

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

WIRTGEN AMERICA, INC.,
Petitioner

v.

CATERPILLAR INC.,
Patent Owner

Case No. IPR2022-01397
Patent No. 9,975,538

DECLARATION OF ABID KEMAL, PH.D.

CATERPILLAR-EXHIBIT 2001
Wirtgen America, Inc. v. Caterpillar, Inc.
IPR2022-01397

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I, Abid Kemal, declare as follows:

I. QUALIFICATIONS

1. I am a Practice Director and Principal at Exponent, Inc., an engineering and scientific consulting firm. I have also held an appointment as an Adjunct Professor, and currently hold an appointment as Lecturer, in the School of Engineering at Stanford University where I teach a graduate level class in the department of Aeronautics and Astronautics.

2. I received a Ph.D. in mechanical engineering from Stanford University in 1998. I also received a M.S. degree in mechanical engineering from Stanford University in 1994 and a B.S. degree in mechanical engineering from the University of Engineering and Technology in Peshawar, Pakistan, in 1989.

3. Prior to joining Stanford University as a graduate student, I worked as a production engineer at a joint venture between Pakistan Telecommunication Corporation and Siemens, and as a management trainee at the Imperial Chemical Industry's soda ash plant in Pakistan.

4. I have provided complex and multidisciplinary technical consulting services for hundreds of clients including Fortune 500 companies, major automotive and construction equipment manufacturers, and federal and state government agencies. These have included leading multidisciplinary teams to investigate high profile accidents involving failure of thermal and mechanical

hardware, including powertrains, as well as assisting clients develop products with improved performance and safety.

5. I have extensive experience and knowledge on the design and development of machine powertrains and control systems for controlling their operation. As part of my mechanical engineering education and training, I have studied automotive engineering and gained advanced knowledge of machine powertrains, including internal combustion engines, transmissions, differentials, clutches, brakes, and other components. I also have advanced knowledge of fuel and hydraulic systems, exhaust and emission systems, and engine controllers. My graduate research at Stanford University involved developing novel real-time active and adaptive control strategies for heavy equipment powertrains used in propulsion of marine vessels and aircraft. I have worked on numerous projects where I assessed engine performance as a function of load, including for transportation, construction, and earthmoving machinery. I have developed and/or analyzed dynamic control systems for, amongst others, combustion systems, power generation hardware, powertrains, and hydraulic systems.

6. I have assessed hydraulic system failures as well as issues related to fuel and exhaust systems for automotive and marine sectors. I have repaired and replaced automotive clutches and brakes. More recently, I have assisted clients in developing safer electric powertrains for vehicles.

7. For a more detailed listing of my credentials, please see my curriculum vitae, EX2002.

II. SCOPE OF WORK

8. I have been retained by counsel for Caterpillar Inc. as an expert witness in the above-captioned proceeding. I understand that Wirtgen America, Inc. (“Petitioner”), filed a petition with the United States Patent and Trademark Office for *inter partes* review of U.S. Patent No. 9,975,538 (EX1001, “the ’538 patent”), the subject of this proceeding.

9. I further understand that the Patent Trial and Appeal Board (the “Board”) has decided to institute *inter partes* review of claims 1-13 of the ’538 patent under 35 U.S.C. § 103 based on U.S. Patent Application Publication No. 2010/0014917 (EX1005, “Willis”), U.S. Patent No. 9,656,656 (EX1006, “Xing”), and U.S. Patent No. 9,864,347 (EX1012, “Laux”). I understand the petition challenges the claims of the ’538 patent based on the following grounds:

Ground	Claims	Basis
1	1-13	Obvious over Willis in view of Xing
2	8, 13	Obvious over Willis in view of Xing and Laux

10. I have been specifically asked to provide my expert opinions on the patentability of the claims of the ’538 patent in view of the grounds asserted in the

petition. In connection with this analysis, I have reviewed the '538 patent, including the claims of the '538 patent in view of the specification. I have also reviewed the petition for *inter partes* review, the documents cited in the petition, including Dr. Jeffrey Stein's declaration (EX1003), the Board's institution decision, as well as the materials cited in this declaration, which are listed in the Appendix.

11. My employer Exponent, Inc., is being compensated at a rate of \$750 per hour for my general services in this matter. Exponent is also being reimbursed for reasonable and customary expenses associated with my work in this investigation. Exponent's charges, and my compensation, are not contingent upon the outcome of this matter or the specifics of my testimony.

III. LEGAL STANDARDS

12. I have been advised that the burden is on Petitioner to demonstrate the unpatentability of the challenged claims based on a preponderance of the evidence.

13. I have been advised that anticipation is about prior invention and therefore a single prior art reference must be found to disclose all elements of the claimed invention arranged as in the claim. I have been further advised that it is not enough that the prior art references include multiple, distinct teachings that may somehow be combined to achieve the claimed invention. Rather, it is my understanding that the reference must clearly and unequivocally disclose the

claimed invention or direct a person of ordinary skill in the art to the claimed invention without any need for picking, choosing, and combining various disclosures that are not directly related to each other in the reference.

14. I understand that differences between the prior art reference and a claimed invention, however slight, invoke the question of obviousness, not anticipation.

15. I have been advised that a claimed invention is not patentable under 35 U.S.C. §103 if it is obvious. A patent claim is unpatentable if the claimed invention would have been obvious to a person of ordinary skill in the art at the time the claimed invention was made. This means that even if all of the requirements of the claim cannot be found in a single prior art reference that would anticipate the claim, a person of ordinary skill who knew about all this prior art would have come up with the claimed invention.

16. I have further been advised that the ultimate conclusion of whether a claim is obvious should be based upon several factual determinations. That is, a determination of obviousness requires inquiries into: (1) the level of ordinary skill in the field; (2) the scope and content of the prior art; (3) what difference, if any, existed between the claimed invention and the prior art; and (4) any objective indicia of nonobviousness.

17. I have been advised that, in determining the level of ordinary skill in the field that someone would have had at the time the claimed invention was made, I should consider: (1) the levels of education and experience of persons working in the field; (2) the types of problems encountered in the field; and (3) the sophistication of the technology.

18. I have been advised that a patent claim composed of several elements is not proved obvious merely by demonstrating that each of its elements was independently known in the prior art. In evaluating whether such a claim would have been obvious, I may consider whether there is a reason that would have prompted a person of ordinary skill to combine the elements or concepts from the prior art in the same way as in the claimed invention.

19. I have also been advised, however, that I must be careful not to determine obviousness using the benefit of hindsight; many true inventions might seem obvious after the fact. I should put myself in the position of a person of ordinary skill at the time the claimed invention was made and I should not consider what is known today or what is learned from the teaching of the patent.

20. I have been advised that any obviousness rationale for modifying or combining prior art must include a showing that a person of ordinary skill would have had a reasonable expectation of success.

IV. OVERVIEW OF THE '538 PATENT

21. The '538 patent is entitled “Milling Machine Fuel Efficiency Control System.” EX1001, (54). The patent is generally directed to road milling machines and “to methods and systems for controlling the rotor speeds of cold planers and rotary mixers with optimized performance and fuel efficiency.” EX1001, 1:6-9.

22. The '538 patent acknowledges that, “[t]ypically, it may be desirable to maintain substantially constant rotor speed at the speed specified by the operator for at least the duration of a given milling task and/or until the operator chooses otherwise,” but that “changes in engine speed and engine load throughout the operation can cause unwanted variations in the rotor speed.” *Id.*, 1:28-34. The '538 patent also explains that some milling machines “provide variable transmissions which allow for variations in the engine speed without affecting rotor speed,” but “these conventional systems do not further address fuel efficiency, which is another concern that can be adversely affected by variations in engine speed and engine load.” *Id.*, 1:34-40.

