

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CMS CEP COR LTD., and CMS CEP COR AMERICAS LLC,
Petitioner,

v.

SANDVIK INTELLECTUAL PROPERTY AB,
Patent Owner.

Patent No. 11,014,090

Inter Partes Review No. IPR2024-01381

DECLARATION OF HARRI KYTÖMAA, PH.D.

I, Harri Kytömaa, Ph.D., make this declaration in connection with the proceeding identified above.

I. INTRODUCTION

1. I have been retained by counsel for Patent Owner, Sandvik Intellectual Property AB (“Sandvik”) as a technical expert in connection with the proceeding identified above. I submit this declaration in support of Patent Owner’s Preliminary Response to the Petition for *Inter Partes* Review of United States Patent No. 11,014,090 (“the ’090 patent”) filed by CMS Cepcor Ltd. and CMS Cepcor Americas LLC (collectively, “Petitioner”).

2. I am being paid at an hourly rate for my work on this matter. I have no personal or financial stake or interest in the outcome of the present proceeding.

II. QUALIFICATIONS

3. In this section, I summarize my educational background, experience, career history, publications, and other relevant qualifications. A detailed description of my professional qualifications, including a list of publications, awards, and professional activities, is contained in my curriculum vitae, attached as Appendix A.

4. I am a Licensed Professional Engineer in the states of Texas, Louisiana, Oklahoma, Arkansas, Alabama, California, Washington, Michigan, Florida, Maine, New Jersey, New York, and Massachusetts.

5. In 1979, I graduated with a Bachelor of Science degree (First Class with Honors) in Engineering Science from Durham University. Subsequently, I attended the California Institute of Technology (“Caltech”) where I received a Master of Science degree in Mechanical Engineering in 1982, as well as my Ph.D., also in Mechanical Engineering, in 1987.

6. My Ph.D. thesis research at Caltech focused on the dynamics of particle flows. As part of my research, I designed and constructed a two-story experimental facility and designed and built a custom hopper to contain and dispense solid materials and a gate valve to control their flow. During my tenure as a graduate student at Caltech, I was also a teaching assistant of Caltech undergraduate and graduate-level mechanical engineering courses.

7. I was a member of the faculty at The Massachusetts Institute of Technology (“MIT”) from 1986 to 1994 in the Mechanical Engineering department. From 1986 to 1990, I was an Assistant Professor, and from 1990 to 1994, I was an Associate Professor. I was Head of MIT’s Fluid Mechanics Laboratory in the Department of Mechanical Engineering from 1990 to 1994. As a Professor at MIT, my responsibilities also included teaching undergraduate and graduate level courses. I taught a capstone mechanical engineering design course that included machine design, experimental methods courses, and courses in thermal sciences. Some of my research at MIT focused on comminution and

methods of efficient particle size reduction through crushing, for example. Such methods are energy intensive and, in an effort to render these more efficient, my work addressed ways of segregating particles by their size. I designed and constructed a test section in which mixtures of particulate materials of different sizes were submerged in water and were dynamically fluidized with a sudden upward jets of water to separate them by size. Another part of my research studied the behavior of dense granular and particulate materials. For this work, I designed and built a shear cell that was driven by a bearing-supported shaft, a gear box, and an electric motor.

8. While a Professor at MIT, I also spent some of my time on engineering consulting in the oil and gas industry. This work included developing the use of acoustic telemetry in drilling and downhole applications by sending sound waves through drilling muds (dense suspensions of solids). This work contributed to Measurement-While-Drilling (MWD) techniques, an enabling technology for directional drilling. In this consulting capacity, I also developed concepts for downhole rotating valves that were driven by a shaft to create pressure pulses.

9. While at MIT, I also published articles about my research work in peer-reviewed journals. I was awarded the ASME Lewis F. Moody Award for my

work on dense suspensions of solids and served as Workshop Group Leader for the U.S. National Science Foundation.

10. I joined Failure Analysis Associates in 1994 as a full-time employee with the title of Managing Engineer. The firm was renamed Exponent in 1998. In that same year, I became the Director of the Thermal Science practice, a position that I held until October 1, 2016. I am currently Corporate Vice President of Exponent. My responsibilities with Exponent include providing scientific and engineering consulting services as a mechanical engineer.

11. At Exponent, I have continued to work on mechanical and machine design. Examples of past projects include working on coal handling equipment including crushers associated with coal mining and coal fired power plants, fasteners (such as threaded components and rivets), manufacturing techniques (casting, forging, welded and riveted assemblies), mechanical seal designs, bearing design and performance, shaft misalignment, eccentric shaft motion and vibration. These have often been in the context of rotating equipment such as aircraft engines, compressors, turbines and pumps.

12. I have also worked and testified on intellectual property matters involving machine design of heavy mechanical equipment, such as large valves, aircraft engines and downhole tools, as well as smaller equipment, such as fire-fighting nozzles and various kinds of mechanical fasteners.

13. I am an active member of several professional organizations including the American Society of Mechanical Engineers (“ASME”) and the American Society of Chemical Engineers (“AIChE”). In January 2016, I was elected Fellow of the ASME in recognition for the contributions I have made to the profession.

14. As noted above, attached as Appendix A is a copy of my *curriculum vitae*.

III. MATERIALS CONSIDERED

15. In preparing this declaration, I have reviewed, among other things, the following materials:

- The '090 patent (Ex. 1001);
- The Petition for *Inter Partes* Review of the '090 patent to which my declaration related (“Petition”) and Exhibits thereto, with particular attention to the Exhibits set forth below;
- The prosecution history of the '090 patent (Ex. 1001-1, “'090 prosecution history”);
- The Expert Declaration by David G. Smith that accompanies the Petition (Ex. 1002, “Smith”);
- Excerpts from Richard G. Budynas & J. Keith Nisbett, *Shigley’s Mechanical Engineering Design*, Ninth Edition (2011) (Ex. 2003);

- Excerpts from Andrew W. Batchelor & Gwidon W. Stachowiak, *Engineering Tribology*, Second Edition (2001) (Ex. 2004);
- Excerpts from Robert C. Juvinall & Kurt M. Marshek, *Fundamentals of Machine Component Design*, 3rd Edition (2000) (Ex. 2005);
- Excerpts from Oscar J. Horger, *Metals Engineering Design*, First Edition (1953) (Ex. 2006);
- U.S. Patent No. 4,410,143 issued to Polinski (Ex. 1017, “Polinski”);
- U.S. Patent No. 6,270,026 issued to Piepho (Ex. 1018, “Piepho”); and
- U.S. Patent No. 2,840,399 issued to Harless (Ex. 1033, “Harless”).

IV. DEFINITIONS AND STANDARDS

16. I have been informed and understand that claims are construed from the perspective of one of ordinary skill in the art at the time of the claimed invention. For the purposes of this Declaration, I have been informed that the time of the claimed invention is November 12, 2013, the earliest effective filing date for the '090 patent, corresponding to when European Patent Application No. 13192402.9 was filed.

17. I have further been informed, that during *inter partes* review, claims are to be construed using the same standard applied in district court. This standard is sometimes referred to as the *Phillips* standard. I understand that, under this standard, a claim term presumptively receives its plain and ordinary meaning to a

person of ordinary skill in the art. I have been further informed that claim construction begins with the language of the claim, the specification, and the prosecution history, but that extrinsic evidence including dictionary definitions and expert testimony may also be considered.

18. I have also been informed and understand that the subject matter of a patent claim is obvious 35 U.S.C. § 103 if the differences between the subject matter of the claim 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 the subject matter pertains. I have also been informed that the framework for determining obviousness involves considering the following factors: (i) the scope and content of the prior art; (ii) the differences between the prior art and the claimed subject matter; (iii) the level of ordinary skill in the art; and (iv) any objective evidence of non-obviousness.

