* ¶ 154 (citing Ex. 1008, 4:1–4). Dr. Abhari points out that Kodama teaches a tapered rotor disk. *See id.* (“Kodama’s fan[] includes a tapered disk.”). Dr. Abhari testifies further that “Brownell explains that its process improves the aerodynamic profile of the fan,” and that Brownell teaches the “linear friction welding process reduces the weight of the blisk. *Id.* ¶ 97 (citing Ex. 1008 at 3:53–56, 6:34–38).

Dr. Abhari is consistent that a person of ordinary skill in the art would have understood that Kodama’s embodiment c discloses a hub-to-tip ratio of approximately 0.20, that is within the range of “less than 0.29,” as recited in claim 1. Ex. 1003 ¶ 131. Dr. Abhari explains persuasively that a person of ordinary skill in the art desiring to make Kodama’s fan, including

embodiment c, would have looked to Brownell “to achieve the benefits of a blisk design, as well as the specific benefits of linear friction welding to form a blisk, as described in Brownell.” Ex. 1003 ¶ 153. We are persuaded by Dr. Abhari’s testimony as it relates to embodiment c that a person of ordinary skill in the art would have combined Brownell and “Kodama to achieve the benefits of a blisk design, as well as the specific benefits of linear friction welding to form a blisk, as described in Brownell.” Ex. 1003 ¶ 153. Even crediting Patent Owner’s argument and evidence that it would be impossible to linear friction weld embodiment d, Dr. Abhari was unequivocal during his deposition, specifically explaining that linear friction welding of Kodama’s embodiment “C is possible and in between D and C, it would also be possible.” Ex. 2025, 110:16–17.

Weighing all declarants’ testimony and other evidence provided by both parties during the trial we are persuaded that a person of ordinary skill in the art would have considered and had a reasonable expectation of success in designing and fabricating a gas turbine fan manufacturing process using linear friction welding and a blisk having stubs as taught by Brownell, for joining a complex blade geometry and a hub-to-tip ratio of less than 0.29 as taught by Kodama. *See KSR*, 550 U.S. at 416 (“The combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results.”); *see also Hoffman-La Roche Inc. v. Apotex, Inc.*, 748 F.3d 1326, 1331 (Fed. Cir. 2014) (“Conclusive proof of efficacy is not necessary to show obviousness. All that is required is a reasonable expectation of success.”).

We are also persuaded that Petitioner has provided sufficient articulated reasoning and persuasive evidentiary underpinnings from its

Declarants and the prior art to support the combination of Kodama and Brownell. Overall, based on the complete record before us, Petitioner has shown by a preponderance of the evidence that the limitations of claim 5 would have been obvious over Kodama and Brownell.

6. Claims 6–8

Petitioner argues that the limitations of claims 6–8, each of which depend either directly or indirectly from claim 5, are taught by Brownell. Pet. 97–98 (citing Ex. 1008, 2:38–42 2:49–53 4:36–38, Fig. 5). Patent Owner does not argue specifically the limitations of claims 6–8. PO Resp. 63–69.

Our understanding of Brownell is consistent with Petitioner’s arguments and evidence. With respect to claims 6 and 7, Brownell discloses that linear friction welding airfoils to root stubs of a blisk to form an integrally bladed rotor (IBR) was a known structure and manufacturing method. Ex. 1008, 2:18–37, Figs. 1, 5. As to claim 8, Brownell explains that it was well known in the prior art for IBR assemblies that “[t]he disk 10 is provided with a plurality of upstanding stubs 11 on its periphery, that is its circumferential surface.” *Id.* at 3:28–30. Given all the evidence of record now before us, we are persuaded that Petitioner has shown by a preponderance of the evidence that claims 6–8 are unpatentable over Kodama and Brownell.

7. Claims 13–16 and 19

Claims 13–16 depend either directly or indirectly from independent claim 9 and dependent claim 12. Claims 9 and 12 are disclaimed. Ex. 2003. Claims 13–16 correspond to claims 5–8 discussed above and include similar limitations. One difference being that a “fan blade” recited in claims 13–16

includes an “air foil with a leading edge.” Ex. 1001, 5:58–69, 6:5–6.

Petitioner argues that Kodama discloses that each of the fan blades includes an airfoil. Pet. 77–78 (citing Ex. 1003 ¶ 139). Patent Owner does not dispute that Kodama’s fan blades each include an air foil. Patent Owner does not specifically address claims 13–16, instead relying on its contention that “each of GE’s proposed combinations is inoperable; persons of ordinary skill would not have been motivated to combine them.” PO Resp. 33.

Because of the high degree of similarity in limitations between these claims, our analysis for claims 13–16 obtains the same outcome as for claims 5–8 as discussed above.

Claim 19 is a method claim, depending indirectly from disclaimed independent claim 17, and is essentially a combination of the limitations in claims 4 and 5 requiring “a hub preform having a number of root stubs” and “fastening the fan blade airfoils to the root stubs to form fan blades integrally formed with the rotor hub.” Ex. 1001, 6:41–48. Patent Owner neither specifically addresses claim 19, nor disputes that Kodama and Brownell disclose all the limitations of claim 19. Patent Owner again relies on its contention that “each of GE’s proposed combinations is inoperable; persons of ordinary skill would not have been motivated to combine them.” PO Resp. 33. Because claim 19 includes the same and similar limitations, just in method format, as claims 4 and 5 discussed above, based on the high degree of similarity in limitations between these claims our analysis for claim 19 obtains the same outcome as that for claims 4 and 5.

8. Conclusion as to Kodama and Brownell

Given the complete record now before us, we are persuaded that Petitioner has shown by a preponderance of the evidence that claims 5–8, 13–16, and 19 are unpatentable over Kodama and Brownell.

C. Claims 5–8, 13–16, and 19 — Obviousness over Kaplan and Brownell

Petitioner asserts that claims 5–8, 13–16, and 19 would have been obvious over Kaplan and Brownell. Pet. 35–51. Having considered the complete record now before us, we determine that Petitioner has established by a preponderance of the evidence that claims 5–8, 13–16, and 19 would have been obvious for the reasons explained below.

1. Kaplan

Kaplan is an ASME paper titled “Design of a Highly Efficient Low-Noise Fan for Ultra-High Bypass Engines,” that is part of Proceedings of the ASME Turbo Expo 2006.¹⁰ Kaplan discloses a fan design that “includes blade shape and the flow path optimization as well as the computation of stress distribution in all blades and the rotor disc,” and “presents the computational design work of an ultra-high bypass ratio fan.” Ex. 1005, 21. Kaplan’s Figure 3, illustrating the engine flowpath, is reproduced below.

¹⁰ We note the Journal is titled “Proceedings of the ASME Turbo Expo 2006” and also states “presented at [t]he 2005 ASME Turbo Expo, June 6–9, 2005, Reno-Tahoe, Nevada USA.” Ex. 1005, 2 (emphasis omitted).

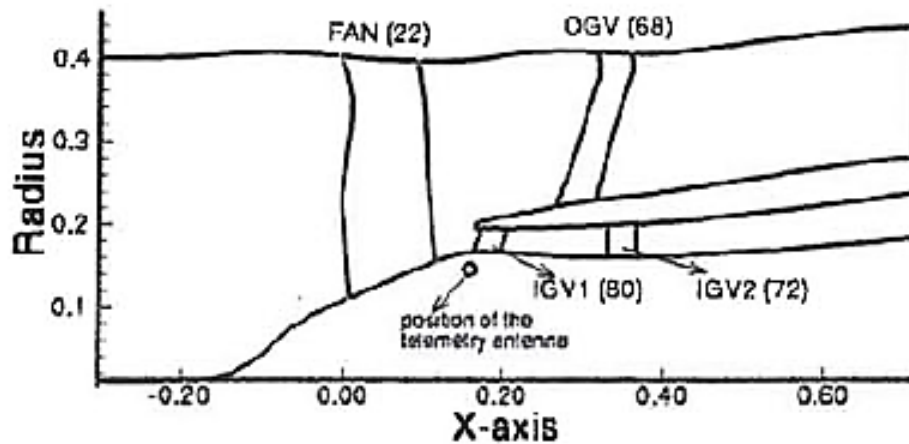


Figure 3 – The flowpath

Kaplan's Figure 3, above, illustrates a cross-section of an engine flowpath as well as a fan having 22 blades. *Id.* at 23. Kaplan's Figure 17 is reproduced below.