23. The '538 patent thus describes and claims specific control methods and systems for controlling a rotor coupled to an engine through a variable transmission in a fuel-efficient manner. *See, e.g., id.*, 1:41-44, 1:52-2:18, 4:48-63. In particular, as I describe more below, the claimed control methods and systems take into account a load on the engine during operation and use that engine load,

along with predetermined efficiency points, to determine optimum engine speeds at which the engine may operate at the engine load to achieve enhanced fuel efficiency.

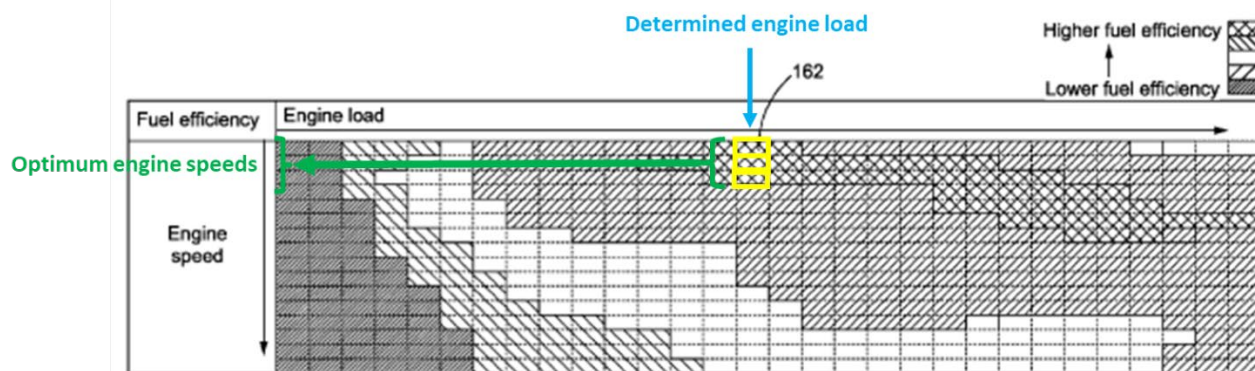
24. For instance, the '538 patent describes an example embodiment of a milling machine 100, which includes a rotor 118 for cutting and/or removing materials from the surface of roadways. *See id.*, 2:38-46, 2:57-60, FIG. 1. The milling machine 100 also includes an engine 122 as a power source that “drive[s] the rotor 118 via a hydrostatic, mechanical, or hydromechanical drive arrangement, such as a continuously variable transmission (CVT) 124, or the like.” *Id.*, 2:63-3:4.

25. The milling machine 100 further includes a control system 128 for controlling the rotor 118 to achieve a desired rotor speed. *Id.*, 3:8-12. At the same time, the control system 128 is also configured to adjust the gear ratio between the engine output 136 and the CVT output 138 to maintain the desired rotor speed irrespective of changes in the engine speed, including changes that are made to achieve a more fuel-efficient state based on the current load on the engine. *See id.*, 3:51-62, 4:4-8, 4:31-37, FIG. 2.

26. During operation, the '538 patent teaches that the control system 128, via a controller 130, is configured to receive a desired speed at which to operate the rotor 118. *Id.*, 4:64-5:3. The controller 130 “monitor[s] or determine[s] the

current engine speed and current engine load of the milling machine 100, such as via a sensor 134 located at the engine output 136.” *Id.*, 5:3-7. The term “engine load” is used in the ’538 patent in a conventional manner and represents the total load on the engine, including, as the ’538 patent explains, “loads due to the rotor 118, the hydrostatic arrangement 144, and other parasitic loads.” *Id.*, 4:9-14.

27. Once the control system 128 determines the current engine load on the engine, the controller 130 then “retrieve[s], recall[s] and/or refer[s] to predefined fuel efficiency points 162, or any other predetermined information pertaining to the fuel consumption characteristics of the milling machine 100 stored in memory 132, to determine an optimum engine speed *for the given engine load.*” *Id.*, 5:7-12 (emphasis added). This reference step to identify an optimum engine speed for the determined engine load as recited in the claims of the ’538 patent is best illustrated in the table shown in FIG. 4, which I have reproduced and annotated below.



28. As shown above, to identify an optimum speed at which to operate the engine in a fuel-efficient manner, the controller 130 references the table at the determined engine load (the blue downward arrow along the “Engine load” axis) and identifies predefined efficiency points 162 at that determined engine load (yellow annotations). The predefined efficiency points 162, in turn, provide optimum engine speeds (green leftward arrow) at which the engine can operate at the determined engine load for higher fuel efficiency. As such, in this way, by “using the efficiency points 162 as reference, the controller 130 may be able to control the engine 122 to output *an engine speed that is not only appropriate for the determined engine load, but also [is] fuel efficient.*” *Id.*, 4:23-27 (emphasis added); *see also id.*, 5:7-12 (after determining the current engine load, the controller “retrieve[s], recall[s] and/or refer[s] to predefined fuel efficiency points 162 . . . to determine an optimum engine speed for the given engine load”).

29. Thus, unlike Xing (which I detail more below), the fuel-efficiency method of the claimed invention provides a simple and robust control process that relies on the determination of the total load on the engine, which serves as a basis and reference point for determining the appropriate engine speed at which the engine should operate at the given load for optimum fuel efficiency.

30. The ’538 patent further teaches that, “[o]nce the optimum engine speed, or the engine speed expected to provide the optimum fuel efficiency, has

been determined for the given engine load,” the controller 130 then compares the actual engine speed to the optimum engine load. EX1001, 5:12-17. “If the actual engine speed is not at the optimum engine speed as derived from the predefined fuel efficiency points 162,” the controller 130 then increases or decreases the engine speed until the optimum engine speed is substantially achieved. *Id.*, 5:18-22. Next, the controller determines the actual speed of the rotor 118 and compares it to the desired rotor speed “to determine if any adjustments need to be made in the gear ratio of the CVT 124.” *Id.*, 5:22-35. “If the actual rotor speed is not in substantial agreement with the desired rotor speed,” the controller 130 “adjust[s] the gear ratio of the CVT 124 accordingly.” *Id.*, 5:36-39.

31. The challenged claims of the ’538 patent include two independent claims, claims 1 and 6. Claims 2-5 and 7-13 depend from either claims 1 or 6.

Claim 1 recites:

“A controller-implemented method of controlling a machine having a rotor coupled to an engine through a variable transmission, comprising:

receiving a desired rotor speed;

determining an engine load of the engine;

adjusting an engine speed of the engine based on the engine load and one or more predefined efficiency points at least partially based on predetermined fuel consumption rates and providing optimum engine speeds for different engine loads; and

adjusting a gear ratio of the variable transmission based on the engine speed and the desired rotor speed.”

32. Claim 6 recites:

“A machine, comprising:
an engine;
a variable transmission operatively coupled to an output of the engine;
a rotor operatively coupled to an output of the variable transmission; and
a controller in electrical communication with one or more of the engine, variable transmission, and the rotor, the controller being configured to determine an engine load, adjust an engine speed based on the engine load and one or more predefined efficiency points being based at least partially on predetermined fuel consumption rates and providing optimum engine speeds for different engine loads, and adjust a gear ratio of the variable transmission based on the engine speed to maintain a desired rotor speed.”

33. I understand that the application that led to the '538 patent was filed on May 18, 2015. EX1001, (22). For the purposes of my opinions, I have applied May 18, 2015, as the relevant timeframe for my analysis.

V. LEVEL OF ORDINARY SKILL

34. I understand that Dr. Stein contends that a person of ordinary skill in the art, as of May 18, 2015, “would have had a bachelor’s degree in mechanical engineering or an equivalent degree and two to five years of experience working on designing or developing machine powertrains in which a controller controls a powertrain’s internal combustion engine and coupled transmission. Additional education may substitute for lesser work experience and vice versa.” EX1003 (Stein Declaration), ¶24; *see also id.*, ¶23 (stating a skilled artisan “would have had general knowledge of machine powertrains, including internal combustion engines,

transmissions, differentials, controllers and other powertrain components”). For the purposes of my declaration, I have applied this understanding of the person of ordinary skill in the art.