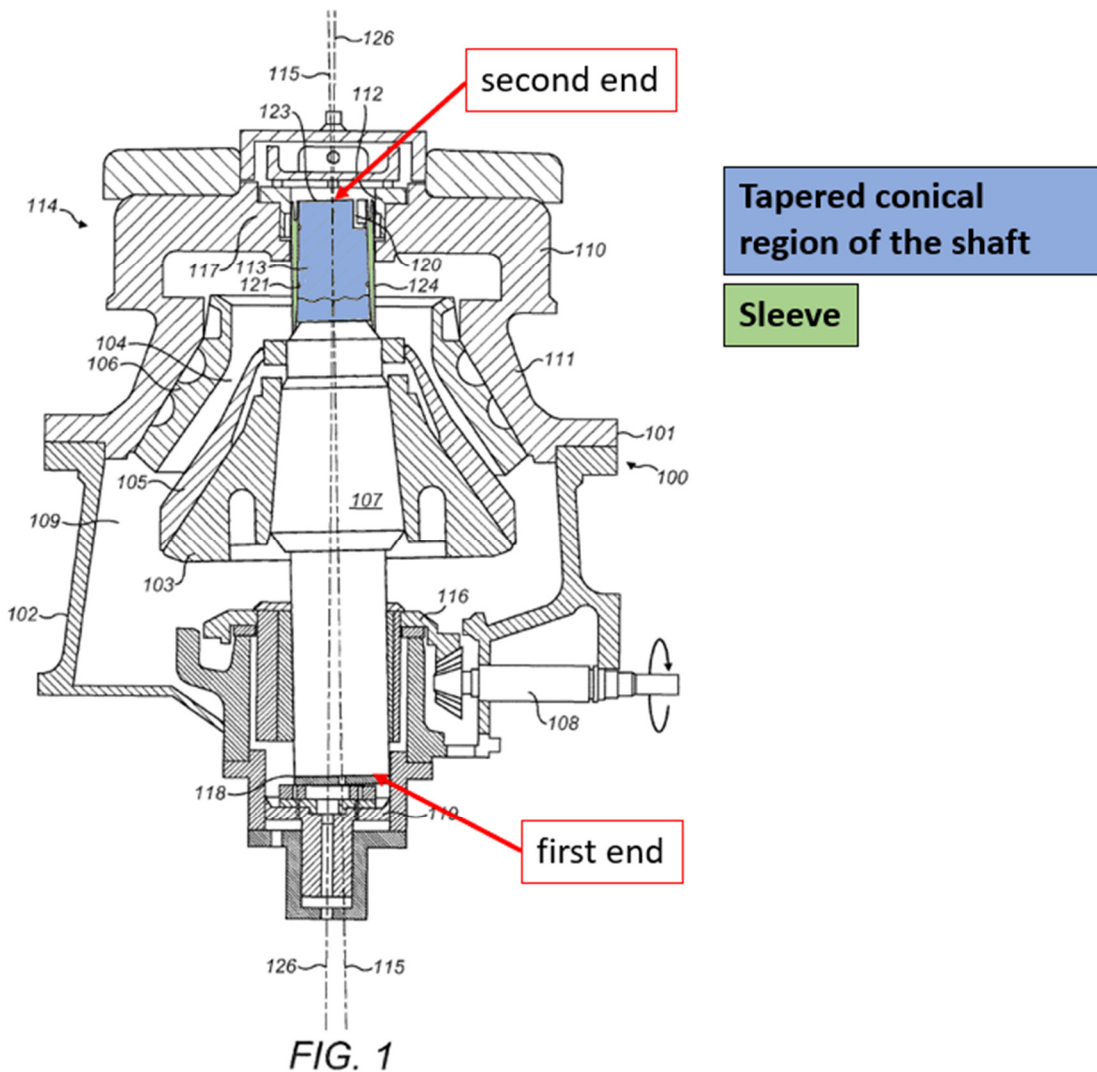
19. I understand that the claimed subject matter would have been obvious to one of ordinary skill in the art if, for example, it results from the combination of known elements according to known methods to yield predictable results, the simple substitution of one known element for another to obtain predictable results, use of a known technique to improve similar devices in the same way or applying a known technique to a known device ready for improvement to yield predictable results. I have also been informed that the analysis of obviousness may include

recourse to logic, judgment and common sense available to the person of ordinary skill in the art that does not necessarily require explication in any reference.

V. THE '090 PATENT

A. Overview of the '090 Patent

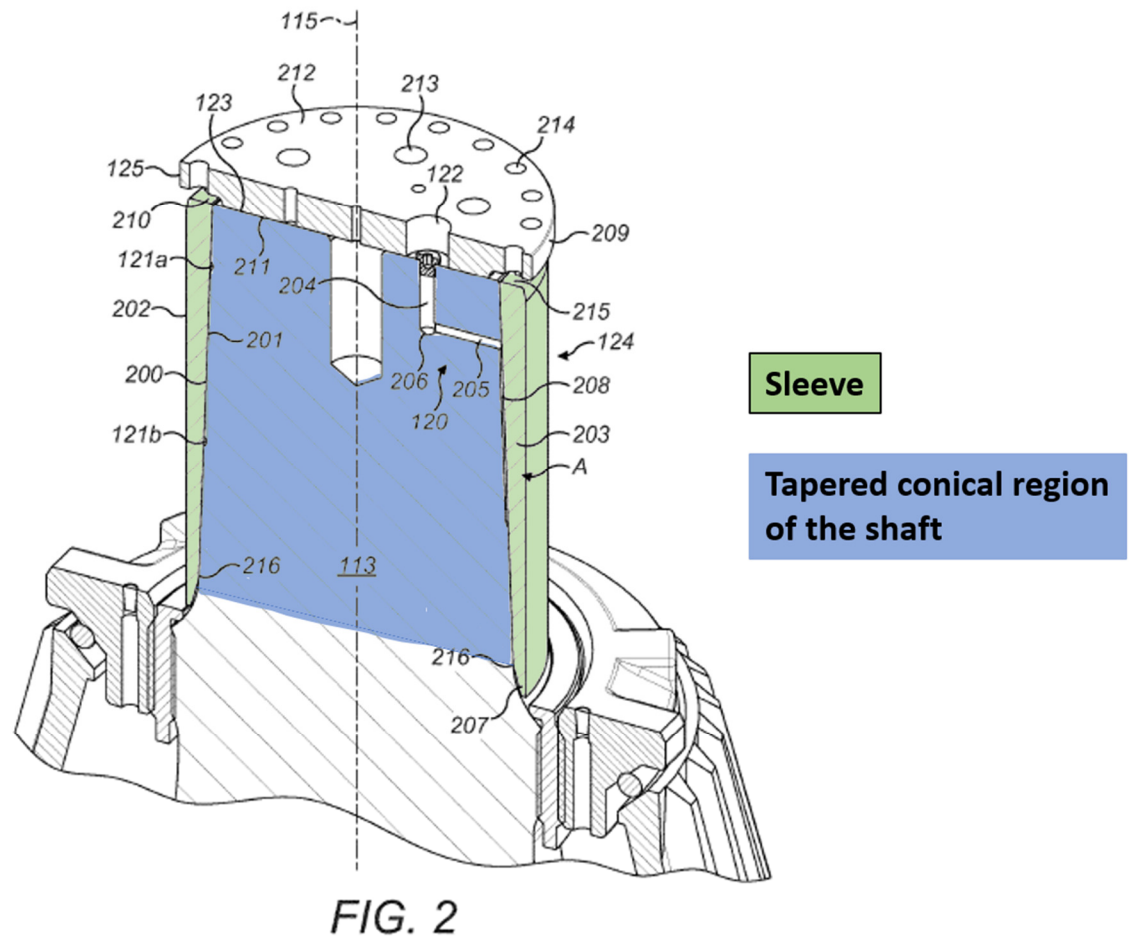
20. The '090 patent is directed to “a gyratory crusher main shaft assembly,” which includes “a main shaft, an axially upper region of the main shaft including a tapered conical section with a protective sleeve friction fitted over the cone.” (*E.g.*, '090 patent, Abstract.)