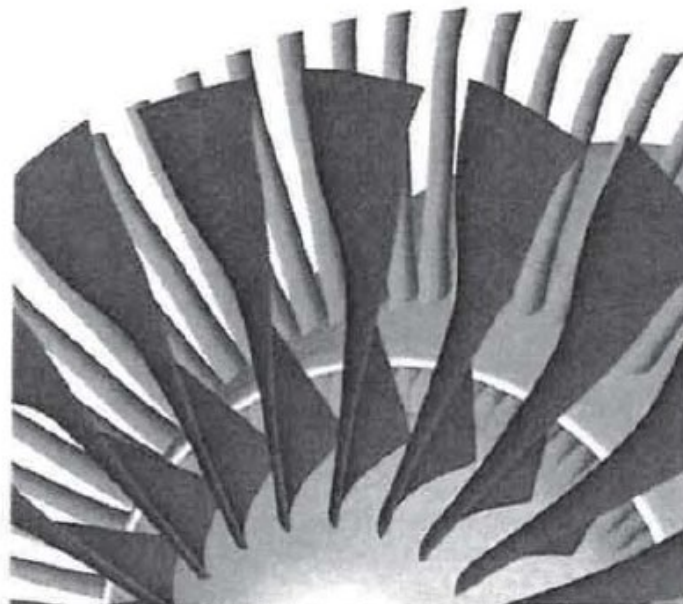


Figure 17 – SILENCER FAN TEST RIG

Kaplan's Figure 17, above, depicts a computer generated model of Kaplan's test fan design. *Id.* at 29. Kaplan states with respect to Figure 17 that "since

the fan blades are going to be manufactured together with the disk (disk), the shape of the disk can also be seen.” *Id.*

2. *Claim 1 (disclaimed)*

Claim 5 depends from disclaimed claims 1 and 4, the elements of which we discuss below in relation to Kaplan.

Petitioner argues that Kaplan discloses all the elements of claim 1 including, referring to Kaplan’s Figure 3, a fan blade and hub shown rotating about a centerline axis, (“X-axis”), as part of the “core engine” of a turbofan gas turbine engine. Pet. 19–24 (citing Ex. 1005, 21–23, 29; Ex. 1003 ¶¶ 57–60; Ex. 1018, 5). Petitioner contends that Kaplan’s Figure 17 illustrates a plurality of circumferentially spaced blades arranged “in a single axial blade row” as called for in claim 1. *Id.* at 25 (citing Ex. 1003 ¶¶ 61–62). Petitioner argues, using an annotated version of Kaplan’s Figure 3, reproduced below, that each fan blade “has a leading edge, a hub radius, and a tip radius.” *Id.* at 26 (citing Ex. 1005, 23).

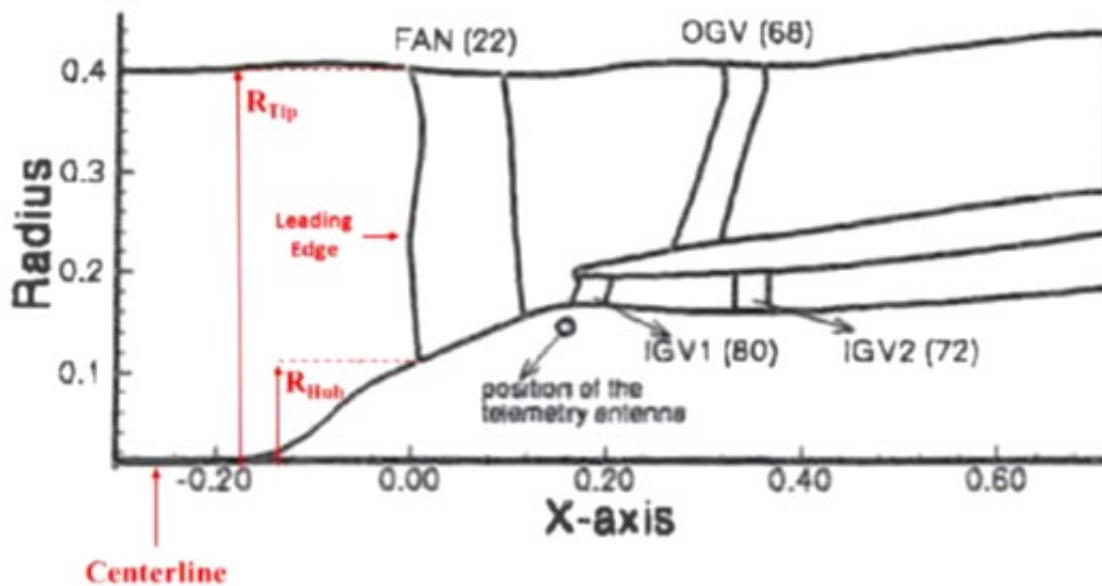


Figure 3 – The flowpath

Ex. 1005.023, Figure 3

Kaplan's Figure 3, as annotated by Petitioner, pointing out fan "[c]enterline," "*R_{Tip}*," "*R_{Hub}*," and "[l]eading edge" of fan blade.

Petitioner asserts that Kaplan discloses a hub/tip ratio of 0.27, which meets the limitation in claim 1, "wherein the ratio of the hub radius to the tip radius (*R_{HUB}*/*R_{TIP}*) is less than 0.29." Pet. 27 (citing Ex. 1005, 23).

Patent Owner does not expressly dispute that Kaplan discloses a fan having hub-to-tip ratios of less than 0.29 or the other limitations required by claim 1, but argues mainly, as we address in detail below, that "[p]ersons of ordinary skill in the art were not motivated to make *Kaplan*'s fan assembly using *Brownell*'s teachings because *Kaplan*'s fan design leaves insufficient space between blades, rendering the combination inoperable." PO Resp. 35 (citing Ex. 2001 ¶¶ 58–69; 2010 ¶¶ 57–84).

3. *Claim 4 (disclaimed)*

Claim 4, which depends from claim 1, further includes the limitation “wherein the fan is an integrally bladed rotor, the fan blades being integrally formed with the rotor hub.” Ex. 1001, 5:36–38. Petitioner argues that Kaplan also teaches “that the fan blades are to be manufactured together with the rotor disk as a blisk.” Pet. 28 (citing Ex. 1005, 29). Relying on the testimony of Dr. Abhari, Petitioner asserts that a person of ordinary skill in the art “would have understood that a blisk is synonymous with an integrally bladed rotor, in which the fan blades are integrally formed with the rotor disk (i.e., hub).” *Id.* at 29 (citing Ex. 1003 ¶ 67). Patent Owner does not dispute that Kaplan teaches a blisk. *See generally* PO Resp. 35–51.

4. *Claim 5*

Before analyzing claim 5, we point out that, on the complete record now before us, we find GE’s contentions that Kaplan describes the elements recited in claims 1 and 4 to be consistent with our review of Kaplan.

Claim 5 depends from claim 4 and includes the further limitation “wherein the rotor hub of the *integrally bladed rotor includes a preform having root stubs* disposed on the rotor hub.” Ex. 1001, 5:39–41 (emphasis added).

a. *Petitioner’s Arguments*

GE argues that “Brownell discloses forming an IBR [integrally bladed rotor] by joining airfoil blades, including fan blades, to corresponding stubs on the outer periphery of a rotor disk via linear friction welding.” Pet. 88 (citing Ex. 1008, 2:49–59). Petitioner also argues that “Figure 6 of Brownell . . . shows the preform having root stubs on the rotor hub before the blades are welded.” *Id.* at 94 (citing Ex. 1003 ¶ 102).

Claim 5 also requires “having root stubs disposed on the rotor hub at circumferential positions corresponding to at least alternate ones of said fan blades.” Ex. 1001, 5:40–42. One reason for this limitation, the ’070 patent explains, is that

[i]t has been contemplated that alternative methods may also be used, such as forming a root stub 44 only for every alternate blade, while machining the full blade 20 between each alternate root stub. This would allow sufficient access for machine tools between two alternate full blades, to machine [] around the remaining root stub.

Id. at 4:67–5:5. Petitioner argues that Brownell’s Figure 9 “shows a portion of a rotor hub, including stubs disposed on the rotor hub at circumferential positions that correspond to each of the fan blades in the single axial blade row.” Pet. 96 (citing Ex. 1003 ¶103).