35. My education, experience, and training qualify me to opine as a skilled artisan regarding the understanding of a person of ordinary skill in the art at the relevant time, as I was by 2015 a person of ordinary skill in the art.

VI. CLAIM CONSTRUCTION

36. I have been advised that the claim terms of the ’538 patent are to be given their plain and ordinary meaning, *i.e.*, the meaning that the terms would have had to the skilled artisan at the time of the invention. I understand that the relevant timeframe is May 18, 2015.

37. I understand that this analysis focuses on intrinsic evidence, including how the claim term is used in the claims, specification, and prosecution history. I also understand that dictionaries or other extrinsic sources may assist in determining the plain and ordinary meaning but cannot override a meaning that is unambiguous from the intrinsic evidence. I have followed these principles in my analysis throughout this declaration.

VII. GROUND 1: CLAIMS 1-13 WERE NOT OBVIOUS OVER WILLIS AND XING

38. Dr. Stein’s contentions that claims 1-13 were obvious over Willis and Xing are based on modifying the milling machine disclosed in Willis to

incorporate the continuously variable transmission and fuel-efficiency control method of Xing for driving Willis's milling drum at a desired speed. *See* EX1003 (Stein Declaration), ¶¶65-66. As I explain in more detail below, it is my opinion that Willis and Xing fail to disclose each and every limitation of claims 1-13.

A. Independent Claims 1 and 6

39. Independent claims 1 and 6 of the '538 patent claim a controller-implemented method for operating a machine that drives a rotor in a fuel-efficient manner. *See supra*, section IV. The method requires an initial determination of "an engine load" for the engine of the machine. An "engine speed" is then adjusted based on (1) the determined engine load and (2) one or more predefined efficiency points, which are, in turn, based on predetermined fuel consumption rates and provide optimum engine speeds for different engine loads.

40. Dr. Stein relies primarily on Xing as disclosing the fuel-efficient method claimed by the '538 patent. *See* EX1003 (Stein Declaration), ¶¶67-87. However, as I explain in more detail below, Xing's method relies on a starting point—the determination of a "load power requirement"—that is distinct from the engine load recited in the claims of the '538 patent. Xing uses the "load power requirement" as the starting point in its fuel-efficiency method as opposed to the engine load. In Xing's method, once the "load power requirement" is estimated or forecasted, multiple candidate engine speeds are identified, and the power loss is

estimated at each candidate engine speed. Xing's method then calculates candidate engine powers by adding the "load power requirement" and the power loss determined at each candidate engine speed. The method then calculates candidate torques on the engine using the candidate engine powers and engine speeds at each candidate engine speed. Finally, Xing's method comes up with a number of pairs of candidate engine torque and candidate engine speed, and selects a pair with the lowest fuel consumption value. Thus, not only does Xing seek to identify a target operating speed for its engine, but also a target engine *load* to determine which pair is most fuel efficient. Therefore, in view of these distinctions, it is my opinion that Xing's method fails to "adjust an engine speed based on the engine load" and fails to "adjust an engine speed" based on "predefined efficiency points" that "provid[e] optimum engine speeds for different engine loads."

1. Xing fails to adjust the engine speed "based on the engine load"

41. Each of claims 1 and 6 require a controller to "determine an engine load" and "adjust an engine speed based on the engine load." In his declaration, Dr. Stein contends that Xing discloses this limitation by arguing that Xing "calculates a load power requirement (P_{load})—the amount of power demanded from the machine or the amount of power required for the vehicle to accomplish useful work—by measuring the current engine power or load (P_{engine}), and estimating current power loss (P_{loss})," based on the equation: " $P_{engine} = P_{load} + P_{loss}$." EX1003

(Stein Declaration), ¶78. During his deposition, I understand that Dr. Stein conceded that Xing's load power requirement (P_{load}) is "**not** the engine load" because it only represents the power required for the vehicle to do useful work. EX2003 (Stein Deposition), 52:3-11 (emphasis added); *see also* EX1006 (Xing), 9:18-21 (stating the load power requirement "generally corresponds to the amount of power required for the vehicle 10 to finish useful work"), FIG. 4 (step 202). Dr. Stein further conceded that "[t]he engine load is higher than" the load power requirement and instead represents the **total** load on the engine, including loads caused by machine inefficiencies or losses. *See* EX2003, 24:18-25:14, 29:24-30:20, 52:3-11.

42. I agree that the plain and ordinary meaning for the term "engine load" is the total amount of torque required from the engine to operate the machine at a given time, which is proportional to the mean effective pressure. This understanding is consistent with the '538 patent, which explains that the engine load not only encompasses loads for operating the work component of the machine (*e.g.*, the rotor), but also loads caused by other elements of the machine, such as the hydrostatic arrangement and other parasitic loads. EX1001 ('538 patent), 4:9-14. Thus, the claimed "engine load" that is determined by the system represents the **total** load on the engine, which encompasses both the load required to do useful work and loads caused by system inefficiencies or losses.

43. While the load on an engine is typically expressed in terms of the amount of torque produced at the output of the engine, I understand that Dr. Stein contends that the engine load can also be expressed in terms of power (*i.e.*, engine torque times engine speed) produced at the output of the engine. *See* EX2003, 26:18-27:7. With this understanding, Dr. Stein's declaration therefore relies on the measurement of "the current load on the engine" in Xing through the use of "sensors communicatively coupled to [the] controller, such as torque sensors coupled to the engine for monitoring the engine torque loads." EX1003 (Stein Declaration), ¶78. Dr. Stein also argues that a person of ordinary skill "would have understood that engine load measured in terms of torque can be converted to engine load in terms of power by multiplying measured torque by engine speed," which is then used to calculate Xing's load power requirement (P_{load}). *Id.*; *see also id.* ("measuring the current engine power or load (P_{engine})").

44. Thus, in view of the above, Dr. Stein therefore relies on Xing's disclosure where the load power requirement (P_{load}) is calculated indirectly (rather than measured directly). This is performed through the measurement of a current engine speed and a current engine torque at the engine's output to calculate "the current engine power or load (P_{engine})," which is the product of the measured engine speed and the measured engine torque. *See* EX1006 (Xing), 9:37-44; EX1003 (Stein Declaration), ¶78. The load power requirement (P_{load}) is then calculated by

first estimating the current power loss (P_{loss}) and then subtracting the estimated current power loss (P_{loss}) from the current engine power (P_{engine}). *Id.* Thus, according to Dr. Stein, to the extent Xing describes determining an engine load (whether in terms of torque or power), it is done for the purpose of calculating the load power requirement.

45. However, while Xing may describe that one means for determining the load power requirement (P_{load}) is indirectly through measurement of a current engine torque or engine power, Xing nevertheless uses the load power requirement—not the measured engine torque or engine power (or any “engine load,” according to Dr. Stein)—as a basis for defining the set of engine operating parameters from which to choose for fuel-efficiency purposes. As I explain more below, Xing’s fuel-efficiency method centers on determining a target engine speed to achieve the load power requirement, not an engine load. This is evidenced by the fact that Xing also discloses measuring the load power requirement directly, without needing to measure any current engine load. *See* EX1006 (Xing), 9:57-64. Furthermore, under Xing’s method, the engine load (*i.e.*, the total torque or power at the engine’s output) is allowed to vary for each of the candidate speed/torque combinations analyzed for fuel efficiency in Xing. As a result, Xing’s speed adjustment is not based on a determined engine load.

46. As I explained above, the method described and claimed by the '538 patent starts with a determination of the engine load as a reference point from which predefined efficiency points are retrieved for that given load, which then provide optimum engine speeds at which to operate the engine at the determined engine load to achieve better fuel efficiency. *See* EX1001 ('538 patent), 5:7-12; *supra*, section IV. This is illustrated in FIG. 5 of the '538 patent, where the process starts with the determination of the engine load based on the desired rotor speed (steps 164-1 and 164-2), then refers to fuel efficiency points (step 164-3) that provide optimum engine speeds, and then adjusts the engine speed to the optimum speed for the engine load (steps 164-4 and 164-5).