(*Id.*, FIG. 1 (Annotated).)

21. As illustrated in annotated Figure 1 above, a main shaft 107 is positioned within a gyratory crusher. The main shaft 107 has a first end positioned at a bottom end of the crusher and a second end positioned at the top end of the crusher. A tapered conical region 113 (in blue) of the main shaft 107 extends from

the second (top) end of the main shaft 107 toward the first (bottom) end of main shaft 107.



(*Id.*, FIG. 2 (Annotated).)

22. Figures 1 and 2 of the '090 Patent provide additional details. For example, annotated Figure 2 above shows protective sleeve 124 (in green) mounted to tapered region 113 (in blue) of the main shaft 107. (*Id.*, 5:26–51.)

Tapered region 113 forms a conical shape profile. (*Id.*) The protective sleeve 124 includes an inward facing surface 201 that has a conical shape profile corresponding to the conical shape profile of the main shaft tapered region 113. (*Id.*)

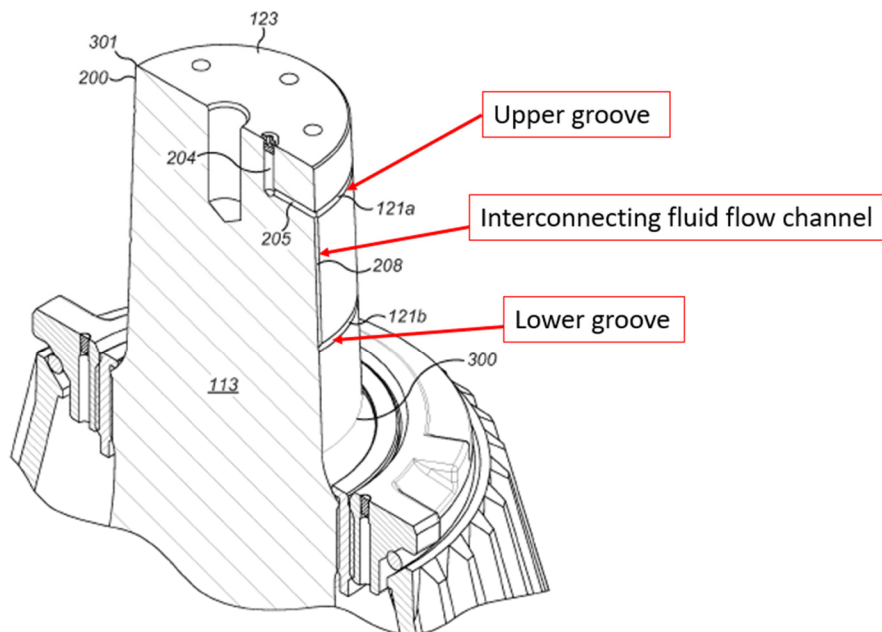


FIG. 3

(*Id.*, FIG. 3 (Annotated).)

23. As illustrated in annotated Figure 3 above, tapered region 113 may be uniform along the axial length between ends 300 and 301. (*Id.*) The shaft includes a fluid supply conduit 120 (shown in Figure 2 above) that connects to a groove 121a. The groove 121a is indented into the shaft and extends circumferentially around the tapered region 113. (*Id.*, 5:22–25; 6:24–31.) Fluid, such as oil, can be delivered to the groove 121a to lubricate the interface between an outer surface 200

of the shaft 107 and the inward facing surface 201 of sleeve 124. (*Id.*, 6:54–62.)

An interconnecting fluid flow channel 208 extends axially from upper groove 121a to a lower groove 121b, providing fluid communication between groove 121a and groove 121b. (*Id.*, 6:39–42.) Groove 121b is also indented into the shaft and extends circumferentially around tapered region 113. (*Id.*, 6:32–42.) Groove 121a, groove 121b, interconnecting fluid flow channel 208, and the corresponding tapered surfaces of the shaft and sleeve, promote efficient mounting and dismounting of the sleeve to the main shaft. (*Id.*, 2:46–60.)

B. The Independent Claims

24. The '090 patent includes three independent claims, claims 1, 9, and 14.

25. These claims are recited below, but my focus in this Declaration is independent claim 1. My opinions in this Declaration as to independent claim 1 also apply to independent claims 9 and 14.

1. A gyratory crusher main shaft of a crusher comprising:
 - a shaft body having a radially outward facing external surface, and a first end and a second end;
 - an axial region of the shaft body extending from the second end and being tapered relative to a longitudinal axis of the shaft body such that a cross sectional area of the shaft body at the tapered axial region decreases in a direction from the first end to the second end;
 - a shaft sleeve mounted on the tapered axial region; and
 - at least one groove indented at the external surface and positioned at the tapered axial region, the at least one groove being arranged to receive a pressurized fluid to facilitate mounting and dismounting of the shaft sleeve at the shaft body.

9. A gyratory crusher main shaft assembly for a crusher comprising:

a shaft body having a radially outward facing external surface, and a first end and a second end, an axial region of the shaft body extending from the second end and being tapered relative to a longitudinal axis of the shaft body such that a cross sectional area of the shaft body at the tapered axial region decreases in a direction from the first end to the second end, a shaft sleeve mounted on the tapered axial region, and at least one groove indented at the external surface and positioned at the tapered axial region, the at least one groove being arranged to receive a pressurized fluid to facilitate mounting and dismounting of the sleeve at the shaft body; and

a sleeve fitted over the tapered axial region, the sleeve having a tapered wall thickness, such that the wall thickness at a second end of the sleeve is greater than the wall thickness at a first end of the sleeve.

14. A gyratory crusher comprising;

a main shaft including a shaft body having a radially outward facing external surface, a first end for positioning at a lower region of the crusher and a second end for positioning at an upper region of the crusher relative to the first end, an axial region of the shaft body extending from the second end and being tapered relative to a longitudinal axis of the shaft body such that a cross sectional area of the shaft body at the tapered axial region decreases in a direction from the first end to the second end, the tapered axial region being configured to mount a shaft sleeve;

a sleeve fitted over the tapered axial region, the sleeve having a tapered wall thickness such that a wall thickness at a second upper end of the sleeve is greater than a wall thickness at a first lower end of the sleeve; and

at least one groove indented at the external surface and positioned at the tapered axial region, the at least one groove being arranged to receive a pressurized fluid to facilitate mounting and dismounting of the sleeve at the shaft body.

C. The Level of Skill in the Art

26. Mr. Smith, an expert for Petitioner, states that “a person having ordinary skill in the art would be a person who has a bachelor’s degree in mechanical engineering or a related field and at least two years of experience with industrial equipment design and development. A POSITA may also have a combination of more formal education and less work experience or a combination of less/different formal education and more work experience.” (Smith, ¶ 30.) For the purposes of this Declaration only, I do not object to Mr. Smith’s position on the level of skill in the art. I reserve the right to provide my own definition of the level of skill and to challenge both Mr. Smith’s defined level and his analysis in defining that level. (Smith, ¶¶ 15–30.)

