

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

WIRTGEN AMERICA, INC.
Petitioner v.

CATERPILLAR INC.
Patent Owner

U.S. Patent No. 9,975,538

Case No. TBD

EXHIBIT 1003

DECLARATION OF JEFFREY L. STEIN, PhD., IN SUPPORT OF PETITION
FOR *INTER PARTES* REVIEW OF UNITED STATES
PATENT NO. 9,975,538

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I, Jeffrey L. Stein, declare as follows:

I. Introduction

1. I have been asked by Wirtgen America, Inc. (“Wirtgen America” or “Petitioner”) to provide my opinions in the above-captioned *Inter Partes* Review proceeding involving U.S. Patent No. 9,975,538 (“the ’538 Patent”; EX1001), which is titled “Milling Machine Fuel Efficiency Control System.”

2. I am being compensated for my time spent on this matter at the rate of \$525.00 per hour for the time I spend in connection with the proceeding. My compensation is not dependent in any way on the substance of my opinions or in the outcome of this proceeding.

II. Summary of My Opinions

3. To assist and orient the reader in reviewing this declaration, I have provided a summary of my main opinion below. A person of ordinary skill in the art (“POSITA”) at the time of the alleged invention would have found the subject matter of claims 1-13 (the “challenged claims”) obvious in view of the prior art.

Ground	Prior Art	Basis (Post-AIA)	Claims Challenged
1	Willis in view of Xing	35 U.S.C. § 103	1-13
2	Willis in view of Xing and Laux	35 U.S.C. § 103	8, 13

4. Claims 1-13 would have been obvious over Patent Application Publication No. US2010/0014917 to Willis et al. (“Willis”; EX1005) in view of U.S. Patent No. 9,656,656 to Xing et al. (“Xing”; EX1006).

5. Claims 8, 13 would have been obvious over Patent Application Publication No. US2010/0014917 to Willis et al. (“Willis”; EX1005) in view of U.S. Patent No. 9,656,656 to Xing et al. (“Xing”; EX1006) and further in view of U.S. Patent No. 9,864,347 (“Laux”; EX1012).

III. Qualifications and Experience

6. A copy of my *curriculum vitae* is provided as Exhibit 1004.

7. I earned a Ph.D. in Mechanical Engineering from the Massachusetts Institute of Technology in 1983, as well as Masters of Science and Bachelors of Science degrees in Mechanical Engineering from the same university in 1976. I was a Registered Professional Engineer from 1990-2020.

8. My academic and professional experience includes modeling of dynamic systems and modeling, analysis, design, and control of mechanical systems and vehicle control systems. This experience has included the design and control of machine powertrain systems, such as the internal combustion engine and transmission systems, of machines.

9. I am currently a Professor of Mechanical Engineering at the University of Michigan, where I have been a Full Professor since 1996 and held Assistant

Professor and Associate Professor positions between 1983 and 1996. Additionally, I held the Associate Director position at University of Michigan's Automotive Research Center ("ARC") from 1994-2009. I have studied, taught, and/or researched vehicle technology for over 40 years.

10. In my capacity as a Professor, I teach undergraduate and graduate courses in mechanical design, dynamics, systems and control engineering. My research and teaching has focused on system dynamics, control, machine diagnostics, machine design and control, computer-assisted modeling and design, vehicle dynamics (for traditional combustion and hybrid vehicles), as well as the control of artificial limbs. Examples of my research are in the field of vehicle engineering, and include projects specializing in algorithms for deducing or reducing proper dynamic system models to design and control autonomous, resilient, and sustainable systems with a focus on transportation. Some projects have involved modeling predictive control for autonomous vehicles, hybrid and electric vehicles, and vehicle to grid integration using fuel economy and exhaust emissions metrics. Since 2012, I have also held the role of Professor in the University of Michigan Ann Arbor's Design Science Ph.D. Program. At ARC, I was the leader of the Dynamics and Controls of Vehicle and Mobile Robotics Thrust Area and my research included modeling and simulation of ground vehicles, including heavy duty military vehicles, hybrid and autonomous vehicles, and vehicle batteries.

11. In addition to being the ARC Associate Director, I was also a Principal Investigator (PI) of various projects and I have developed computer-based methods for facilitating the design evaluation of automotive powertrains, including hybrid electric powertrains, as well as four- and six-wheel drive vehicles. I have also developed algorithms for controlling both the steering and propulsion of autonomous and semi-autonomous vehicles.

12. Between 1983 and 1991, I also worked as an independent consultant concentrating in the area of design and risk analysis of mechanical systems and manufacturing machines. Much of this work is particularly germane to the area of vehicle engineering. Some examples include: hybrid electric vehicles, automated mechanical transmissions for heavy duty trucks, four wheel drive vectoring and transfer cases for on-demand, four-wheel drive vehicles.