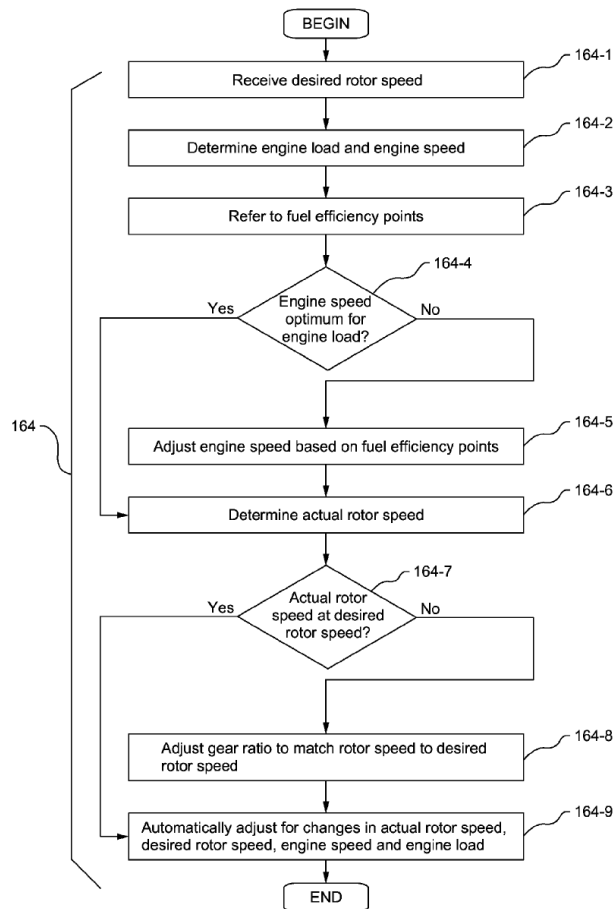


FIG.5

47. In contrast, Xing describes a different process for selecting target engine parameters, such as a target engine speed, for operating its engine. As illustrated in Xing's FIG. 4, Xing begins with an determination of the load power requirement (step 202) to identify a set of candidate (or possible) engine speeds for achieving the load power requirement (step 204), determining power loss for each candidate engine speed (step 206), and then calculating a set of corresponding candidate (or possible) engine powers and torques (step 208), which are then compared to efficiency values to find the candidate engine speed-torque pair

associated with the fuel consumption value (step 210). Thus, unlike the method claimed by the '538 patent, Xing's process moves from a determined load power requirement to identification of candidate engine speeds, to estimation of power loss at each candidate engine speed, to the calculation of candidate engine powers and/or torques, and then comparison of fuel consumption values to select an engine speed amongst the candidate speeds that is most fuel efficient. This shows that the Xing method is clearly different than the method described in the '538 patent.

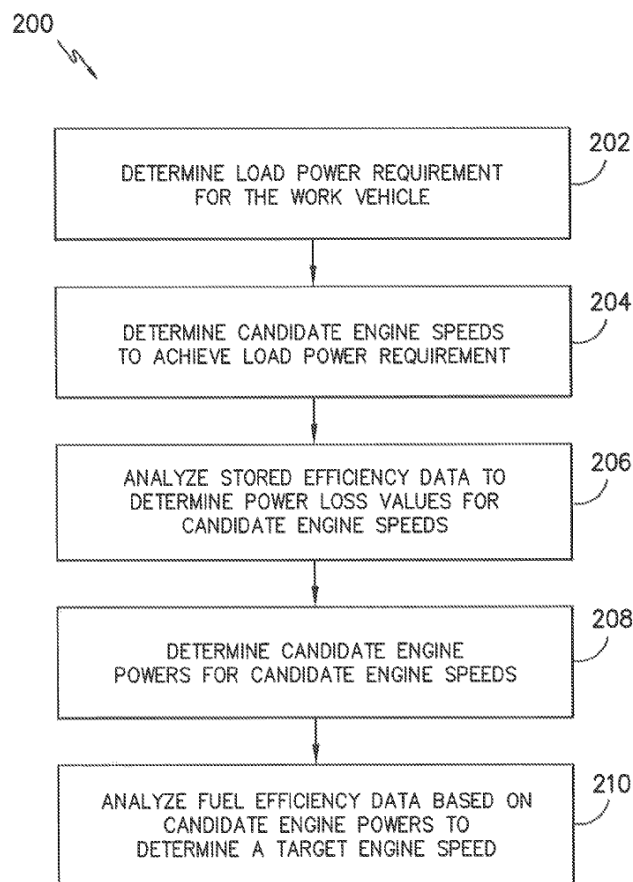


FIG. -4-

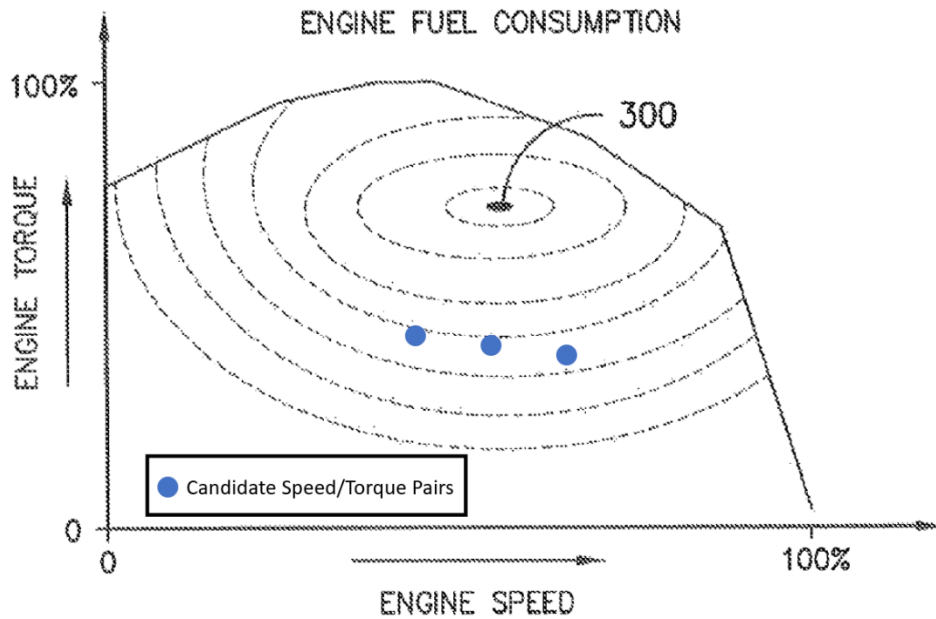
48. More specifically, as Xing discloses, after determining the load power requirement, “a plurality of candidate engine speeds may be determined based on the load power requirement.” EX1006 (Xing), 10:16-18, FIG. 4 (step 204). These speeds are potential engine speeds that “may be utilized to achieve the vehicle’s load requirement.” *Id.*, 10:18-22. For each candidate engine speed, “a power loss value (P_{loss})” is determined based on “suitable efficiency data for one or more of the components of the work vehicle 10.” *Id.*, 10:43-46; *see also id.*, 10:46-67 (identifying power loss due to components such as the transmission, power take-off (PTO), drive axle, fan, or other), FIGS. 6-10.