VI. CLAIM CONSTRUCTION

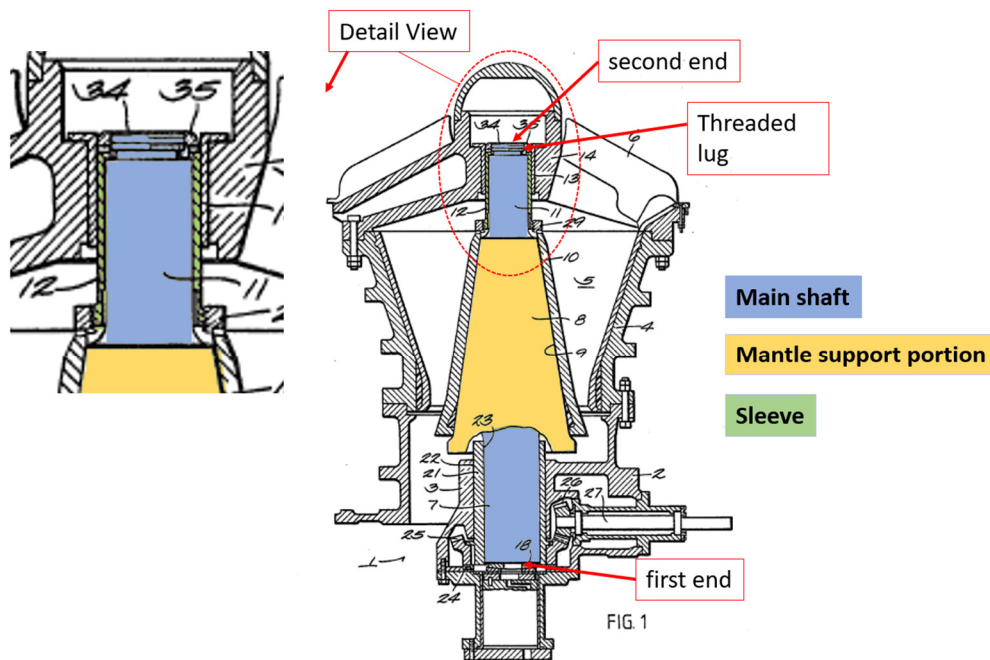
27. I understand that neither party in this proceeding is seeking to construe any term, and I therefore give my opinions in this Declaration consistent with what I understand to be the plain and ordinary meaning.

VII. SUMMARY OF THE REFERENCES IN THE SOLE GROUND

A. Polinski (Ex. 1017)

28. Polinski discloses a gyratory crusher and corresponding gyratory crusher shaft and bearing sleeve arrangement. (Ex. 1017, 1:44–47.) As illustrated in annotated Figure 1 of Polinski (below), the shaft includes a first end positioned near the bottom of the crusher and a second end positioned near the top of the

crusher. (*Id.*, FIG. 1.) Above the cylindrical bearing journal 11, shaft 7 includes a threaded lug that extends to the second (top) end and is adapted to receive a sleeve nut 35 of a cylindrical bearing sleeve 12. (*Id.*, 3:15–48.) The shaft further includes a mantle support portion 8 inserted into a conically shaped bore of a crusher mantle 10 and a cylindrical bearing journal 11 fit with a corresponding cylindrical bearing sleeve 12 (in green). (*Id.* 2:32–47.)



(*Id.*, FIG. 1 (cropped and annotated).)

29. Polinski teaches that conventional gyratory crusher shafts often attach a crusher mantle (such as crusher mantle 10 in Figure 1 above) directly to the main

shaft using threads cut into the main shaft. (*Id.*, 1:10–20.) Polinski teaches that such threads, which form geometrical discontinuities, should be eliminated from high stress regions of the shaft. (*See id.*) Specifically, with reference to the use of threads cut into the shaft to secure the crusher mantle, Polinski provides:

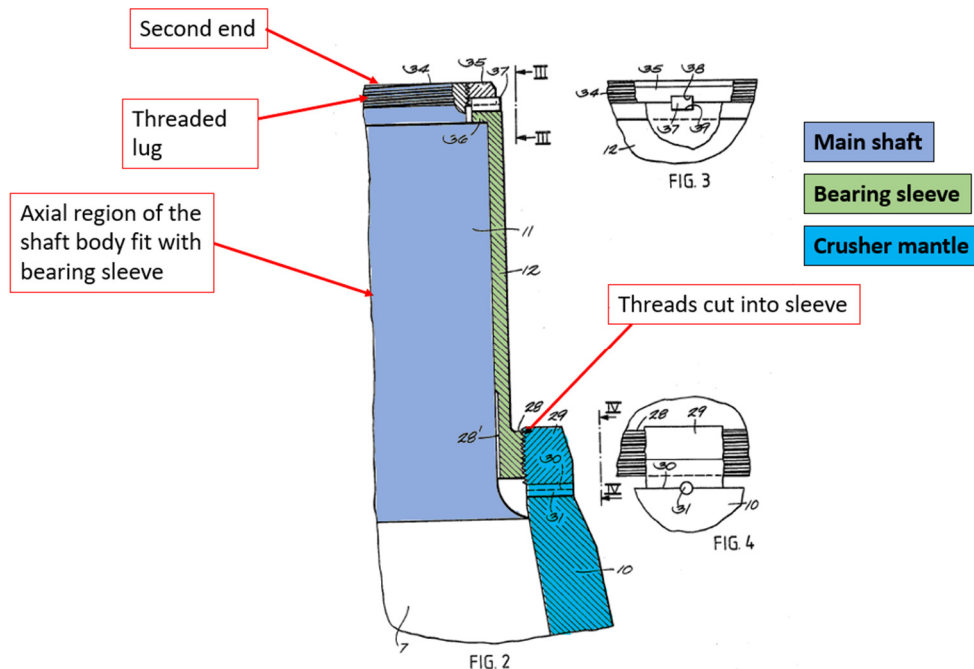
While this type of arrangement [threads cut into the shaft] has proven to be satisfactory for most crusher installations, experience has indicated that the relatively abrupt changes in the cross-sectional area of the shaft above and below the threaded section have resulted in high local stress concentrations in these regions of the shaft. **These stress concentrations are in addition to the *substantial stresses* generated by the *cyclic bending loads* applied to the shaft by the mantle during operation of the crusher. The result has been the development of *fatigue cracks* or fractures in the threaded section of the shaft as well as immediately above and below it where the highest stresses occur due to the abrupt changes in the cross-sectional area of the shaft. Over a period of time the cracks continue to grow and ultimately render the shaft unserviceable requiring that the crusher be taken out of service and the shaft replaced before crushing operations can be resumed.**¹ (*Id.*, 1:20–37.)

30. Polinski is directed to mitigating failure in gyratory crusher shafts by eliminating geometrical discontinuities from high-stress regions of the shaft. (Ex. 1017, 1:61–67.) Specifically, Polinski provides that:

[T]he invention contemplates an arrangement wherein abrupt structural discontinuities in the normally high-stressed regions of the main shaft have been essentially eliminated [by instead cutting threads into the sleeve] to minimize the development of fatigue fractures in the shaft while at the same time providing an arrangement which can be easily maintained and repaired in the field. (*Id.*)

¹ In this Declaration, all emphases have been added unless otherwise noted.

31. To that end, Figure 2 of Polinski, below, illustrates the above discussed threads cut into a bearing sleeve as opposed to the shaft. Polinski provides that “the bearing sleeve 12 extends generally coextensively with the bearing journal 11 and includes an externally threaded annular shoulder 28 about its lower periphery threadably receiving a head nut 29.” (*Id.*, 2:67–68; 3:1–9.) “The head nut 29 abuts the upper edge 30 of the mantle 10 to secure it to the tapered portion of the main shaft 7, and at least one rod or dowel 31 is welded in a corresponding pair of semi-circular keyways in the head nut and the mantle to prevent rotation between these members after the head nut is secured in position.” (*Id.* 3:3–9.) Accordingly, geometrical discontinuities are “essentially eliminated” from the high-stress bearing journal 11 of shaft 7. (*Id.*, 1:61–67.) The geometrical discontinuities are instead included in the bearing sleeve 12 to reduce fatigue crack initiation in the shaft 7. (*Id.*)



(Id., FIG. 2 (annotated).)