13. I have received numerous awards as a result of my work at the University of Michigan. Most recently, in 2020, I received the American Society of Mechanical Engineers (“ASME”)’s Dynamic Systems and Control Division’s Henry M. Paynter Outstanding Investigator Award for “seminal contributions to the basic engineering science of proper modeling of physical systems with a broad range of applications including rehabilitation, transportation and manufacturing engineering.” In 2017, I won an award for Best Paper for ASME’s Automotive and Transportation Systems’ American Control Conference for the paper “Moving Obstacle Avoidance for Large

Size, High-Speed Autonomous Ground Vehicles.” I have also supervised numerous student papers that have gone on to win awards from ASME and other institutions. In 2012, I received the ASME Dynamics Systems and Control Division’s Michael J. Rabins Leadership Award for “distinguished and steadfast leadership within the Dynamics Systems and Control Division.”

14. In 2011, I was invited to speak at the congressional office building for briefing on “The Road to the New Energy Economy: Electric Cars,” and in 2010, I was a plenary speaker at the American Association for Advancement of Science’s program on Green Mobility. In both of these talks I emphasized the fuel economy gained by decoupling the engine from the output and thus being able to run the engine in its “sweet spot.” In 2015, I served as a member and Chair of the ASME Energy and Environmental Standards Advisory Board from 2011-2021.

15. I have authored with my students and colleagues approximately 80 journal articles, including many that are related to automotive engineering. I have also authored with my students and colleagues over 130 referenced conference papers, including many that are related to automotive engineering. These publications included articles focused on large trucks as well as passenger automobiles and hybrid vehicles. For example, in 2001, I co-authored an article entitled “Design of an Advanced Heavy Tactical Truck: A Target Cascading Case Study,” for the 2001 Society of Automotive Engineers Journal of Commercial Vehicles. Similarly, in

2003, I co-authored a paper on ‘Generating Proper Dynamic Models for Truck Mobility and Handling,” for a Special Issue on Advanced Vehicle Design and Simulation of the International Journal of Heavy Vehicle Systems.

16. In light of my extensive training and experience, I consider myself an expert in the design and control of machine powertrain systems, which includes the internal combustion engine and transmission systems of machines such as those described in the ’538 Patent.

IV. Materials Considered

17. In formulating my opinions, I have relied upon my training, knowledge, and experience that are relevant to the ’538 patent. Furthermore, I have specifically considered the following documents, in addition to any other documents cited in this declaration:

Exhibit No.	Description
1001	U.S. Patent No. 9,975,538
1002	U.S. Patent No. 9,975,538 file history
1004	Curriculum Vitae of Jeffrey Stein
1005	U.S. Patent Pub. No. US 2010/0014917 A1 to Willis <i>et al.</i> (“Willis”)
1006	U.S. Patent No. 9,656,656 to Xing <i>et al.</i> (“Xing”)
1007	Norman H. Beachley & Andrew A. Frank, <i>Continuously Variable Transmissions Theory and Practice</i> (Lawrence Livermore Laboratory, Report UCRL-15037, 1979);
1008	U.S. Patent No. 8,622,871 to Hoff (“Hoff”),
1009	<u>rotor</u> , The Concise Oxford Dictionary of Current English, 9th Ed., 1995

1010	Eli Orshansky & William E. Weseloh, <i>Characteristics of Multiple Range Hydromechanical Transmissions</i> , SAE International, 81 SAE TRANSACTIONS 720447 (1972)
1011	Antonio Rosetti & Alarico Macor, <i>Multi-Objective Optimization of Hydro-Mechanical Power Split Transmissions</i> , 62 MECHANISM AND MACHINE THEORY 112 (2013)
1012	U.S. Patent No. 9,864,347 to Laux <i>et al.</i> (“Laux”);
1013	U.S. Patent No. 8,465,105 to Parker <i>et al.</i> (“Parker”)
1014	U.S. Patent No. 8,781,694 to Sheidler <i>et al.</i> (“Sheidler”)
1015	U.S. Patent Pub. No. 2009/0118912 to Hugenroth <i>et al.</i> (“Hugenroth”)
1016	U.S. Patent Pub. No. 2015/0091363 to Reuter <i>et al.</i> (“Schomaker”)
1017	U.S. Patent No. 8,167,378 to Busely <i>et al.</i> (“Busely”)
1018	William A. Ross, <i>Designing a Hydromechanical Transmission for Heavy Duty Trucks</i> (Society of Automotive Engineers, Working Paper 72075, 1972)
1019	Director Vidal Memorandum, “Interim Procedure for Discretionary Denials in AIA Post-Grant Proceedings with Parallel District Court Litigation,” June 21, 2022
1020	Dkt. 33, Amended Complaint, C.A. No. 17-770-RGA (Sept. 2, 2021)
1021	Dkt. 43, Answer to Amended Complaint and Counterclaims, C.A. No. 17-770-RGA-MPT (Oct. 14, 2021)
1022	Caterpillar Inc. v. Wirtgen Am., Inc., IPR2022-01264, Petition (P.T.A.B., July 22, 2022)
1023	Dkt. 92, Wirtgen Am., Inc. v. Caterpillar Inc., C.A. No. 17-770-RGA, Court’s Order Setting Claim Construction Hearing
1024	Dkt. 88, Stipulation Extending Fact Discovery Cutoff (Apr. 4, 2022)
1025	Federal Court Management Statistics (Mar. 31, 2022)
1026	Dkt. 56, <i>Wirtgen America, Inc. v. Caterpillar Inc.</i> , C.A. No. 17-770-RGA, (D. Del. Nov. 4, 2021) (“Motion to Sever and Transfer”)