49. Then, for each of the candidate engine speeds, candidate engine powers are determined by adding the calculated power loss values (P_{loss}) to the specific load power requirement of interest (*e.g.*, 150 kW as shown in FIG. 5) (EX1006 (Xing), 11:65-12:6):

CANDIDATE ENGINE SPEEDS (RPM)	FORECASTED LOAD POWER REQUIREMENT (Kw)	ASSOCIATED SYSTEM POWER LOSS (Kw)	CANDIDATE ENGINE POWER (Kw)	CANDIDATE ENGINE TORQUE (Nm)	ENGINE BSFC EFFICIENCY (g/Km-h)	FUEL CONSUMPTION (g/h)
1500	150	15	165	1050	212	34980
1600	150	24	174	1038	200	34800
1700	150	33	183	1028	205	37515
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FIG. -5-

50. “[F]or each pair of candidate engine powers and speeds,” a candidate engine torque (*i.e.*, candidate engine loads, expressed in terms of torque) is determined by dividing each candidate engine power with its associated candidate engine speed. EX1006 (Xing), 12:28-33. Each set of engine torques and engine speeds is then “utilized to determine the most fuel efficient engine settings for achieving the desired load power requirement.” *Id.*, 12:33-35. An example of this is shown in Xing’s FIG. 11, which I have reproduced and annotated below. As shown below, the candidate engine torque and candidate engine speed pairs are plotted (annotated in blue) to determine which pair of candidate engine torque and candidate engine speed intersect closest to “an optimal efficiency point 300 at which the fuel efficiency of the engine is maximized (*i.e.* at the minimum bsfc value).” *Id.*, 12:36-47.



51. Therefore, in Xing’s process, the ultimate speed adjustments are based on the load power requirement, which is the only constant, as shown in Xing’s FIG. 5. All other “candidate” variables and associated efficiency values are potential values that will vary depending on which candidate engine speed is chosen. In addition, as Xing discloses, the speed adjustments are not based on any measured load at the engine (whether in terms of measured engine torque or power) because while engine power has a loss component that varies with engine speed, the ultimate value of concern is the load power requirement (*i.e.*, “the amount of power required for the vehicle 10 to finish useful work”). EX1006 (Xing), 9:18-36. As such, the engine speed adjustments of Xing are based on determining the load power requirement rather than the current engine load.

52. That Xing’s load power requirement, and not the current engine load (torque or power), serves as the basis for determining the most fuel-efficient engine operating parameters is made further apparent by Xing’s disclosure of other methods for calculating the load power requirement, which do not involve determining an engine load. For instance, while Dr. Stein relies on Xing’s “indirect[]” calculation of P_{load} (*see* EX1003 (Stein Declaration), ¶78), Xing also teaches that, “[a]lternatively, the power load requirement may be determined directly by monitoring the output torque and the output speed of the work vehicle 10.” EX1006 (Xing), 9:57-64. In other words, any measurement of the load at the engine can be bypassed entirely by directly measuring the variable of interest, P_{load} , at the source—*i.e.*, where the useful work is occurring.

53. Furthermore, Xing also teaches that a “future load power requirement” may be used as a starting point to its method by forecasting the load power requirement based on previously calculated load power requirement. *Id.*, 10:2-15. Thus, these methods for determining the load power requirement demonstrate that determining a current engine load is not necessary in Xing’s fuel-efficiency method because the load power requirement forming the basis for its method can be calculated ***without*** making a determination as to the current engine load.

54. Moreover, as another distinction, Xing's target engine speed (*i.e.*, the adjusted speed of the engine) does not maintain an initially measured engine torque or power, which provides an additional illustration of why Xing's speed adjustment is not based on a determined engine load. Specifically, as demonstrated in Xing's FIG. 5, in addition to engine speed, engine torque (and power) is also treated as a variable parameter that is optimized in Xing's calculations, such that the pair of candidate engine speeds and candidate engine torques that will benefit fuel efficiency is identified. *See* EX1006 (Xing), 12:16-21 (the controller is configured "to consider every possible combination of engine speeds and torques . . . to create a large pool of candidate engine settings for achieving the best fuel efficiency"); EX2003 (Stein Deposition), 87:13-88:9 (acknowledging Xing "look[s] for an engine torque and engine speed that gives you the best fuel consumption").

55. Thus, Xing seeks to vary ***both*** engine speed and engine torque to identify the target candidate engine speed (which itself is paired with a candidate engine torque), which further illustrates that the selection of the target engine speed is made ***independent*** of any existing and measured engine load. As a result, Xing's adjustment of an engine speed is not "based on the [determined] engine load" as recited in the claims of the '538 patent.

2. Xing fails to adjust the engine speed “based on . . . providing optimum engine speeds for different engine loads”

56. In addition, because of Xing’s different approach to efficiency assessment, Xing also does not adjust an engine speed based on predetermined fuel efficiency points that provide optimum engine speeds for different engine loads.

57. As I detailed above, Xing’s efficiency tables (*i.e.*, FIGS. 5 and 11) are used in a very different way than the ’538 patent’s FIG. 4. *See supra*, sections IV, VII.A.1. Specifically, with respect to FIG. 4 of the ’538 patent, the determined engine load serves as a reference point from which predetermined efficiency points are identified that provide optimum engine speeds for the determined engine load, which then becomes the adjusted speed for that determined engine load. In contrast, as I detailed above with respect to Xing, Xing seeks to identify pairs of speed and torque that can achieve a given load power requirement, and then determines which of these pairs is the most efficient.¹

¹ I note that Dr. Stein seemed to misinterpret how FIG. 4 is applied in the ’538 patent: during his deposition he appeared to read the figure in the same manner as Xing’s FIG. 11—*i.e.*, that both engine load and engine speed are varied to find a fuel-efficient speed-load pairing. *See* EX2003 (Stein Deposition), 81:10-82:10,

58. Moreover, by considering the distinctions between the method claimed by the '538 patent and the method described in Xing, a person of ordinary skill in the art would have appreciated that Xing's method does not "adjust an engine speed" based on "predefined efficiency points" that "provid[e] optimum engine speeds for different loads." This is because Xing's method relies on the identification of a number of candidate engine speed-torque pairings that will achieve a given load power requirement. Xing does not indicate that the candidate speeds associated with each of these pairings represent the *optimum* speed of the paired candidate engine torque; instead, Xing seeks to identify the most efficient combination of candidate engine speed-torque by comparing each of the pairings to an associated efficiency value. This means that Xing fails to disclose the "predefined efficiency points" as claimed in the '538 patent, insofar as any efficiency points in Xing do not "provid[e] optimum engine speeds for different engine loads."

83:14-25. However, as I explained above, this reading is incorrect as the determined engine load is a constant in the '538 patent that is used as the reference point for referring to the predetermined efficiency points that provide optimum engine speeds for that determined load.

59. First, to the extent Xing's FIG. 11 (or any similar fuel efficiency table) includes efficiency points identifying the optimum engine speed for a given torque value, those points are not used for Xing's speed adjustments. Specifically, as I detailed above, Xing's process first identifies multiple candidate engine speeds for a given load power requirement and then calculates a candidate engine torque for each candidate engine speed. EX1006 (Xing), 10:16-18, 12:16-33. To the extent that, for any particular candidate engine torque, an "efficiency point" designating an "optimum engine speed" could be identified (*e.g.*, the speed at which that torque can be most efficiently achieved), that speed is not necessarily the candidate engine speed that is paired with the given candidate engine torque. Instead, the candidate engine speed *determines* the candidate engine torque by establishing the power loss associated with that candidate engine speed, by which the candidate engine torque is calculated. *Id.* As such, Xing does not "adjust an engine speed" based on such an optimal point because Xing instead adjusts the engine speed by selecting one of the engine speed-torque pairings based on its efficiency value relative to other pairs. *See id.*, 12:33-47.

60. Xing illustrates this point in stating that its method "tak[es] into consideration component efficiencies *other than the engine's efficiency*," and as a result, "the most fuel efficient settings for the engine 22 may not result in the lowest fuel consumption for the vehicle 10 given the current load power

requirement and/or other operating parameters.” *Id.*, 13:36-50 (emphasis added).

In other words, Xing’s method does not aim to provide an “optimum engine speed for different engine loads,” and thus it does not adjust an engine speed on this basis.