32. Polinski does not disclose that bearing journal 11 (to which sleeve 12 is mounted) includes a taper extending from the second end of the shaft 7. Polinski also does not disclose that sleeve 12 includes a taper. Finally, Polinski does not disclose any grooves indented at the external surface of the bearing journal 11 (to which sleeve 12 is mounted). Mr. Smith agrees, because he relies on other references—not Polinski—for a tapered shaft and sleeve and for grooves on a shaft, as discussed below.

B. Piepho (Ex. 1018)

33. Piepho discloses a main shaft for a coal pulverizer having a portion of the shaft coated with a material to mitigate fretting wear and fatigue failure. (Ex.

1018, 2:15–25.) Piepho discloses that conventional coal pulverizer shafts are known to fail due to stress concentrations in the shaft, fretting wear, and cyclic bending loads. (*Id.*, 1:45–65.) Specifically, Piepho explains:

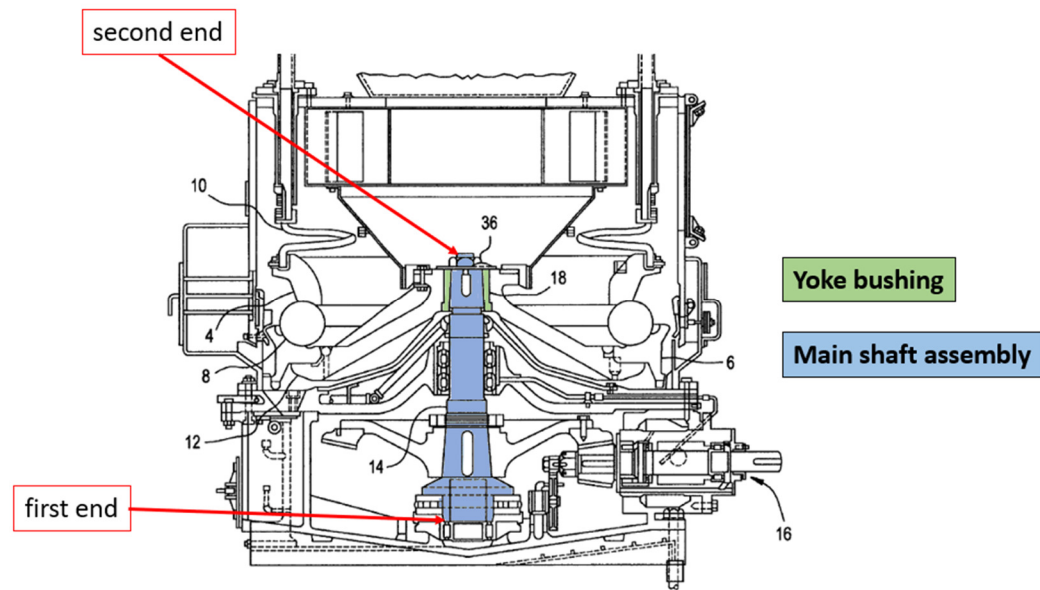
The pulverizer design generates cyclic or alternating type bending loads in the top end of the main shaft. Because the loads are cyclic, rubbing or fretting corrosion will occur. Also of concern is fatigue failure when stress concentration, cyclic loading and fretting corrosion are combined. (*Id.*, 1:53–58.)

34. Piepho further provides that various remedial efforts have failed to correct main shaft failure in coal pulverizers:

[T]here have been many attempts to correct main shaft failure frequency such as employing an anti-seize compound at the taper joint, using a bushing with a undercut center portion, using full contact bushings with no undercut center portion, shot peening, and nitriding as a surface hardening process. Remedial efforts notwithstanding, even carefully fitted taper joints, when subjected to cyclic bending forces often exhibit vulnerability to fatigue failure of shafts because of fretting and strain produced within the assembly. (*Id.*, 1:66–67; 2:1–8.)

35. To that end, Piepho is directed to techniques for mitigating shaft failure. Specifically, Piepho provides that “[t]he present invention resides in an improved main shaft for a coal pulverizer to reduce shaft failure due to fretting induced bending fatigue,” as described further below. (*Id.*, 2:56–58.)

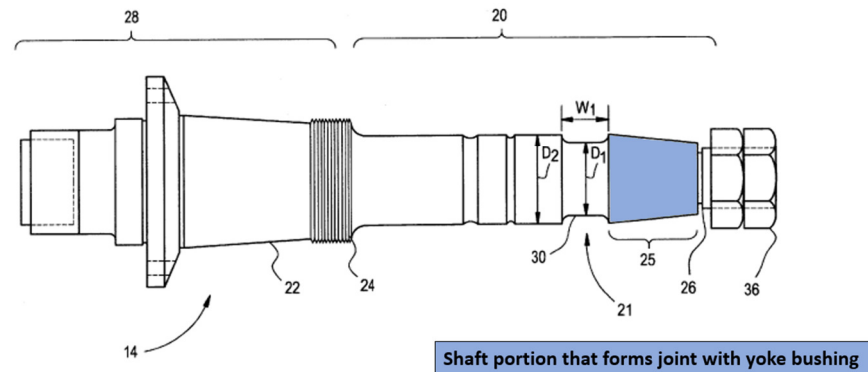
36. Figure 1 of Piepho, shown below, illustrates a conventional B&W type EL ball and race pulverizer in which the purported invention of Piepho may be used.



(*Id.*, FIG. 1 (annotated and cropped).)

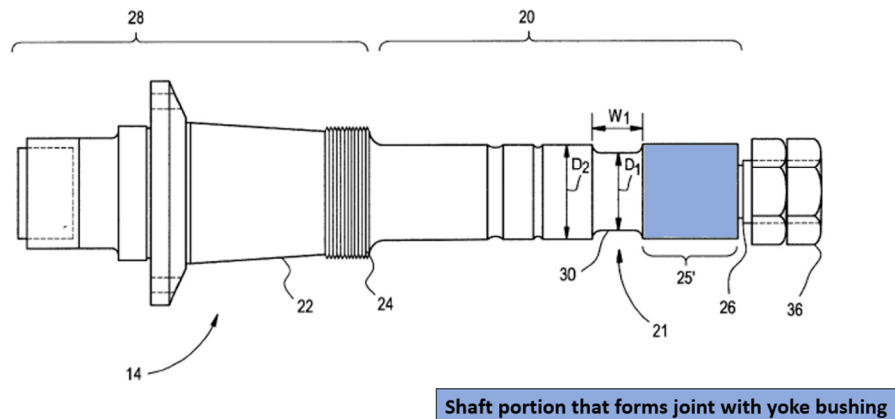
37. As shown in Figure 1 above, the B&W type EL ball and race coal pulverizer includes a main shaft fit into a bore of a yoke bushing. The main shaft of Piepho, which may be incorporated into a coal pulverizer, such as the one depicted in Figure 1, is illustrated in Figures 3 and 4 of Piepho, shown below. (*Id.*, 2:47–51.)

FIG.3



(*Id.*, FIG. 3 (annotated).)

FIG.4



(*Id.*, FIG. 4 (annotated).)

38. The portion of the shaft that is configured to be fit with a yoke bushing (item 18 highlighted in Figure 1 above) when assembled into a coal pulverizer is labeled 25 and is highlighted above in Figures 3 and 4. As illustrated, the portion of the shaft that is configured to be fit with a yoke bushing does not

extend from the second (top) end of the shaft. Instead, a cylindrical portion labeled 26 extends from the second end of the shaft to the portion labeled 25 configured to be fit with a yoke bushing. The cylindrical portion 26 would be configured such that a corresponding fastener component 36 can be attached to secure the yoke depicted in Figure 1, shown above, to the shaft. (*See id.*, FIGS. 1, 4.)