Petitioner argues that it would have been obvious to one of ordinary skill in the art to fabricate Kaplan’s fan as a blisk with a rotor hub and stubs as taught by Brownell because it was well “known that manufacturing a fan as a blisk would provide numerous advantages, including improved aerodynamic performance (*i.e.*, improved efficiency), improved structural integrity, and reduced weight.” Pet. 89 (citing Ex. 1017, 1:15–18; Ex. 1003 ¶¶ 91–97). Petitioner argues that a person of ordinary skill in the art would have been motivated to manufacture the blisk using linear friction welding “because it allows for separate manufacturing of the rotor disk and blades. Thus, each portion of the blisk can be made from the optimal material and manufacturing process.” *Id.* at 90 (citation omitted) (citing Ex. 1003 ¶ 95; Ex. 1008 1:17–30).

b. Patent Owner's Arguments

Patent Owner's main argument is that a person of ordinary skill in the art would not have been motivated to use Brownell's linear friction welded blisk and the use of root stubs for manufacturing an integrally bladed rotor fan to achieve the low hub-to-tip ratio of Kaplan. PO Resp. 35. According to Patent Owner, "GE never considers whether there would be enough space between *Kaplan's* fan blades. Specifically, GE fails to address whether there is space for (1) the collar, (2) clamps, (3) oscillation, and (4) flash." *Id.* at 37 (emphasis omitted). Based on calculations done by Dr. Benini, Patent Owner argues "it is clear that *Kaplan's* fan assembly does not provide enough space to use *Brownell's* teachings." *Id.* at 40.

To establish that there is not enough space between Kaplan's blades to accommodate the function and structure to linear friction weld a blade to a hub, Dr. Benini first calculates blade pitch, which is the distance between the leading edge of adjacent blades. Ex. 2009 ¶ 63.

$$\text{Blade Solidity} = \frac{\text{Chord Length}}{\text{Pitch}}$$

$$3.3 = \frac{0.12 \text{ m}}{\text{Pitch}}$$

$$\text{Pitch} = 0.36 \text{ m or } 3.6 \text{ cm}$$

Id. Dr. Benini explains that because the pitch is the difference between leading edges of adjacent fan blades, the actual available space between adjacent blades is the pitch minus the blade width. *Id.* ¶ 64. Dr. Benini testifies that "a typical value for maximum thickness (t_{max}) is approximately 10% of a fan blade's chord length at the hub." *Id.* ¶ 65 (citing Ex. 2022, 3; Ex. 2023, 5; Ex. 2024). Dr. Benini calculates that "*Kaplan's* fan blades have a length of 0.12 m, meaning that they are about 1.2 cm wide. Subtracting

this 1.2 cm blade width from the calculated pitch of 3.6 cm leaves only 2.4 cm (less than an inch) between *Kaplan*'s adjacent blades.” *Id.* ¶ 66.

Dr. Benini testifies that, based on this space between blades of 2.4 cm, there would be blade and tooling interference and a person of ordinary skill in the art would not have been motivated to use linear friction welding as taught by Brownell to manufacture *Kaplan*'s fan. *Id.*

Patent Owner relies on the testimony of Dr. Schmid to support its position that 2.4 cm is insufficient space to accommodate the collar, clamp, and tangential oscillation needed to weld *Kaplan*'s blade to its hub.

Dr. Schmid testifies that

Given the geometry of *Kaplan*'s fan assembly, including a blade width of 1.2 cm, one of ordinary skill would have expected *Kaplan* to require a collar of at least 3.6 cm to provide sufficient stiffness and rigidity for the linear friction welding process. Collars of 3.6 cm are equal to the pitch of *Kaplan*'s fan—leaving no space between adjacent blade collars.

Ex. 2010 ¶ 64. Dr. Schmid testifies that if every blade on the circumference of the fan assembly were provided with a collar, as shown for example in certain annotated exemplary photographs reproduced below, there would be no room between the collars of *Kaplan* for the clamps and also that oscillation could not occur for linear friction welding because of interference. *Id.*

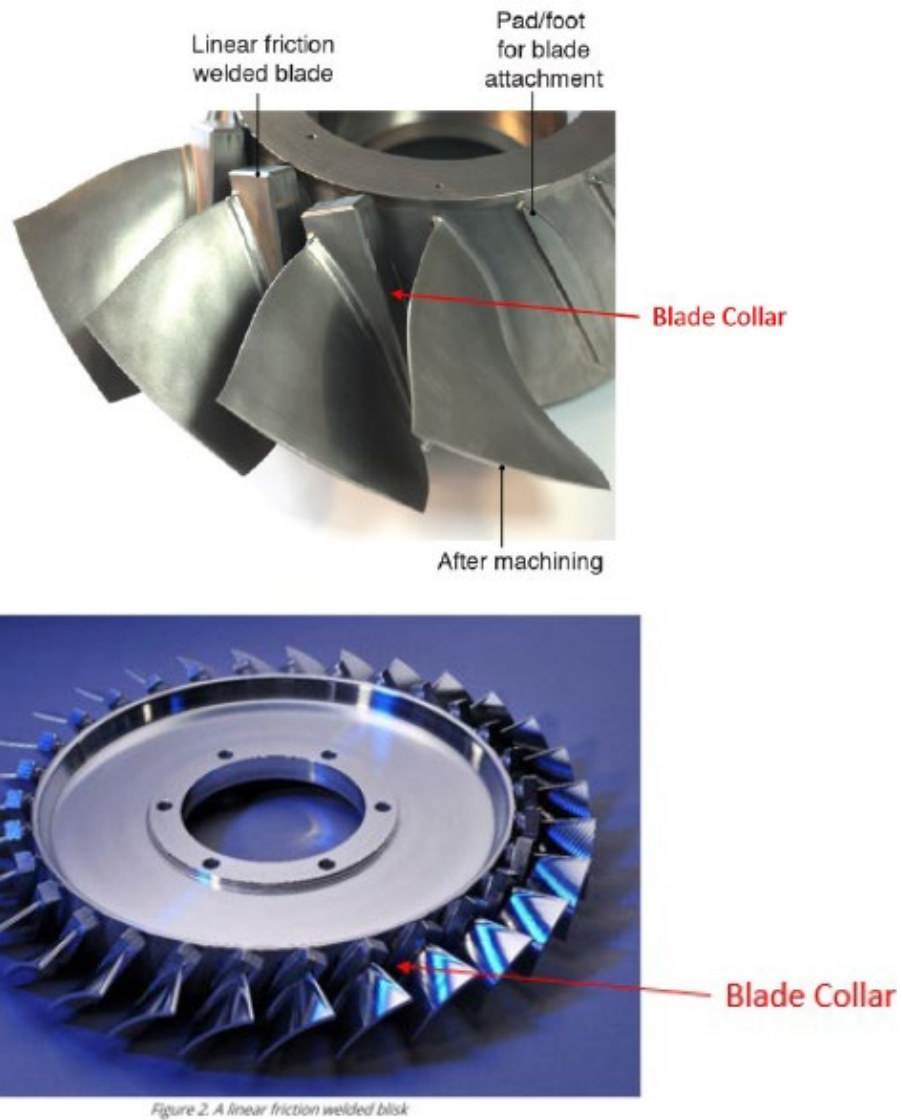


Figure 2. A linear friction welded blisk

Id. (citing Ex. 2015, 5; Ex. 2016, 4) (annotations added by Patent Owner). The photographs above, from Dr. Schmid’s declaration, each depict a blisk with collars provided for blades on the circumference of the hub.

Dr. Schmid testifies further that a person of ordinary skill in the art would understand that flashing produced by linear friction welding “cannot be allowed to interfere with oscillation and flash of neighboring blades.” *Id.* ¶ 69. According to Dr. Schmid

the amount of flash that would be generated during the linear friction welding process using *Brownell's* method of tangential oscillation would be ***more than the width of the blade***, one of ordinary skill would have expected *Kaplan* to generate ***more than 1.2 cm*** of flash in the direction of each adjacent blade. This causes interference and does not leave room for linear friction welding.

Id. ¶ 73 (emphasis in original). Dr. Schmid also opines that as blades are welded the flash produced would harden and “would cause linear friction welding to be impractical because it would cause interference during the welding process.” *Id.* ¶ 78. Dr. Schmid also explains that a person of ordinary skill in the art would have known “that it would be impractical and inefficient to clear the flash after linear friction welding each individual blade. Instead, one of ordinary skill would have welded all blades, then placed the structure in a machining center to remove the flash and collars to create the final IBR shape.” *Id.* n.6.

c. Motivation to Combine

Weighing the declarants’ testimony in conjunction with the evidence in this proceeding as discussed below, we are persuaded that a person of ordinary skill in the art would have been motivated to combine *Kaplan* and *Brownell* and to manufacture a fan where “the rotor hub of the integrally bladed rotor includes a preform having root stubs disposed on the rotor hub,” as recited in claim 5. Ex. 1001, 5:39–41.