61. Second, for similar reasons, to the extent each of Xing’s candidate engine speed-torque pairings could be said to correspond to a “predetermined efficiency point” (*e.g.*, on Xing’s FIG. 11) that serves as a basis of an efficiency assessment and subsequent speed adjustment, those points do not constitute *optimum* engine speeds for different engine loads. This is due to Xing’s process, which first identifies candidate engine speeds *before* candidate engine torques are calculated. Thus, each candidate speed-torque pairing cannot be said to provide *optimum* engine speeds for the candidate engine torques because the candidate engine speeds are already determined before any candidate torque is identified.

B. Dependent Claims 2-5 and 7-13

62. I understand claims 2-5 and 7-13 depend from either claim 1 or claim 6. In my opinion, these claims are not obvious over Willis and Xing for the same reasons I identified above with respect to claims 1 and 6. Below, I provide further reasons why dependent claim 13 was not obvious over Willis and Xing.

1. Claim 13

63. Claim 13 depends from claim 6 and recites that the machine further comprises “a clutch disposed between the engine and the rotor, the controller being configured to selectively disengage the rotor from the engine through control of the clutch.”

64. I understand that Dr. Stein alleges that the combination of Willis and Xing taught the limitations of claim 13 based on three different components disclosed in Xing: (1) forward and reverse directional clutches 52, 54; (2) parking brake 70; and (3) PTO clutch 114 of Xing’s power take-off (PTO) component. *See* EX1003 (Stein Declaration), ¶¶150-53. Dr. Stein alleges that each of these components constitutes a “clutch” that is controlled by the controller “to selectively disengage” a load (*i.e.*, Willis’s milling drum) “from the engine.” *Id.* As I explain below, however, these components are not a “clutch” that is controlled to “selectively disengage the rotor from the engine.”

a) Xing’s directional clutches 52, 54 do not “disengage the rotor from the engine”

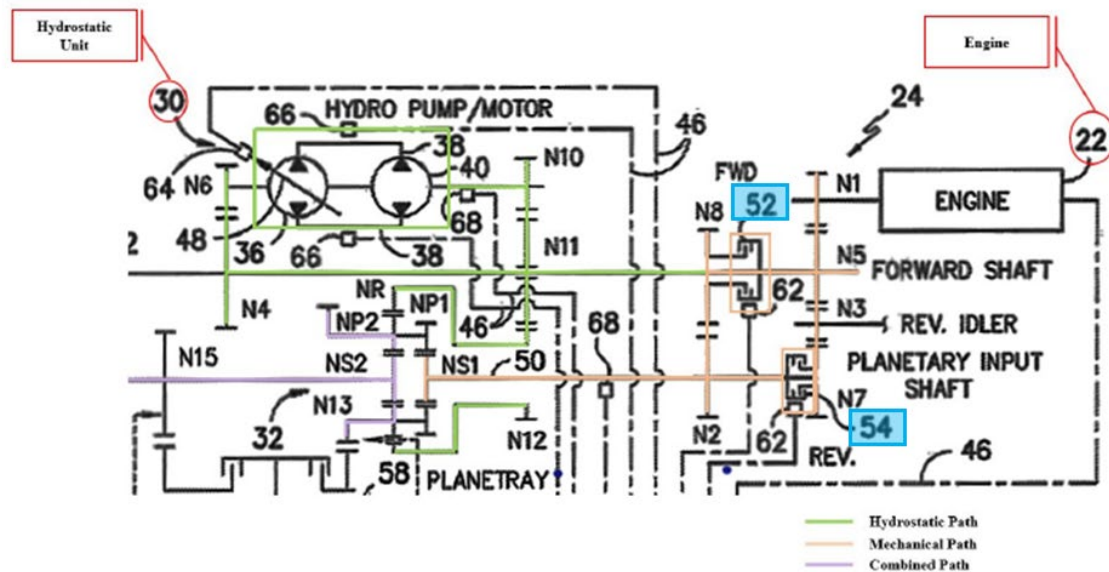
65. First, Dr. Stein contends that “Xing’s control algorithm used the controller to actuate directional clutches to disengage a load from the engine when the transmission output shaft 56 was connected to the load.” *Id.*, ¶150. In particular, Dr. Stein argues that “Xing taught that forward directional clutch 52 and reverse directional clutch 54 selectively couple the engine to its planetary gear”

and “[c]ontroller 116 could disengage both directional clutches 52, 54 from planetary unit 32.” *Id.*

66. However, while Dr. Stein alleges that directional clutches 52, 54 “selectively couple the engine to its planetary gear,” this fails to show that the *load* (e.g., Willis’s milling drum in the proposed combination) would be disengaged from the engine. In fact, Xing discloses the opposite—the load connected to the engine would still be engaged with the engine even when directional clutches 52, 54 are disengaged because the directional clutches only operate to direct engine power output through the hydrostatic branch of the transmission alone or both the hydrostatic and mechanical branches to drive the connected load.

67. Specifically, Xing teaches a machine having a transmission 24 that incorporates a hydromechanical arrangement for driving a coupled load (e.g., Willis’s milling drum). EX1006 (Xing), 4:38-46, 5:56-6:6, FIG. 2; *see also* EX1003 (Stein Declaration), ¶55. As noted by Dr. Stein, “[p]ower from the engine flows in parallel through both a hydrostatic branch and a mechanical branch and combines through a planetary unit or gear set 32.” EX1003 (Stein Declaration), ¶55 (citing EX1006 (Xing), 4:42-53, 5:14-17, 5:65-6:3). “In the mechanical branch, the sun gear NS1 of the planetary unit 32 receives power from the engine 22 via a planetary input shaft 50, which is connected to engine 2, when either the forward or reverse directional clutch 52, 54 is engaged.” *Id.* (citing EX1006

(Xing), 5:9-14, 5:65-6:3). In his declaration, Dr. Stein annotates this mechanical branch (orange) in Xing's FIG. 2, as I reproduce below. I have further highlighted forward and reverse directional clutches 52, 54 in blue.



Xing, Fig. 2 (excerpt annotated)

68. In the hydrostatic branch, which is also partially annotated above by Dr. Stein (green), “the ring gear NR of the planetary unit 32 receives power from the output gear N10 of hydrostatic unit 30 through gears N11, N12.” EX1003 (Stein Declaration), ¶55 (citing EX1006 (Xing), 4:54-63). Power flow from the engine is directed through both of the mechanical and hydrostatic branches and then combined at the planetary unit 32, which is then applied to the load (*e.g.*, milling drum) via an output shaft 56 (annotated in purple above). See EX1006 (Xing), 5:17-20.

69. Xing further discloses that the directional clutches 52, 54 direct whether the mechanical branch receives power output from the engine, while having no effect on the hydrostatic branch. In particular, Xing teaches that, “[d]uring operation, the transmission 24 may be operated to have a combined hydrostatic and mechanical power flow by engaging the reverse directional clutch 54 to the power planetary unit 32 via gears N1, N3, N5, and N7 or by engaging the forward directional clutch 52 to power the planetary unit 32 via gears N1, N8, and N2.” Ex1006 (Xing), 5:65-6:3. “Alternatively, the transmission 44 may be operated to have a pure hydrostatic power flow by disengaging both of the directional clutches 52, 54.” *Id.*, 6:3-6.

70. Given the above, Xing discloses two possible arrangements when directional clutches 52, 54 are controlled: (1) when either clutch 52, 54 is engaged, the transmission operates to provide “combined hydrostatic and mechanical power flow” from the engine to the transmission’s output; or (2) when both clutches 52, 54 are disengaged, the transmission operates to provide “pure hydrostatic power flow” from the engine to the transmission’s output. *See* EX1006 (Xing), 4:54-63 (explaining that power from the engine 22 flows through the hydrostatic unit 30 via “driven gear N4 mounted on a forward shaft 42 of the transmission 10 and engaged with the input gear N6” and is outputted to the planetary unit 32 via gears N11 and N12).