39. Piepho further explains that “[t]he fit or joint between the yoke bushing (18) and upper taper (25) is an interference type fit. This type [of] fit generates a stress concentration or a stress multiplier. This stress concentration increases when the interference fit increases and will also increase when the length of the yoke bushing is increased.” (*Id.*, 3:6–11.)

40. As discussed above, Piepho teaches that stress concentrations, in combination with fretting wear and bending fatigue, can result in failure of coal pulverizer shafts. For instance, with reference to the shafts depicted in Figures 3 and 4, Piepho teaches:

The pulverizer operation generates cyclic or alternate type bending loads in the top end (20) of the main shaft (14). Shaft failures occur, most likely the result of deterioration of the finely machined shaft (14) surfaces within the joint between the shaft (25) and the bore of the yoke (12). This deterioration may be caused by cyclic movement between the respective surfaces of the shaft and the yoke bore. This movement results from bending of the shaft which produces differing stress fields in the shaft (14) and the yoke (12). This movement gives rise to a progressive form of damage known as fretting. (*Id.*, 3:12–22.)

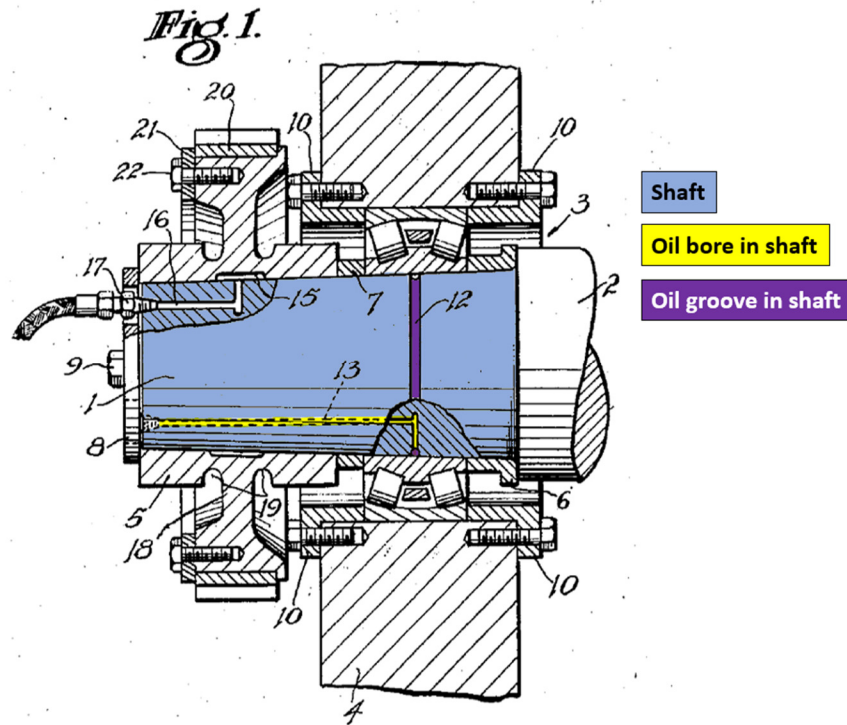
41. To mitigate fretting wear (and bending fatigue), Piepho discloses application of an intervening material between the shaft and yoke bushing to reduce local stresses in the shaft within the joint by *reducing the relative movement*. (*Id.*, 2:19–25.) For example, Piepho discloses:

The present invention provides an intervening material between the shaft end (25) and the mating bore in yoke bushing (18) fitted within the bore of yoke (12) to prevent fretting damage. (*Id.*, 3:23–26.)

42. Piepho teaches that the material *must* be suitable for refinement to a high surface finish for accurate fit-up, and that a suitable intervening material is thermal sprayed ceramic coating such as chrome oxide or a carbide coating like tungsten carbide. (*Id.*, 3:35–45.)

C. Harless (Ex. 1033)

43. Harless discloses “improvements in the attachment of gears and other members having axially projecting hubs to tapered shaft ends.” (Ex. 1033, 1:15–17.) Specifically, Harless discloses that “[i]t is an object of the invention to provide for the attachment of a gear or other drive member to a tapered shaft, by expanding certain portions of the hub of the gear, while avoiding the excess pressure necessary to expand the web or any other radially extending part of the gear.” (*Id.*, 1:30–34.) Figure 1 of Harless, below, illustrates a tapered end 1 of a shaft 2 supported by a bearing 3 and frame 4. A gear 5 is mounted to the tapered end 1 of the shaft 2.

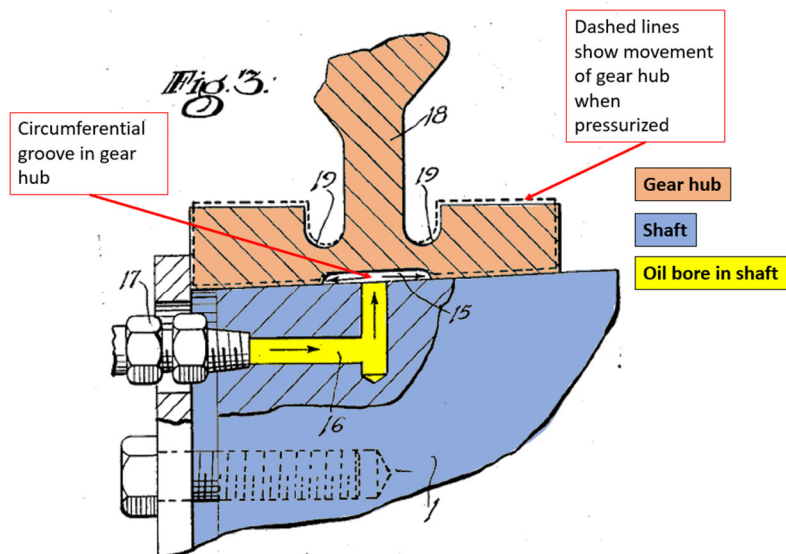


(Id., FIG. 1 (annotated).)

44. As illustrated in Figure 1, above, Harless discloses an oil groove 12 in the tapered end 1 of shaft 2. Oil under pressure can be introduced into circumferential groove 12 through a bore 13 to expand the bearing 3, permitting it to be pushed up against a spacer 6. (*Id.*, 2:19-26.) The oil pressure can then be released, permitting the bearing inner race to contract and fixing it to the shaft with a shrink fit. (*Id.*)

45. Harless also discloses a particular gear hub design that enables avoidance of excess pressure typically necessary to expand the web or any other radially extending part of the gear 5 for mounting on the shaft 2. As shown in

Figure 3 of Harless below, Harless discloses grooves 19 placed near the web 18 of the gear. (*Id.*, 1:30–35.)



(*Id.*, FIG. 3 (annotated).)

46. An oil groove 15 is indented into the gear hub, as depicted above, and radially aligned with the web 18. (*Id.* 2:32–43.) Oil can be provided to the groove 15 via a bore 16 in the shaft, and when a sufficiently high pressure is achieved, the gear hub bends at grooves 19 on either side of web 18 to lift the gear hub from the shaft, allowing it to be installed or removed. (*Id.* 2:32–51.)

47. Harless does not disclose that its shaft is used for crushing applications, including gyratory crushing. Harless does not disclose that its shaft is subjected to the same substantial stresses generated by the cyclic loading as the shafts disclosed by Polinski and Piepho. Harless is the only reference of the three

relied on by Petitioner against claim 1 for meeting a groove indented into a shaft at a location where a sleeve is mounted to the shaft.