We appreciate Patent Owner’s arguments and Dr. Schmid’s testimony that it would difficult, if not inoperable under some conditions, to manufacture by linear friction welding *Kaplan’s* low hub-to-tip ratio fan as an IBR where the distance between the blades is small, for example, where only 2.4 cm of space exists between adjacent blade surfaces. PO

Resp. 39–41 (citing Ex. 2010 ¶¶ 66–67). We acknowledge that oscillating the blade tangentially during linear friction welding, as well as the apparent necessity to permit space for the collar, clamps, and flashing that occurs during linear friction welding, requires a certain amount of space. For the sake of argument, we use Dr. Schmid’s calculations, specifically that a 3.6 cm collar would extend 1.2 cm on either side of a 1.2 cm (width) blade. *See* Ex. 2010 ¶¶ 47–48, 64 (Dr. Schmid describing that the collar would need to be at least three times the total blade width). Where the spacing between blades is 2.4 cm, based on Dr. Schmid’s calculations, two collars positioned next to one another on two immediately adjacent blades would be unable to oscillate and potentially even interfere even without oscillating. PO Resp. 42 (citing Ex. ¶¶ 64, 75–76).

Patent Owner’s arguments and Dr. Schmid’s testimony, however, presume that immediately adjacent blades are all fitted with a collar and clamps for the linear friction welding process. *See* Ex. 2010 ¶¶ 75, 78 n.6 (“[O]ne of ordinary skill would have welded all blades, then placed the structure in a machining center to remove the flash and collars to create the final IBR shape.”). We have before us persuasive evidence that linear friction welding techniques for fan blades do not have to occur in this manner. Rather, Petitioner presents evidence that it was well known where spacing was an issue to weld alternating blades of a fan, machine those blades, then linear friction weld the remaining alternating blades. *See* Pet. Reply 15–16 (“[A] 1993 Patent issued to Rolls Royce describes increasing available space by welding alternate blades, removing the excess material (*i.e.*, collars and flashing), and then welding the remaining blades.”). Petitioner points out that U.S. Patent No. 5,188,275 (Ex. 1027) describes a

linear friction bonding process for a blisk that addresses closely spaced blades. *Id.* The '275 patent explains that where blade spacing is close

a number of blade preforms may be bonded sequentially at locations sufficiently far apart. In the illustrated case the minimum spacing is alternate locations. A whole BLISK could be manufactured, if desired, in this way by bonding blades at, say, alternate locations in a first operation, subsequently removing surplus metal and then bonding the remaining blades in a further operation.

Ex. 1027, 3:20–27.¹¹ Petitioner points out that this same prior art technique is discussed in the '070 patent, specifically that one can form “a root stub 44 only for every alternate blade, while machining the full blade each alternate root stub. This would allow sufficient access for machine tools between two alternate full blades, to machine around [] the remaining root stub.”

Ex. 1001, 4:67–5:5. This description coincides with the specific language of claim 5 which requires root “stubs disposed on the rotor hub at circumferential positions corresponding to *at least alternate ones* of said fan blades in the single axial blade row.” *Id.* at 5:39–44. Neither Dr. Schmid nor Dr. Benini discuss or explain that using such an alternate blade technique would have been inoperable or beyond the level of ordinary skill

¹¹ Ex. 1027, the Rolls Royce '275 patent, was entered into the record along with Petitioner's Reply Brief in direct response to Patent Owner's arguments and evidence regarding spacing between blades raised in the Response. *See* Pet. Reply 14–15. A party is permitted to submit rebuttal evidence in support of its reply. We determine that Exhibit 1027, a prior art patent, is legitimately responsive to arguments and evidence raised in Patent Owner's Response and specifically do not find the '275 patent, which is offered essentially here as background information pertaining to linear friction welding, to be a new argument or evidence that should have been presented earlier as part of Petitioner's *prima facie* case of obviousness. *See Belden Inc. v. Berk-Tek LLC*, 805 F.3d 1064, 1077–78 (Fed. Cir. 2015).

in the art. To the contrary, we are persuaded that Petitioner's evidence from the '275 patent shows that linear friction welding alternating blades was a manufacturing technique that was well known to those of ordinary skill in the art to account for limited spacing and machining between blades.

For purposes of our determination here we assume that Dr. Benini's calculations of blade width, i.e. thickness, and thus blade spacing are reasonable. *See* PO Resp. 38 (citing Ex. 2009 ¶¶ 64–65) (Patent Owner relying on Dr. Benini's testimony that blade thickness to chord ratio is 10%). Petitioner does offer contradictory evidence, asserting that Dr. Benini's estimate of blade width is too high, and that Kaplan's blade thickness to chord ratio is more likely 4.3%. Pet. Reply 20–21 (citing Ex. 1031, 24:12–18). Yet, even considering Dr. Benini's blade and spacing calculations, Petitioner has provided persuasive evidence from the '275 patent that the technique of linear friction welding alternate blades was well-known. Patent Owner has not provided any argument or evidence that there are spacing concerns for the collar, clamps or flashing when welding alternate blades. We are persuaded that a person of ordinary skill in the art would have been motivated to combine Kaplan and Brownell and would have known how to weld alternating blades to accommodate spacing issues between blades in the manufacture of a blisk.

Patent Owner also argues that Brownell advocates for even further space constraint between blades because it teaches that the linear friction weld plane, i.e., where the rotor stub and blade surfaces are welded together, should be formed within the fillet close to the rotor hub. PO Resp. 47 (citing Ex. 1008, 6:31–34; Ex. 2010 ¶ 79); *see also* PO Sur-Reply 6 (Patent Owner arguing that "*Brownell* actually expressly discourages elevating the weld

plane, contrary to the '070 patent.”). According to Dr. Schmid, based on Brownell “one of ordinary skill would have avoided adding height to the root stub, and would have instead attempted to maintain the weld plane in the blade fillet.” Ex. 2010 ¶ 79. Similar to our analysis above, even if the space between neighboring blades was further constrained by forming the weld plane closer to the rotor hub and within the fillet radius, this argument does not apprise us that the technique of alternate blade welding would not have been considered by a person of ordinary skill in the art in order to overcome such spacing issues between blades.

This issue regarding root stubs and the height of the weld plane requires some additional analysis, mainly because Patent Owner contends that raising the height of the stub and hence the weld plane, is an innovative aspect of the '070 patent. *See* PO Resp. 1 (Patent Owner stating that “GE still fails to grasp the '070 patent’s innovation to use root stubs to elevate the weld line to allow linear friction welding.”), *see also id.* at 32 (Patent Owner arguing that a root stub “increases the gap between adjacent blades at the weld line and makes it easier for machine tools to access this gap between adjacent blades.”). Our review shows that Brownell discloses root stubs on a hub. *See* Ex. 1008 3:29–30 (“The disk 10 is provided with a plurality of upstanding stubs 11 on its periphery.”); *see also id.* at Figs. 1–4, 6, 8–10. And, Brownell explains that the weld plane is preferably formed within the fillet. Ex. 1008, 3:53–56 (Brownell explaining it is preferable that “[t]he weld joint plane is shown by line 23, and lies within the fillet, where stresses are lower, the weld area is larger, and where it is possible to clean up the edge of the weld and improve the aerodynamic profile.”). However, to the extent Patent Owner argues that its stub and weld plane *is higher* than

Brownell's stub, and thus not within the fillet, we point out that the claims of the '070 patent merely recite, for example in claim 5, "root stubs disposed on the rotor hub." Ex. 1001 5:40–41, 6:9–10, 43–44. We appreciate that, different from Brownell, the '070 patent explains that using a root stub "it is easier to access the radial gap between adjacent blades 20 with machine tools." *Id.* at 4:62–63. Considering Patent Owner's arguments and evidence regarding location of the weld plane, neither Patent Owner nor Dr. Schmid explain why a similar benefit would not occur due to Brownell's root stubs which also discloses the weld plane elevated above the hub.

The evidence of record establishes that a person of ordinary skill in the art would have reasonably expected to fabricate a gas turbine blade using linear friction welding as claimed. *See KSR*, 550 U.S. at 416 ("The combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results."); *see also Hoffman La Roche*, 748 F.3d 1331 ("Conclusive proof of efficacy is not necessary to show obviousness. All that is required is a reasonable expectation of success.").

We are also persuaded that Petitioner has provided sufficient articulated reasoning and persuasive evidentiary underpinnings from its Declarants and the prior art to support the combination of Kaplan and Brownell. Based on the complete record before us, Petitioner has shown by a preponderance of the evidence that the limitations of claim 5 would have been obvious over Kaplan and Brownell as properly combined.

5. Claims 6–8

Petitioner argues that the limitations of claims 6–8, each of which depend either directly or indirectly from claim 5, are taught by Brownell.