71. In either case, whether clutches 52, 54 are engaged or disengaged, power from the engine can still flow to the planetary unit 32 and to the load (*i.e.*, milling drum) via the output shaft 56. Therefore, a person of ordinary skill would not have understood that directional clutches 52, 54 would selectively *disengage* Willis's milling drum from the engine because power from the engine could still flow to the milling drum to drive it even if both clutches were disengaged.²

b) Xing's parking brake 70 is not a clutch controlled to disengage the rotor from the engine

72. Dr. Stein also points to Xing's parking brake 70, arguing that "[b]y actuating parking brake 70, output shaft 56 and its connected load remained mechanically isolated and disengaged from the engine." EX1003 (Stein

² I note that, to the extent Dr. Stein argues that disengagement of a particular flow path (*e.g.*, the mechanical branch) results in the rotor being "disengage[d]" from the engine, this is unsupported by the plain language of the claim and the specification. For example, FIG. 2 of the '538 patent illustrates clutch 140 as being connected to both the mechanical and hydrostatic arrangements of the transmission, and thus can selectively disengage the rotor from the engine as claimed.

Declaration), ¶150. However, parking brake 70 is not a “clutch” that can be controlled to “disengage the rotor from the engine.”

73. First, Xing’s parking brake 70 would not have been understood to be a “clutch” as conventionally known by those in the art. Those skilled in the art typically understood that a brake, such as a parking brake, is a device that inhibits or prevents motion of a moving load, while a clutch is a device that provides for engaging and disengaging energy transfer from a power input (*e.g.*, engine) to an output (*e.g.*, rotor). Xing confirms this understanding by referring to the component using different terminology (*i.e.*, a parking **brake** versus a clutch). Moreover, Xing explicitly distinguishes parking brake 70 from other “clutch” components of its machine. *See* EX1006 (Xing), 6:29-34 (“Thus, contrary to the various **clutches** of the transmission 24, the parking **brake** 70 may be designed such that it is engaged when the pressure within the brake 70 is reduced and disengaged when the pressure within the brake 70 is increased.”).

74. In addition, apart from stating that the parking brake 70 would “mechanically isolate[]” the rotor from the engine, Dr. Stein does not explain how this would have been understood to **disengage** the rotor from the engine. Xing states only that the parking brake 70 is “operably positioned on the load shaft 56” and the controller 116 “may be configured to proportionally or gradually engage the parking brake 70.” EX1006 (Xing), 6:15-23. Nothing in Xing discloses that

the parking brake 70 selectively disengages the connection between the load (*i.e.*, Willis's milling drum) and the engine. Rather, those skilled in the art would have understood that the load would still be connected to the engine and that the parking brake 70, when engaged, would merely exert a torque on the output shaft 56 to prevent unwanted movement when the vehicle is parked. In fact, such a configuration would not have been understood to “mechanically isolate[]” the load from the engine because, given a high enough torque outputted from the engine to the output shaft 56, the parking brake 70 could be overcome and the engine's output would be transferred to the rotor.

c) Xing's power take-off (PTO) clutch is not controlled to disengage the rotor from the engine

75. Finally, Dr. Stein argues that “Xing's transmission could be configured so that the transmission output shaft 56 is connected indirectly (through PTO 110) to a load, such as a milling drum, via PTO shaft 112 and a third clutch set, PTO clutch 114, under control of controller 116.” EX1003 (Stein Declaration), ¶151. Dr. Stein contends that a person of ordinary skill “would have modified Willis's milling machine so that the output of Willis's engine was connected to the input shaft of Xing's CVT and PTO shaft 112 was connected to Willis's milling drum,” and “PTO clutch 114 would have connected PTO shaft 112—and Willis's milling drum—to Xing's transmission output shaft 56 and the engine.” *Id.*

76. Dr. Stein further alleges that, “[a]s additional support for this combination, Laux teaches connecting a transmission in this manner.” *Id.* (citing EX1012 (Laux), 6:45-7:3). However, Dr. Stein’s citation to Laux does not describe a clutch that is controlled to “disengage” a load (*i.e.*, a milling drum) from the engine. Instead, as I describe in greater detail below with respect to Ground 2, Laux discloses a similar clutch arrangement as that of Xing in that the clutch of Laux also fails to “disengage” the load from the engine. *See infra*, section VIII.

VIII. GROUND 2: CLAIMS 8 AND 13 WERE NOT OBVIOUS OVER WILLIS, XING, AND LAUX

77. For Ground 2, Dr. Stein contends that Laux further teaches the limitations of dependent claims 8 and 13. *See* EX1003 (Stein Declaration), ¶¶154-58. Dr. Stein, however, does not rely on Laux as disclosing the limitations recited in independent claims 1 and 6. For this reason, claims 8 and 13 were not obvious over Willis, Xing, and Laux for the same reasons I detailed above for Ground 1 as to why claims 1 and 6 were not obvious over Willis and Xing. *See supra*, section VII.A.

78. In addition, claim 13 was not obvious over Willis, Xing, and Laux for additional reasons. In particular, as I explain more below, Dr. Stein relies on Laux as teaching a clutch that is controlled “to selectively disengage the rotor from the engine,” but Dr. Stein relies on Laux’s clutch in substantially the same manner as in Xing’s directional clutches. That is, as with Xing, whether the clutch Dr. Stein

identifies in Laux is engaged or disengaged, the rotor is still connected to the engine such that power flow from the engine may be transferred to the rotor. Moreover, Dr. Stein's contentions as to why a person of ordinary skill would have been motivated to incorporate Laux's clutch into Willis's milling machine as a "safety feature" is not supported by the references.

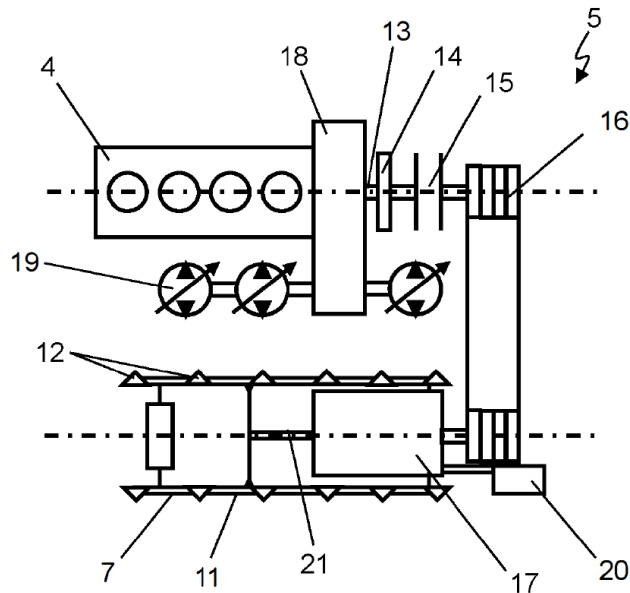
A. Laux's clutch 15 does not "selectively disengage" a rotor from an engine

79. Dr. Stein argues that, "to the extent a POSITA would have found Xing's teachings insufficient to permit disengagement of the rotor from the engine through the control of a clutch, Laux taught a milling machine powertrain in which clutch 15 was disposed between the engine and the rotor to selectively disengage the rotor from the engine." EX1003 (Stein Declaration), ¶157. In particular, Dr. Stein contends that "[c]lutch 15 could disengage engine 4 from belt drive 16, drive transmission 17, and rotor 7." *Id.* However, Laux fails to disclose that clutch 15 "disengage[s]" rotor 7 from engine 4 because, even when clutch 15 is disengaged, rotor 7 would still be connected to engine 4 via a secondary drive 20 and hydraulic pumps 19.

80. Specifically, as I reproduce below, Laux describes a ground milling machine 1 having a drive train 5. EX1012 (Laux), 9:3-4. "The drive train 5 transmits drive energy from the main drive unit 4, which is implemented as an internal combustion engine, to the milling drum 7." *Id.*, 9:4-7. The drive train 5

includes “an elastic clutch 14, a shift clutch 15, a belt drive 16, and a drive transmission 17” that “are connected to the output shaft 13 of the internal combustion engine 4.” *Id.*, 9:7-10.