VIII. ANALYSIS OF PRIOR ART

A. POSITA Would Not Have Been Motivated to Combine Polinski, Piepho, and Harless as alleged by Petitioner to Arrive at the Claimed Invention

48. Petitioner and Mr. Smith argue that it would have been obvious to modify the combination of Polinski and Piepho to include “at least one groove indented at the external surface and positioned at the tapered axial region,” as claimed, based on the teachings of Harless. (*See* Paper 2, 18–20; Ex. 1002, 61–63.) I disagree. A person of skill in the art would not have been motivated to modify the combination of Polinski and Piepho in view of Harless to include an oil groove at the tapered axial surface. Polinski and Piepho both teach that imperfections and discontinuities in the shaft region fit with a bearing sleeve (or yoke bushing) are not desirable because they increase the likelihood of shaft failure.

49. As discussed above, Polinski teaches that its invention lies in removing structural discontinuities from high stress regions of the shaft, as follows.

[T]he invention contemplates an arrangement wherein abrupt structural discontinuities in the normally high-stressed regions of the main shaft have been essentially eliminated [by instead cutting threads into the sleeve] to minimize the development of fatigue fractures in the shaft while at the same time providing an arrangement which can be easily maintained and repaired in the field. (Ex. 1017, 1:61–67.)

50. The region of the shaft disclosed by Polinski, referred to in Polinski as the bearing journal 11 (the region fit with bearing sleeve 12), is subjected to “substantial stresses generated by the cyclic bending loads applied to the shaft by the mantle during operation of the crusher.” (*Id.* 1:26–29.) Polinski teaches that the relatively abrupt changes in the cross-sectional area of the shaft above and below the threaded section have resulted in high local stress concentrations in these regions of the shaft. Adding an oil groove to the bearing journal would have a similar effect to the threads described by Polinski. This would have been evident to a person of ordinary skill in the art based on well-known engineering machine design concepts.

51. For example, Shigley’s *Mechanical Engineering Design* (“Shigley”) provides that “[a]ny discontinuity in a machine part alters the stress distribution in the neighborhood of the discontinuity so that the elementary stress equations no longer describe the state of stress in the part at these locations. Such discontinuities are called *stress raisers*, and the regions in which they occur are called areas of *stress concentration*.” (Ex. 2003, 110 (emphasis in original).) Shigley further provides that irregularities not inherent in a member, such as grooves, result in stress concentrations. (*See id.*) Specifically, Shigley provides that “[s]tress concentrations can also arise from some irregularity not inherent in the member, such as tool marks, holes, notches, grooves, or threads.” (*Id.*)

52. Shigley instructs that while ductile materials under static loading are not typically at high risk of fracture due to stress raisers and corresponding stress concentrations, ductile materials are at risk of brittle fracture under *cyclic loading*. (*See id.*, 112.) Shigley specifically provides that “[f]or *dynamic loading*, the stress concentration effect is significant for *both* ductile and brittle materials and must always be taken into account.” (*Id.* (emphasis in original).) As noted above, the Polinski shaft is subjected to cyclic (i.e., dynamic) loading. Thus, the Polinski shaft is at risk of brittle failure (e.g., fracture) resulting from stress concentration induced by stress raisers, such as oil grooves. Cutting oil grooves into the Polinski shaft in the bearing journal 11 would introduce stress raisers and corresponding stress concentrations into the shaft, thus increasing the chance of fracture, precisely what Polinski aims to prevent by removing threads from the shaft.

53. Piepho also teaches that such geometrical discontinuities are undesirable and lead to shaft failure. Piepho is particularly concerned with fretting wear and corresponding bending fatigue. Fretting wear is caused by relative motion between bodies in contact, such as the tapered end of the shaft and the yoke bushing disclosed by Piepho. (*E.g.*, Ex. 1018, 1:51–55.)

54. A person of ordinary skill in the art would understand that adding an oil groove to the shaft end fit with the yoke bushing disclosed by Piepho (or with the bearing sleeve of Polinski) would increase relative motion adjacent to the oil

groove between the shaft end and corresponding sleeve or yoke bushing, thus inducing fretting wear. Once again, this would have been evident to a person of ordinary skill in the art based on well-known engineering design concepts. For example, as indicated by Andrew W. Batchelor & Gwidon W. Stachowiak's *Engineering Tribology*, the interference fit between the shaft end and yoke bushing in Piepho (Ex. 1018, 1:51–55) means that the contact between the shaft end and yoke bushing is defined by high pressure no-slip regions and low-pressure slip regions. (Ex. 2004, 593–595.)

55. More specifically, *Engineering Tribology* discusses fretting wear and fretting induced fatigue failure and describes how contact edges between two surfaces in hertzian contact (e.g., two surfaces fit together via an interference fit) are particularly vulnerable to fretting wear:

Contacts which seem to be devoid of relative movement such as **interference fits** do in fact allow sliding on the scale of 1 [µm] when alternating and oscillating loads are carried. It is very difficult to eliminate such movements and the resultant fretting. Fretting wear and fretting fatigue are present in almost all machinery and are the cause of total failure of some otherwise robust components. (*Id.*, 593.)

56. *Engineering Tribology* teaches that when two solids are pressed together (e.g., in the case of an interference fit), “the contact is characterized by a central no slip region surrounded by an annular slip region. Slip, which reciprocates along with the tangential force, *is the source of fretting damage and the edges of the contact are most vulnerable.*” (*Id.*, 595.)

57. Considering this concept, a person of ordinary skill in the art would not combine Harless with Polinski and Piepho as proposed by Petitioner and Mr. Smith. The addition of grooves as taught by Harless to the surface of the shaft that is fit to the yoke bushing would add corresponding edges of contact (e.g., the edges of contact next to the groove), resulting in additional slip regions to the interface between the shaft and yoke bushing. These additional slip regions would be additional sources of fretting—exactly what Piepho seeks to avoid.

58. Furthermore, such fretting would ultimately lead to fatigue failure. The roughness and pitting caused by fretting make the surface more vulnerable to fatigue failure. As discussed in *Fundamentals of Machine Component Design* by Robert C. Juvinall & Kurt M. Marshek, “[r]educing fatigue strength is a major consequence of fretting.” (Ex. 2005, 373 (emphasis in original).) Indeed, fatigue failure is also more likely at the edges of contact regions between two surfaces. As discussed in *Metals Engineering Design* by Oscar J. Horger, “Fatigue failure, under conditions where fretting is present occurs in all instances either at the edge of the contact area between the two contacting members or close to it but within the contact surface.” (Ex. 2006, 231.) Thus, adding grooves to the portion of the shaft fit to the yoke bushing of Piepho would amount to adding edges of contact, and corresponding slip regions, that are particularly susceptible to fretting. Such edges are also likely susceptible to fatigue failure brought on by fretting wear. The

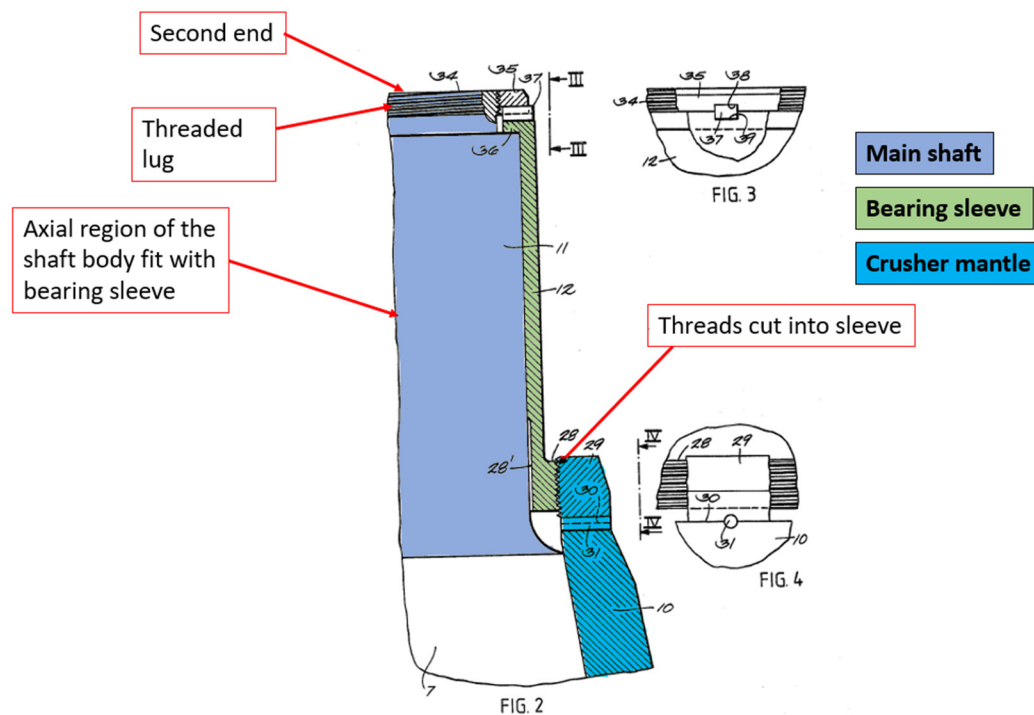
fatigue failure brought on by fretting is yet another failure mode that the purported invention of Piepho aims to prevent.