Pet. 97–98 (citing Ex. 1008, 2:38–42 2:49–53 4:36–38, Fig. 5). Patent Owner does not argue specifically the limitations of claims 6–8.

Our understanding of Brownell is consistent with Petitioner’s arguments and evidence. With respect to claims 6 and 7, Brownell discloses that linear friction welding airfoils to root stubs of a blisk to form an IBR was a known structure and manufacturing method. Ex. 1008, 2:18–37, Figs. 1, 5. As to claim 8, Brownell explains that it was well known in the prior art for IBR assemblies that “[t]he disk 10 is provided with a plurality of upstanding stubs 11 on its periphery, that is its circumferential surface.” *Id.* at 3:28–30. Given all the evidence of record now before us, we are persuaded that Petitioner has shown by a preponderance of the evidence that claims 6–8 are unpatentable over Kaplan and Brownell.

6. Claims 13–16 and 19

Claims 13–16 depend either directly or indirectly from independent claim 9 and dependent claim 12. Claims 9 and 12 are disclaimed. Ex. 2003. Claims 13–16 correspond to claims 5–8 discussed above and include the same and similar limitations. One minor difference being that a “fan blade” recited in claims 13–16 includes an “air foil with a leading edge.” Ex. 1001, 5:58–69, 6:5–6. Petitioner argues that Kaplan discloses that each of the fan blades includes an airfoil. Pet. 31–32 (citing Ex. 1003 ¶ 77). Patent Owner does not dispute that Kaplan’s blade includes an airfoil. Patent Owner does not specifically address claims 13–16, instead relying on its main contention that “each of GE’s proposed combinations is inoperable; persons of ordinary skill would not have been motivated to combine them.” PO Resp. 33. Because of the high degree of similarity in limitations between these claims

our analysis for claims 13–16 obtains the same outcome as that for claims 5–8 discussed above.

Claim 19 is a method claim, depending indirectly from disclaimed independent claim 17, and is essentially a combination of the limitations in claims 4 and 5 requiring “a hub preform having a number of root stubs” and “fastening the fan blade airfoils to the root stubs to form fan blades integrally formed with the rotor hub.” Ex. 1001, 6:41–48. Patent Owner does not specifically address claim 19, nor dispute that Kaplan and Brownell disclose all the limitations of claim 19. Patent Owner instead relies on its main contention that “each of GE’s proposed combinations is inoperable; persons of ordinary skill would not have been motivated to combine them.” PO Resp. 33. Because claim 19 includes the same and similar limitations, just in method format, as claims 4 and 5 discussed above, based on the high degree of similarity in limitations between these claims our analysis for claim 19 obtains the same outcomes as that for claims 4 and 5. We are persuaded that Petitioner has shown by preponderance of the evidence that claims 13–16 and 19 are unpatentable over Kaplan and Brownell.

7. Conclusion as to Kaplan and Brownell

Given the complete record now before us, we are persuaded that Petitioner has shown by a preponderance of the evidence that claims 5–8, 13–16, and 19 are unpatentable over Kaplan and Brownell.

D. Claims 5–8, 13–16, and 19 — Obviousness over Gray and Brownell

Petitioner asserts that claims 5–8, 13–16, and 19 would have been obvious over Gray and Brownell. Pet. 35–51. Having considered the complete record now before us, and as discussed in detail below, we

determine that Petitioner has established by a preponderance of the evidence that claims 5–8, 13–16, and 19 would have been obvious.

1. Gray

Gray is a technical paper sponsored by a NASA program titled “Energy Efficient Engine Program” that occurred in conjunction and under contracts with Pratt & Whitney. Ex. 1019, 1–3. The program had “the objective of improving the energy efficiency of future United States commercial aircraft so that substantial savings in fuel can be realized.” *Id.* at 18. Gray evaluates eight gas turbine engine designs “candidate engines.” *Id.* at 20. Gray’s Table 4.2-II, annotated by the board, is reproduced below.

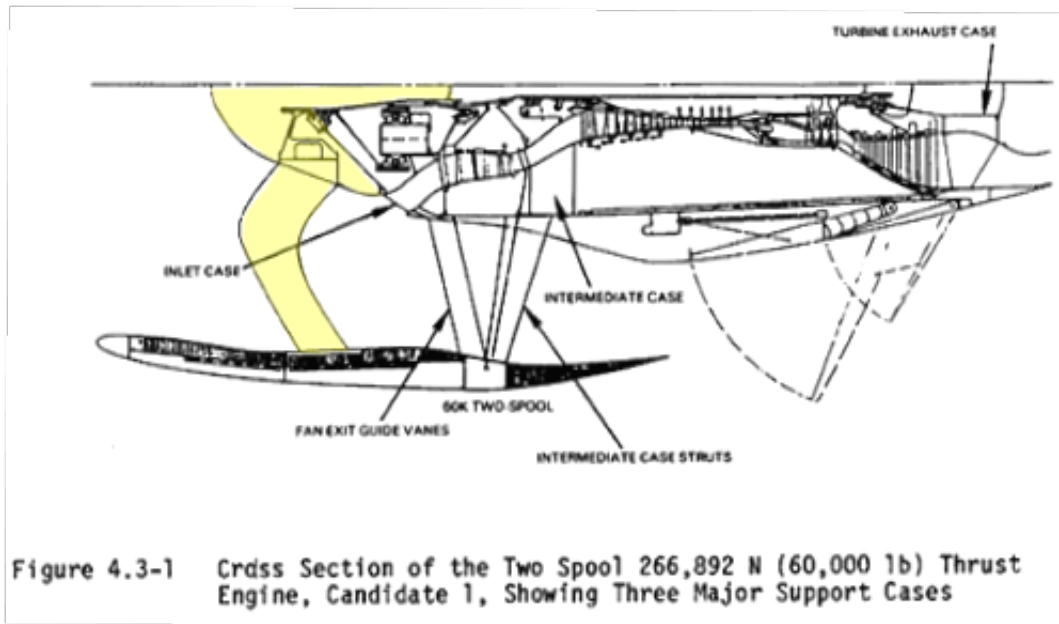
TABLE 4.2-II
SUMMARY OF FLOWPATH CANDIDATE FAN DESIGNS

		Candidate							
	Reference Engine	1 1.5 FPR 2 Spool	2 3 Spool (No LPC)	3 3 Spool (With LPC)	4 1.3 FPR 2 Spool	5 2 Spool 46 OPR	6 2 Spool Axi-Cent.	7 2 Spool Dir Drv	8 2 Spool Dir Drv
Corrected Flow	1498.0	2612.0	2664.0	2664.0	4167.0	940.8	1052.0	2437.0	1883.0
Outer Diameter Pressure Ratio	1.65	1.50	1.50	1.50	1.30	1.50	1.50	1.50	1.70
Inner Diameter Pressure Ratio	1.50	1.27	1.29	1.27	1.10	1.27	1.28	1.37	1.45
Bypass Ratio	7.2	12.8	13.1	13.1	21.0	12.3	11.7	11.9	8.96
Tip Diameter, cm (in)	215.9 (85.0)	271.2 (106.8)	274.0 (107.9)	274.0 (107.9)	341.8 (134.6)	162.8 (64.1)	172.2 (67.8)	262.1 (103.2)	230.4 (90.71)
Configuration	Direct	Geared	Geared	Geared	Geared	Geared	Geared	Direct	Direct
Corrected Tip Speed, m/sec	441 (1450)	356 (1170)	356 (1170)	356 (1170)	274 (900)	356 (1170)	356 (1170)	441 (1450)	441 (1450)
Flow per Unit Area, lbm/sec/ft ² (kg/sec/m ²)	43.0 (209.8)	45.0 (219.6)	45.0 (219.6)	45.0 (219.6)	45.0 (219.6)	45.0 (219.6)	45.0 (219.6)	45.0 (219.6)	45.0 (219.6)
Hub/Tip Ratio	0.340	0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.260
Blade Aspect Ratio	4.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Number of Blades	36	24	24	24	24	24	24	24	24

LPC = Low Pressure Compressor

Gray’s Table 4.2-II, above, summarizes certain engine flowpath design data for each of the eight evaluated engine designs, including the highlighted hub-to-tip ratio of 0.26 for each candidate. *Id.* at 50.

Gray selected three candidates, Candidates 1, 2, and 6, as the most feasible for further study. *Id.* at 60–63. Petitioner relies mainly on Gray’s Candidate 1 shown in Figure 4.3-1, as highlighted by the board and reproduced below.



Gray's Figure 4.3-1, above, illustrates in partial cross-section certain engine components of Candidate 1 including the hub and fan highlighted in yellow. *Id.* at 63. Figure 4.2-3 below, as annotated by Petitioner, illustrates the engine flowpath of Candidate 1.