1027	Dkt. 57, <i>Wirtgen America, Inc. v. Caterpillar Inc.</i> , C.A. No. 17-770-RGA, (D. Del. Nov. 4, 2021) (“Opening Brief in Support of Motion to Sever and Transfer”)
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V. Relevant Legal Standards

18. In forming my opinions, I have relied upon various legal principles (as explained to me by Wirtgen America’s counsel). My understanding of these principles is summarized below.

19. I understand that a patent claim defines the scope of an alleged invention. I further understand that a claimed invention must be new, useful, and non-obvious over the prior art for it to be patentable. I understand that in this proceeding Wirtgen America has the burden of proving that the challenged claims would have been unpatentable over the prior art by a preponderance of the evidence. I understand that “a preponderance of the evidence” is evidence sufficient to show that a fact is more likely true than it is not.

20. In determining the patentability of a claim, I understand that the first step is to understand the claim from the perspective of a POSITA to determine its meaning and scope. With that understanding, I will consider the claims at issue against the prior art from the perspective of a POSITA, as further summarized below.

A. Level of Ordinary Skill

21. I understand that a claim must be analyzed from the perspective of a POSITA at the time the claimed invention was allegedly invented by the patentee. Wirtgen

America's counsel has informed me to consider the time period shortly before May 18, 2015, as the earliest potential date of invention of the claims of the '538 Patent.

22. In ascertaining the appropriate level of ordinary skill in the art of a patent, I understand that several factors should be considered, including (1) the types of problems encountered in the art; (2) the prior art solutions to those problems; (3) the rapidity with which innovations are made; (4) the sophistication of the technology; and (5) the education level of active workers in the field of the patent.

23. I further understand that a POSITA is a person who is presumed to be aware of the pertinent art as of the time of the alleged invention, of conventional wisdom in the art, and is a person of ordinary creativity. Accordingly, a POSITA of the '538 Patent would have had general knowledge of machine powertrains, including internal combustion engines, transmissions, differentials, controllers and other powertrain components, as of May 18, 2015.

24. Based on my experience and my understanding of the legal principles summarized here, I believe that in the context of the '538 Patent a POSITA shortly before 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. Also, a POSITA may have

worked as part of a multidisciplinary team and drawn upon not only their own skills, but of others on the team, e.g., to solve a given problem. For example, an electrical or computer engineer may have been part of the team.

B. Claim Construction

25. I understand that it is a basic principle of patent law that assessing the validity of a patent claim involves a two-step analysis. In the first step, the claim language must be properly construed to determine its scope and meaning. In the second step, the claim, as properly construed, must be compared to the alleged prior art to determine whether the claim is valid.

26. My methodology for determining the meaning of claim phrases was first to study the patent carefully. In particular, I studied the claims themselves, followed by the background, detailed specification, figures, and other patent content. Next, I reviewed the prosecution history looking for any clarifications or limitations that might be attached to claim terms. In some circumstances, I looked at other documents, such as references applied by the patent office.

27. I understand that in an *inter partes* review, claim terms are to be given their ordinary and customary meaning as understood by a person of ordinary skill in the art in the context of the entire disclosure at the time of the invention. I understand that one must be careful not to read a specific embodiment appearing in the written description into the claim if the claim language is broader than the embodiment. I

further understand that any special definition for a claim term must be set forth with reasonable clarity, deliberateness, and precision.

28. I understand that this standard is the same as that used in United States district courts, in which claim terms are given their ordinary and customary meaning as would be understood by a person of ordinary skill in the art at the time of the invention having taken into consideration the language of the claims, the specification, and the prosecution history of record under the *Phillips* claim construction standard.

29. In my opinion, the '538 Patent does not use any unusual claim terms. Nor do any claim terms appear to be used outside their ordinary and customary meaning, as understood by a POSITA and in view of the '538 Patent specification and the prosecution history and other patent content.