59. Accordingly, in view of the above, a person of ordinary skill in the art would not be motivated to combine the teachings of Harless with the combined teachings of Polinski and Piepho, as asserted by Petitioner. Polinski and Piepho teach that geometrical discontinuities, including grooves, in the region of the shaft fit with a sleeve (or yoke bushing) are undesirable and lead to fretting wear and fatigue failure. Polinski and Piepho are each directed to techniques for mitigating shaft failure. Introducing a groove to the shaft as disclosed by Harless would detract from the inventive shaft failure mitigation techniques of Polinski and Piepho, and the combination thereof.

B. Polinski and Piepho do not disclose “an axial region of the shaft body extending from the second end and being tapered relative to a longitudinal axis of the shaft body such that a cross sectional area of the shaft body at the tapered axial region decreases in a direction from the first end to the second end,” as claimed.

60. Petitioner argues that Polinski in view of Piepho discloses “an axial region of the shaft body extending from the second end and being tapered relative to a longitudinal axis of the shaft body such that a cross sectional area of the shaft body at the tapered axial region decreases in a direction from the first end to the second end,” as recited in claims 1, 9, and 14. (Paper 2, 15.)

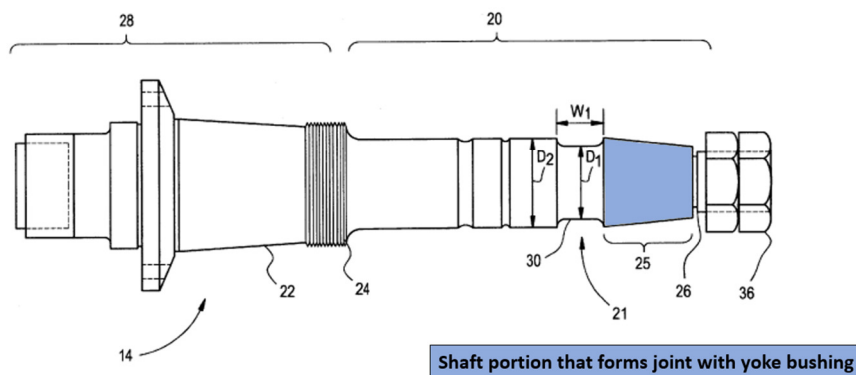
61. Neither Polinski nor Piepho, taken both alone and in combination, disclose the above limitation. First, Polinski does not disclose or suggest an axial region of the shaft body *extending from the second end* and being tapered relative to a longitudinal axis of the shaft body. As shown in annotated Figure 2 of Polinski below, the second (upper) end of the shaft of Polinski is defined by the top end of a threaded lug 34. The threaded lug extends from the second end to a bearing journal 11. As discussed above, the threaded lug is adapted to receive a sleeve nut 35 of a cylindrical bearing sleeve 12. (Ex. 1017, 3:15–48.) The threaded lug 34 thus operates to secure the sleeve 12 on the bearing journal 11. Nothing “extending from the second end” of the shaft disclosed by Polinski is an “axial region . . . being tapered relative to a longitudinal axis of the shaft body.”



(Ex. 1017, FIG. 2 (annotated).)

62. Second, Piepho also fails to disclose or suggest an axial region of the shaft body *extending from the second end* and being tapered relative to a longitudinal axis of the shaft body. As depicted in annotated Figure 3 of Piepho, below, Piepho includes an axial region being tapered relative to a longitudinal axis of the shaft body (region labeled 25). However, Piepho does not disclose or suggest an axial region of the shaft body *extending from the second end* and being tapered relative to a longitudinal axis of the shaft body. A cylindrical portion labeled 26 extends from the second (top) end of the shaft to the tapered portion 25.

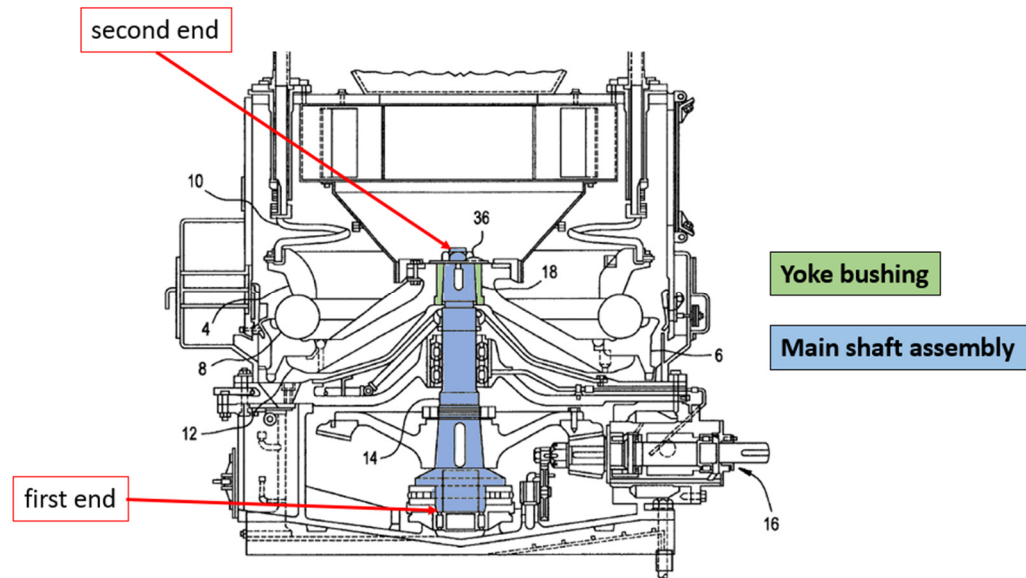
FIG.3



(Ex. 1018, FIG. 3 (annotated).)

63. Figure 1 of Piepho, below, shows that the cylindrical region 26 extends above the yoke and is connected to an element labeled 36. A person of skill in the art would understand that element 36 is a fastener secured to the

cylindrical portion 26 of the shaft to secure the yoke to the shaft of the coal pulverizer.



(*Id.*, FIG. 1 (annotated and cropped).)

64. Thus, neither Polinski nor Piepho, taken both alone and in combination, disclose “an axial region of the shaft body extending from the second end and being tapered relative to a longitudinal axis of the shaft body such that a cross sectional area of the shaft body at the tapered axial region decreases in a direction from the first end to the second end.”

* * *

I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and that

IPR2024-01381

these statements were made with knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code.

Dated: December 23, 2024

A handwritten signature in black ink, appearing to read "H Kytömaa". The signature is written in a cursive, somewhat stylized script.

Harri Kytömaa, Ph.D., P.E., CFEI