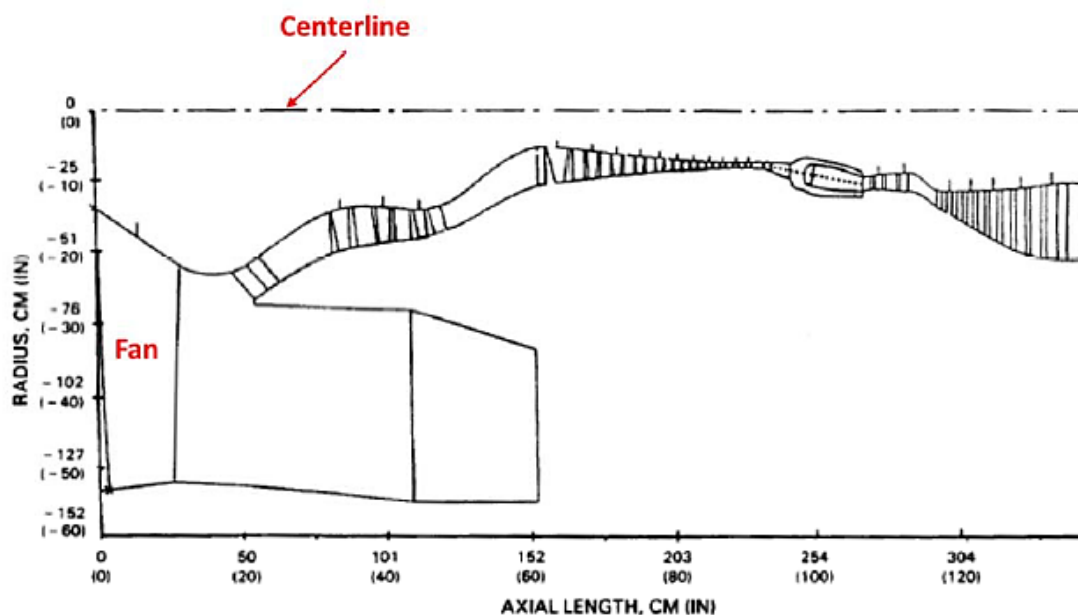


Figure 4.2-3 Flowpath of Advanced Technology Turbofan Candidate 1

Figure 4.2-3, above is a flowpath diagram of Candidate 1 as annotated by Petitioner to denote the fan and centerline.

2. Claim 1 (disclaimed)

Claim 5 depends from disclaimed claims 1 and 4, the elements of which we discuss below in relation to Gray.

Petitioner argues that Gray discloses all the elements of claim 1 including, referring to Gray's Figures 4.2-1, 4.2-3, a fan blade and hub shown rotating about a centerline axis of a gas turbofan engine. Pet. 42–43 (citing Ex. 1003 ¶¶ 163–165; Ex. 1019, 18, Table 4.2-II, Figs 4.2-3). Petitioner contends that Gray's Figure 4.3-1, shown above, illustrates a plurality of circumferentially spaced blades arranged “in a single axial blade row” as called for in claim 1. *Id.* at 44 (citing Ex. 1003 ¶¶ 166–167; Ex. 1019, 50, Fig. 4.3-1). Petitioner argues that Gray discloses each fan blade “has a leading edge, a hub radius, and a tip radius.” *Id.* at 46 (citing 1003 ¶ 168; Ex. 1019, 43; Fig. 4.3-1). Petitioner asserts that Gray discloses a hub-to-tip ratio of 0.26, which meets the limitation in claim 1, “wherein the ratio of the hub radius to the tip radius (R_{HUB}/R_{TIP}) is less than 0.29.” Pet. 48–49 (citing Ex. Ex. 1003 ¶¶ 170-171; Ex. 1019, 50, Table 4.2-XII).

3. Claim 4 (disclaimed)

Claim 4, which depends from claim 1, further includes the limitation “wherein the fan is an integrally bladed rotor, the fan blades being integrally formed with the rotor hub.” Ex. 1001, 5:36–38. Petitioner relies on Brownell for this limitation. Pet. 89–92. Petitioner argues that Brownell “describes forming a blisk for a fan via linear friction welding.” *Id.* at 93 (citing Ex. 1008, 1:14–15). According to Petitioner a person of ordinary skill in the art would have been motivated to manufacture Gray's fan and

hub as a blisk, i.e., and integrally bladed rotor as taught by Brownell, because “a POSITA would have known that manufacturing a fan as a blisk would provide numerous advantages, including improved aerodynamic performance (*i.e.*, improved efficiency), improved structural integrity, and reduced weight.” *Id.* at 89.

4. Claim 5

Before analyzing claim 5, we point out that, on the complete record now before us, we find Petitioner’s comparison of the elements recited in claims 1 and 4 with Grey’s disclosure and Brownell’s disclosure consistent with our own review of Gray and Brownell. Also, Patent Owner does not expressly dispute Petitioner’s mapping of the requisite elements of claims 1 and 4 to Gray and Brownell. *See generally* PO Resp. 51–63.

Claim 5 depends from claim 4 and includes the further limitation “wherein the rotor hub of the *integrally bladed rotor includes a preform having root stubs* disposed on the rotor hub.” Ex. 1001, 5:39–41 (emphasis added).

a. Petitioner’s Arguments

With respect to the asserted combination with Gray, Petitioner argues that “Brownell discloses forming an IBR [integrally bladed rotor] by joining airfoil blades, including fan blades, to corresponding stubs on the outer periphery of a rotor disk via linear friction welding.” Pet. 88 (citing Ex. 1008, 2:49–59). Petitioner also argues that “Figure 6 of Brownell . . . shows the preform having root stubs on the rotor hub before the blades are welded.” *Id.* at 94 (citing Ex. 1003 ¶ 102).

Claim 5 also requires “having root stubs disposed on the rotor hub at circumferential positions corresponding to at least alternate ones of said fan

blades.” Ex. 1001, 5:40–42. One reason for this limitation, the ’070 patent explains, is that

[i]t has been contemplated that alternative methods may also be used, such as forming a root stub 44 only for every alternate blade, while machining the full blade 20 between each alternate root stub. This would allow sufficient access for machine tools between two alternate full blades, to machine [] around the remaining root stub.

Id. at 4:67–5:5. Petitioner argues that Brownell’s Figure 9 “shows a portion of a rotor hub, including stubs disposed on the rotor hub at circumferential positions that correspond to each of the fan blades in the single axial blade row.” Pet. 96 (citing Ex. 1003 ¶ 103). Petitioner notes, and Patent Owner does not contest, that “having a root stub for each blade encompasses at least alternate blades, as required by Claim 5.” *Id.* at 95–96; *see also* PO Resp. 63–69 (not contesting whether prior art describes “having root stubs . . . corresponding to at least alternate blades”).

Petitioner argues that it would have been obvious to one of ordinary skill in the art to fabricate Gray’s fan as a blisk as taught by Brownell because it was well “known that manufacturing a fan as a blisk would provide numerous advantages, including improved aerodynamic performance (*i.e.*, improved efficiency), improved structural integrity, and reduced weight.” Pet. 89 (citing Ex. 1017, 1:15–18; Ex. 1003 ¶¶ 91–97). Petitioner argues that a person of ordinary skill in the art would have been motivated to manufacture Gray as a blisk using linear friction welding “because it allows for separate manufacturing of the rotor disk and blades. Thus, each portion of the blisk can be made from the optimal material and manufacturing process.” *Id.* at 90 (citation omitted) (citing Ex. 1003 ¶ 95; Ex. 1008, 1:17–30).

b. Patent Owner's Arguments

Patent Owner argues that a person of ordinary skill in the art would not have been motivated to use Brownell's linear friction welded blisk and root stubs for manufacturing Gray's low hub-to-tip ratio fan as an IBR because Gray's fan blades are too large and tightly spaced. PO Resp. 51. According to Patent Owner, besides "the fan being quite large, the spacing between blades is especially tight considering their size. *Gray* failed to provide sufficient space necessary for (1) the collar, (2) clamps, (3) oscillation, and (4) flash." *Id.* at 51–52 (emphasis omitted).