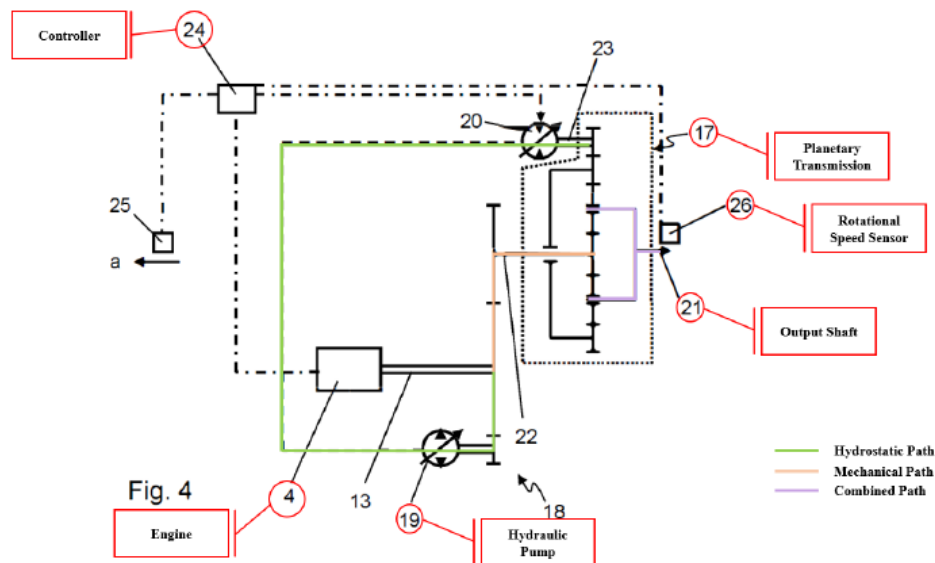
Fig. 3



81. Laux further teaches that “a transfer case 18 is arranged between the internal combustion engine 4 and the elastic clutch 14, to which multiple hydraulic pumps 19 are connected in the present example.” *Id.*, 9:10-13. “Furthermore, a secondary drive or auxiliary drive 20 is provided, which also discharges into the drive transmission 17.” *Id.*, 9:13-15. Laux discloses that engine 4 “drives the hydraulic pump[s] 19, which are used to drive the auxiliary drive 20, which is implemented as a hydraulic motor.” *Id.*, 9:24-28.

82. Given the above, Laux teaches two paths in which drive power from the engine 4 is transmitted to the transmissions and thus to its output shaft 21 for

rotating the rotor 7. The first is a mechanical path where power from the engine 4 is outputted via shaft 13 to the belt drive 16 and inputted into the transmission 17 via shaft 22. The second is a hydrostatic path where power from the engine 4 is outputted to hydraulic pumps 19, which drive hydraulic motor 20, the output of which is inputted into the transmission via shaft 23. This flow path is confirmed by Dr. Stein, who annotates Laux's FIG. 4. *See* EX1003 (Stein Declaration), ¶61. As reproduced below, the hydrostatic path (annotated green) extends from the engine 4, to the hydraulic pumps 19, to the auxiliary drive 20, and into the transmission 17 via input shaft 23. The mechanical path (annotated orange) extends from the engine 4 and into the transmission 17 via input shaft 22.



Laux, Fig. 4 (annotated).

83. Laux discloses that the hydraulic pumps 19 are connected to the engine 4 before (or upstream) from the clutch 15, which is shown by the pumps'

connection to transfer case 18, as illustrated above in Laux's FIG. 3. *See* EX1012, 9:10-13. Due to this arrangement, a person of ordinary skill would have understood that, even with clutch 15 disengaged, the transmission 17 (and thus the rotor 7) would still be connected to the engine 4 via the hydrostatic path (*i.e.*, auxiliary drive 20 and hydraulic pumps 19). Given this connection, a person of ordinary skill would have understood that control of clutch 15 would not "disengage the rotor from the engine" because the rotor would still be engaged with the engine through the hydrostatic path.

B. Those skilled in the art would not have been motivated to combine Willis, Xing, and Laux

84. Dr. Stein also argues that a person of ordinary skill "would have been motivated to incorporate Laux's clutch into Willis's milling machine" because those skilled in the art "would have understood that, for safety reasons, the milling drum needed to be disengaged from the engine to avoid unexpected startup and possible injury." EX1003 (Stein Declaration), ¶158. Relying on a different, unrelated reference, Dr. Stein argues that "this was conventionally achieved using a clutch between the rotor and the engine" and "[b]ecause a POSITA would have wanted to retain this safety feature from conventional milling machine[s], a POSITA would have been motivated to incorporate Laux's clutch." *Id.*

85. First, Dr. Stein's contention that a person of ordinary skill would have viewed Laux's clutch as a "safety feature" for disengaging the milling drum from

the engine during replacement of milling drum tools is unsupported by Laux. As I detailed above, Laux's shift clutch 15 is not configured to disengage the milling drum from the engine. *See supra*, section VIII.B. Instead, the clutch 15 is intended to connect the mechanical path of the drive train to the transmission 17. In other words, those skilled in the art would have understood Laux's clutch 15 to be a component that directs power flow from the engine to the rotor, not a "safety feature."

86. Second, Dr. Stein overlooks that claim 13 requires that the ***controller*** controls the clutch to selectively disengage the rotor from the engine. Even assuming that a person of ordinary skill in the art would have been motivated to incorporate a clutch to disengage Willis's milling drum from the engine for "safety" purposes during tool replacement, in my experience, those skilled in the art would not have been motivated to use a controller to control the clutch for such disengagement.

87. Specifically, as I noted above, Dr. Stein argues that a person of ordinary skill would have been motivated to disengage the milling drum from the engine "to avoid unexpected startup and possible injury." EX1003 (Stein Declaration), ¶158. However, this same rationale applies to why a person of ordinary skill would have sought to ***avoid*** using a controller to control the clutch to disengage the drum from the engine. Those skilled in the art would have

understood that, by relying on a computerized component such as a controller to control the clutch to disengage the drum from the engine, any controller error may inadvertently engage the clutch, and thus, re-engage the drum to the engine, or fail to disengage the clutch entirely. This would thus run into the same issues that a person of ordinary skill would have sought to avoid according to Dr. Stein—*i.e.*, unexpected startup and possible injury. As such, to the extent that those skilled in the art would have even been motivated to use a clutch between Willis’s milling drum and engine as a safety feature during tool replacement, a skilled artisan would have sought to control the clutch using *manual* means, as doing so would “avoid unexpected startup and possible injury” because control of the clutch would not have to rely on a component that itself is subject to failure and also because the manual means allow for a lock out safety procedure.

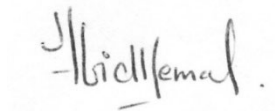
IX. CONCLUSION

88. In signing this declaration, I understand that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I acknowledge that I may be subject to cross-examination in this case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

89. I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the 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: June 20, 2023

By:

A handwritten signature in black ink, appearing to read "Abid Kemal", written on a light-colored rectangular background.

Dr. Abid Kemal

X. APPENDIX – MATERIALS CITED

Exhibit No.	Description
1001	U.S. Patent 9,975,538
1003	Declaration of Jeffrey L. Stein, Ph.D., P.E.
1005	U.S. Patent Application Pub. No. US 2010/0014914 A1 to Willis <i>et al.</i> (“Willis”)
1006	U.S. Patent No. 9,656,656 to Xing <i>et al.</i> (“Xing”)
1012	U.S. Patent No. 9,864,347 to Laux <i>et al.</i> (“Laux”)
2003	Transcript of the Deposition of Jeffrey L. Stein, Ph.D., P.E., held on May 23, 2023