In support of Patent Owner's arguments Dr. Benini explains that Gray's blades are so big that a root and slot manufacturing process is more common to fabricate a fan as compared to an IBR. Ex. 2001 ¶ 75. According to Dr. Benini, this is because "the mechanical connection between the blade and the hub made it easier to repair individual blades by removing damaged blades and inserting an operational blade using the mechanical connection." *Id.*

Patent Owner also relies heavily on testimony from Dr. Schmid. PO Resp. 57–58. Dr. Schmid testifies that the size of Gray's blades generates significantly higher acceleration forces because "both friction and inertia forces are larger using *Gray*'s blades compared to the smaller blades of compressors and turbines traditionally manufactured using linear friction welding." Ex. 2010 ¶ 88. Dr. Schmid further testifies that the "upsetting" forces to weld such a large blade "requires an exponential increase in force." *Id.* ¶ 89. In view of such challenges Dr. Schmid testifies that "[l]inear friction welding the eight-foot, ten-inch fan assembly disclosed in *Gray* in November 2012 would have been extraordinarily difficult, if not

impossible.” *Id.* ¶ 88. Dr. Schmid refers to several references to support his testimony that large blades were very difficult to linear friction weld. *Id.* ¶ 90. Dr. Schmid refers specifically to U.S. Patent No. 8,070,039, for example, which states that “as the size of the vibrated component increases, the momentum that must be controlled becomes problematic.” Ex. 2013, 2:17–21.

c. Motivation to Combine

Weighing the declarants’ testimony in conjunction with all the evidence in this proceeding we are persuaded that a person of ordinary skill in the art would have been motivated to combine Gray and Brownell and to manufacture a fan where “the rotor hub of the integrally bladed rotor includes a preform having root stubs disposed on the rotor hub,” as recited in claim 5. Ex. 1001, 5:39–41.

(1) The Size of Gray’s Blades

Regarding the size of Gray’s fan blades, which Patent Owner argues are essentially too big to manufacture by linear friction welding, we find Dr. Schmid’s testimony and the evidence in the prior art pertinent, but ultimately unconvincing. First, Dr. Schmid testifies that Gray’s fan blade “is particularly large relative to IBRs the person of ordinary skill would have considered as candidates for linear friction welding in November 2012.” Ex. 2010 ¶ 87. Dr. Schmid testifies that “Linear friction welding the eight-foot, ten-inch fan assembly disclosed in *Gray* in November 2012 would have been extraordinarily difficult, if not impossible.” *Id.* ¶ 88. To support this Dr. Schmid explains that the acceleration necessary to overcome inertia and friction forces for Gray’s blade “would be substantially larger than for a typical linear friction welding workpiece.” *Id.* To apply the necessary

upsetting force Dr. Schmid explains that Gray's blade "would require a minimum of 1,200 kN force (269,770 lbf)." *Id.* ¶ 89. Dr. Schmid summarizes, stating "[a]ttempting linear friction welding for *Gray's* blades would require clamps and collars sufficient to transmit these high forces." *Id.*

We understand from Dr. Schmid's testimony that a larger blade like Gray's would require larger clamps and collars and higher acceleration and upsetting forces than a smaller blade. It is not clear from Dr. Schmid's testimony, however, why a larger linear friction welding machine necessary to accomplish the welding process for Gray's larger blades would have been "an almost insurmountable obstacle to the person of ordinary skill." Ex. 2010 ¶ 89. We appreciate that a larger linear friction welding machine is needed for larger blades, yet Dr. Schmid does not explain that making and using a larger linear friction welding machine for Gray's fan would have been beyond the level of ordinary skill in the art.

The MTI blog post that Dr. Schmid cites to is likewise not particularly compelling. *See* Ex. 2010 ¶ 87 (Dr. Schmid testifying that MTI "calls into question the availability of machines to use linear friction welding to make *Gray's* blade."). MTI's blog post states that

[i]n order to make a weld where we oscillate vertically and forge horizontally, we need to be able to open up the tooling after the weld is complete so the welded blade can remain on the hub. That's a big task, both literally and figuratively, because the blades we're welding can be in a full diameter of four feet, with a high degree of twist.

Ex. 2005, 5. The blog post is best understood as an explanation that linear friction welding tooling is sizeable, taking up a significant amount of space even for a four foot diameter blisk. We would agree that this evidence tends

to support the assertion that a larger diameter blade would need larger tooling that takes up more space. But we do not find it very persuasive that necessary manufacturing tooling, tolerances, and forces were exceedingly more difficult, or impossible, for large blades.

Dr. Schmid also points to U.S. Patent No. 8,070,039 as evidence that welding large blades is difficult and expensive. Ex. 2010 ¶ 91. The '039 patent is directed to linear friction welding and also appears to provide certain solutions to this problem, explaining for example that “[a] LFW system and method which allows for smaller components within the system would be beneficial.” Ex. 2013, 2:44–46. On balance, we find the '039 patent evidence neutral as to inoperability of Petitioner’s proposed combination of Gray and Brownell.

Dr. Schmid’s testimony appears also to assume that there may not be “availability” of linear friction welding machines to weld Gray’s blades. Ex. 2010 ¶ 87. This is not persuasive evidence that it was beyond the level of ordinary skill in the art to make and use the necessarily sized tooling including collars and clamps applying the necessary forces to linear friction weld Gray’s blade. Dr. Schmid provides little if any basis for reaching this conclusion, for example, he cites no prior art showing any specific limitations on fan size for linear friction welding. Thus, Dr. Schmid relies mainly on the *absence of disclosure* to support his conclusions, and we do not credit Dr. Schmid’s testimony on this point in light of the prior art teachings discussed below. *Elbit*, 881 F.3d at 1358 (“The PTAB [i]s entitled to weigh the credibility of the witnesses.”; quoting *Trs. of Columbia Univ. v. Illumina, Inc.*, 620 F. App’x 916, 922 (Fed. Cir. 2015)).

We do appreciate that the size and cost of the tooling for larger blades would undoubtedly be a factor in determining whether linear friction welding or another manufacturing process would have been economically appropriate for manufacturing larger fan blades. Petitioner's declarant, Dr. Abhari, testified in his deposition that a person of ordinary skill in the art would consider different manufacturing methods and processes from a business perspective.

Q. And do you know what manufacturing method they used to actually build the fan that's disclosed in Gray and you're relying on?

A. No, I do not. But I would -- I mean, as I mentioned before, this is an older engine. This goes back a while, and I would have suspected a dovetail design, but they could have done it also with friction welding. It's a business issue. So large fans, whether it would make sense to -- it's not a technical restriction because from my point of view Gray blades are more than sufficient space -- space becomes an issue for pitch. They are very large blades, so they need specially designed tools. And then you have to look at the consideration related to the business model of how you repair it and how you replace it and how you handle them.

So whether you use friction welding or the classical dovetail design, from my point of view, becomes an immediate business issue, which approach they would take.

Ex. 2025, 114:19–115:14. Acknowledging Patent Owner's arguments and both parties declarants' testimony that there would be economic and engineering manufacturing efficiency considerations in determining which manufacturing method to use, we do not find this evidence persuasive that linear friction welding of Gray's fan would have been technically impossible or beyond the level of skill in the art. We are not persuaded that making such a business determination shows that a person of ordinary skill in the art would not have considered linear friction welding Gray's fan as taught by

Brownell. *See KSR*, 550 U.S. at 401 (“[I]f a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill”).

(2) Blade Spacing

Patent Owner also argues, similar to Kaplan, that there is not enough space between Gray’s blades to accommodate the function and structure necessary to linear friction weld a blade to a hub. According to Dr. Benini Gray’s blades would be 3.34 cm wide and spaced 5.88 cm apart. PO Resp. 59 (citing Ex 2001 ¶¶ 76–79). Based on Dr. Benini’s calculations, Dr. Schmid testifies that 5.88 cm is insufficient space to accommodate a collar, clamp and tangential oscillation necessary for welding Gray’s blades. Dr. Schmid testifies that “one of ordinary skill would have expected *Gray* to require a collar of at least 10.0 cm to provide sufficient stiffness and rigidity for the linear friction welding process.” Ex. 2010 ¶ 93. Dr. Schmid’s testimony explains that if every blade on the circumference of Gray’s fan assembly were provided with a collar there would be no room between the collars for the clamps and also that oscillation could not occur for linear friction welding. *Id.* ¶¶ 94–95.

Patent Owner’s arguments and Dr. Schmid’s testimony, however, presume that immediately adjacent blades are all fitted with a collar and clamps for the duration of the linear friction welding process. *See* Ex. 2010 ¶¶ 97, 99 n. 9 (“[O]ne of ordinary skill would have welded all blades, then...remove the flash and collars...”). We have before us persuasive evidence that linear friction welding techniques for fan blades do not have to occur in this manner. Rather, Petitioner presents evidence that it was well

known where spacing was an issue to weld alternating blades of a fan, machine those blades, then linear friction weld the remaining alternating blades. Pet. Reply 15–16. Petitioner points out that U.S. Patent No. 5,188,275 describes a linear friction bonding process for a blisk that addresses closely spaced blades. *Id.* The '275 patent explains that where blade spacing is close

a number of blade preforms may be bonded sequentially at locations sufficiently far apart. In the illustrated case the minimum spacing is alternate locations. A whole BLISK could be manufactured, if desired, in this way by bonding blades at, say, alternate locations in a first operation, subsequently removing surplus metal and then bonding the remaining blades in a further operation.

Ex. 1027, 3:20–27. Petitioner points out that this same prior art technique is discussed in the '070 patent, specifically that one can form “a root stub 44 only for every alternate blade, while machining the full blade each alternate root stub. This would allow sufficient access for machine tools between two alternate full blades, to machine around [] the remaining root stub.”

Ex. 1001 4:67–5:5. This description coincides with the specific language of claim 5 which requires root “stubs disposed on the rotor hub at circumferential positions corresponding to *at least alternate ones* of said fan blades in the single axial blade row.” *Id.* at 5:39–44. The '070 patent does not specifically state that this is a prior art technique and during his deposition Dr. Schmid did not know whether welding alternate blades was a known concept. Ex. 1030 89:19–90:4. Neither Dr. Schmid nor Dr. Benini discuss or explain that using such an alternate blade technique would have been inoperable or beyond the level of a person of ordinary skill in the art. To the contrary, we are persuaded that Petitioner’s evidence from the

'275 patent shows that linear friction welding alternating blades was a manufacturing technique that was well known to those of ordinary skill in the art to account for limited spacing and machining between blades.

For purposes of our determination here we assume that Patent Owner's calculations of blade width, i.e. thickness, and thus blade spacing are reasonable. *See* PO Resp. 59 (Patent Owner relying on Dr. Benini's testimony that blade thickness-chord ratio is 10%). Petitioner does offer contradictory evidence, asserting that Dr. Benini's estimate of blade width are too high, and that Kaplan's blade thickness –chord ratio is more likely 4.3%. Pet. Reply 20–21 (citing Ex. 1031, 24:12–18). We need not directly address this discrepancy. Even considering Dr. Benini's blade and spacing calculations, Petitioner has provided compelling evidence from the '275 patent that the technique of linear friction welding alternate blades was well-known. We are persuaded that a person of ordinary skill in the art would have been motivated to combine Kaplan and Brownell and would have known how to weld alternating blades to accommodate spacing issues between blades in the manufacture of a blisk.

Weighing the declarants' testimony and the evidence provided by both parties during the trial we are persuaded that a person of ordinary skill in the art would have considered and had a reasonable expectation of success in designing and fabricating a gas turbine fan manufacturing process using linear friction welding and a blisk having stubs as taught by Brownell, for joining a complex blade geometry and a hub-to-tip ratio of less than 0.29 as taught by Gray. *See KSR*, 550 U.S. at 416 ("The combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results."); *see also Hoffman La Roche*, 748

F.3d 1331 (“Conclusive proof of efficacy is not necessary to show obviousness. All that is required is a reasonable expectation of success.”).

We are also persuaded that Petitioner has provided sufficient reasoning and motivation applying compelling evidentiary underpinnings from its Declarants and the prior art to support the combination of Gray and Brownell. Based on the complete record before us, Petitioner has shown by a preponderance of the evidence that the limitations of claim 5 would have been obvious over Gray and Brownell as properly combined.

5. Claims 6–8

Petitioner argues that the limitations of claims 6–8, each of which depend either directly or indirectly from claim 5, are taught by Brownell. Pet. 97–98 (citing Ex. 1008, 2:38–42 2:49–53 4:36–38, Fig. 5). Patent Owner does not argue specifically the limitations of claims 6–8.

Our understanding of Brownell is consistent with Petitioner’s arguments and evidence. With respect to claims 6 and 7, Brownell discloses that linear friction welding airfoils to root stubs of a blisk to form an integrally bladed rotor (IBR) was a known manufacturing method. Ex. 1008, 2:18–37, Figs. 1, 5. As to claim 8, Brownell explains that it was well known in the prior art for IBR assemblies that “[t]he disk 10 is provided with a plurality of upstanding stubs 11 on its periphery, that is its circumferential surface.” *Id.* at 3:28–30. Given all the evidence of record now before us, we are persuaded that Petitioner has shown by a preponderance of the evidence that claims 6–8 are unpatentable over Gray and Brownell.

6. Claims 13–16 and 19

Claims 13–16 depend either directly or indirectly from independent claim 9 and dependent claim 12. Claims 9 and 12 are disclaimed. Ex. 2003. Claims 13–16 correspond to claims 5–8 discussed above and include the same and similar limitations. One minor difference being that a “fan blade” recited in claims 13–16 includes an “air foil with a leading edge.” Ex. 1001, 5:58–69, 6:5–6. Petitioner argues that Gray discloses that each of the fan blades includes an airfoil. Pet. 53–54 (citing Ex. 1003 ¶ 177). Patent Owner does not dispute that Gray’s blade includes an airfoil. Patent Owner does not specifically address claims 13–16, instead relying on its main contention that “each of GE’s proposed combinations is inoperable; persons of ordinary skill would not have been motivated to combine them.” PO Resp. 33. Because of the high degree of similarity in limitations between these claims our analysis for claims 13–16 obtains the same outcome as that for claims 5–8 as discussed above.

Claim 19 is a method claim, depending indirectly from disclaimed independent claim 17, and is essentially a combination of the limitations in claims 4 and 5 requiring “a hub preform having a number of root stubs” and “fastening the fan blade airfoils to the root stubs to form fan blades integrally formed with the rotor hub.” Ex. 1001, 6:41–48. Patent Owner does not specifically address claim 19, nor dispute that Gray and Brownell disclose all the limitations of claim 19. Patent Owner instead relies on its main contention that “each of GE’s proposed combinations is inoperable; persons of ordinary skill would not have been motivated to combine them.” PO Resp. 33. Because claim 19 includes the same and similar limitations, just in method format, as claims 4 and 5 discussed above, based on the high

degree of similarity in limitations between these claims our analysis for claim 19 obtains the same outcome as that for claims 4 and 5. We are persuaded that Petitioner has shown by preponderance of the evidence that claims 13–16 and 19 are unpatentable over Gray and Brownell.

7. Conclusion as to Gray and Brownell

Given the complete record now before us, we are persuaded that Petitioner has shown by a preponderance of the evidence that claims 5–8, 13–16, and 19 are unpatentable over Gray and Brownell.

III. CONCLUSION¹²

In summary,

Claims	35 U.S.C. §	Reference(s)/ Basis	Claims Shown Unpatentable	Claims Not Shown Unpatentable
5–8, 13–16, 19	103	Kodama, Brownell	5–8, 13–16, 19	
5–8, 13–16, 19	103	Kaplan, Brownell	5–8, 13–16, 19	
5–8, 13–16, 19	103	Gray, Brownell	5–8, 13–16, 19	
Overall Outcome			5–8, 13–16, 19	

¹² Should Patent Owner wish to pursue amendment of the challenged claims in a reissue or reexamination proceeding subsequent to the issuance of this decision, we draw Patent Owner’s attention to the April 2019 *Notice Regarding Options for Amendments by Patent Owner Through Reissue or Reexamination During a Pending AIA Trial Proceeding*. See 84 Fed. Reg. 16,654 (Apr. 22, 2019). If Patent Owner chooses to file a reissue application or a request for reexamination of the challenged patent, we remind Patent Owner of its continuing obligation to notify the Board of any such related matters in updated mandatory notices. See 37 C.F.R. § 42.8(a)(3), (b)(2).

IV. ORDER

For the reasons given, it is

ORDERED, based on a preponderance of the evidence that claims 5–8, 13–16, and 19 are unpatentable; and

FURTHER ORDERED that, because this is a Final Written Decision, any party to the proceeding seeking judicial review of this Decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

For PETITIONER:

Brian Ferguson
Anish Desai
Christopher Pepe
WEIL, GOTSHAL & MANGES LLP
GE.WGM.Service@weil.com
brian.ferguson@weil.com
anish.desai@weil.com
christopher.pepe@weil.com

For PATENT OWNER:

Trenton A. Ward
James R. Barney
Jeffrey C. Totten
Benjamin A. Saidman
FINNEGAN, HENDERSON, FARABOW,
GARRETT & DUNNER, L.L.P.
trenton.ward@finnegan.com
james.barney@finnegan.com
jeffrey.totten@finnegan.com
benjamin.saidman@finnegan.com

Michael J. Valaik
BARTLIT BECK LLP
michael.valaik@bartlitbeck.com