C. Obviousness

30. I have been informed by Wirtgen America's counsel that a patent claim is unpatentable if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious to a POSITA at the time of the alleged invention. Thus, in assessing whether a claim is obvious, I understand that I am to consider (1) the scope and content of the prior art; (2) the level of ordinary skill in the field of the invention; (3) the differences between the

claimed invention and the prior art; and (4) any objective evidence of non-obviousness.

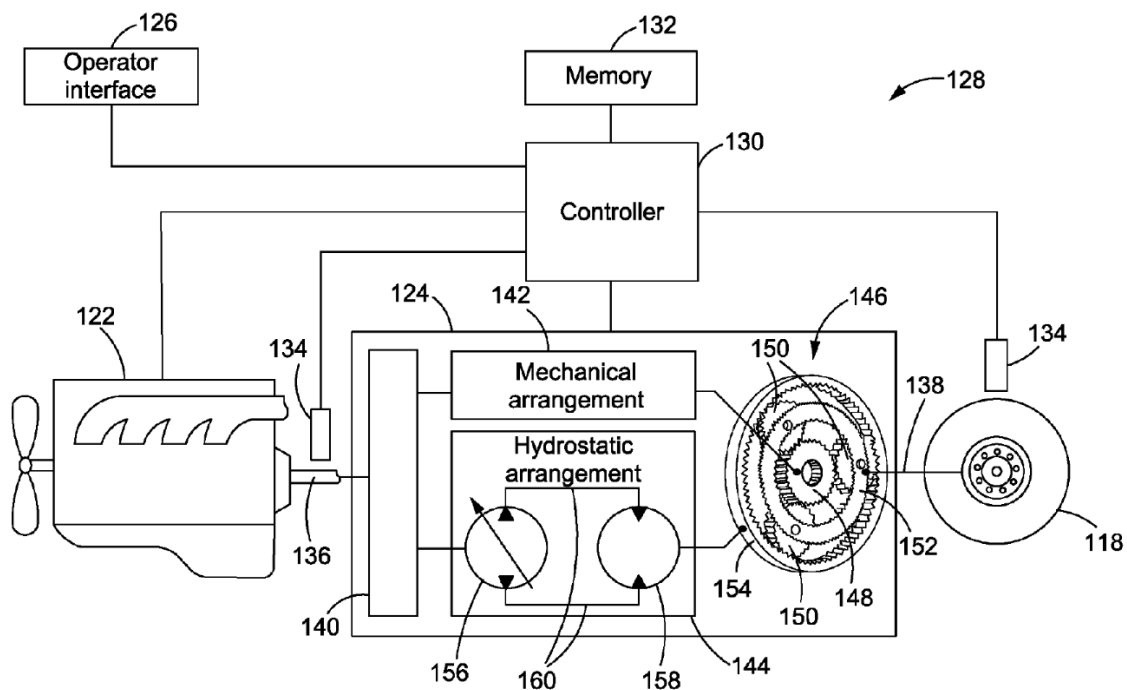
31. Wirtgen America's counsel has explained to me a number of exemplary rationales under which a POSITA could find a claim to have been obvious. To list some examples, I understand that if a POSITA could have arrived at a claimed invention by (a) combining prior art elements according to known methods to yield predictable results; (b) applying a solution from a finite number of identified, predictable solutions, with a reasonable expectation of success; (c) substituting one known element for another to obtain predictable results; or (d) using a known technique to improve similar devices (methods, or products) in the same way, the claimed invention would likely have been obvious to a POSITA. I have taken at least these rationales under consideration in analyzing the claims at issue here.

VI. The '538 Patent

A. Specification

32. The '538 Patent, entitled "Milling Machine Fuel Efficiency Control System," describes "a control system for controlling a machine having a rotor coupled to an engine through a variable transmission." EX1001, '538 Patent, 1:52-55, 1:61-63. A controller 130 in the machine, electrically connected to at least one of the engine, variable transmission, and rotor, is configured to operate the engine and variable transmission by adjusting the transmission gear ratio to maintain an operator's

desired rotor speed and adjusting the engine speed based on engine load and fuel efficiency. EX1001, 2:6-18, Fig. 2. The controller 130 can communicate with a memory 132 that retrievably stores one or more algorithms which configure the controller 130 to operate the engine 122 and transmission 124. EX1001, 1:61-2:5, 3:8-29. The method involves the controller receiving a desired rotor speed, determining the load on the engine, adjusting the speed of the engine based on the engine load and one or more predefined efficiency points, and adjusting a gear ratio of the variable transmission based on the engine speed and the desired rotor speed. EX1001, 1:52-60; 4:48-63.

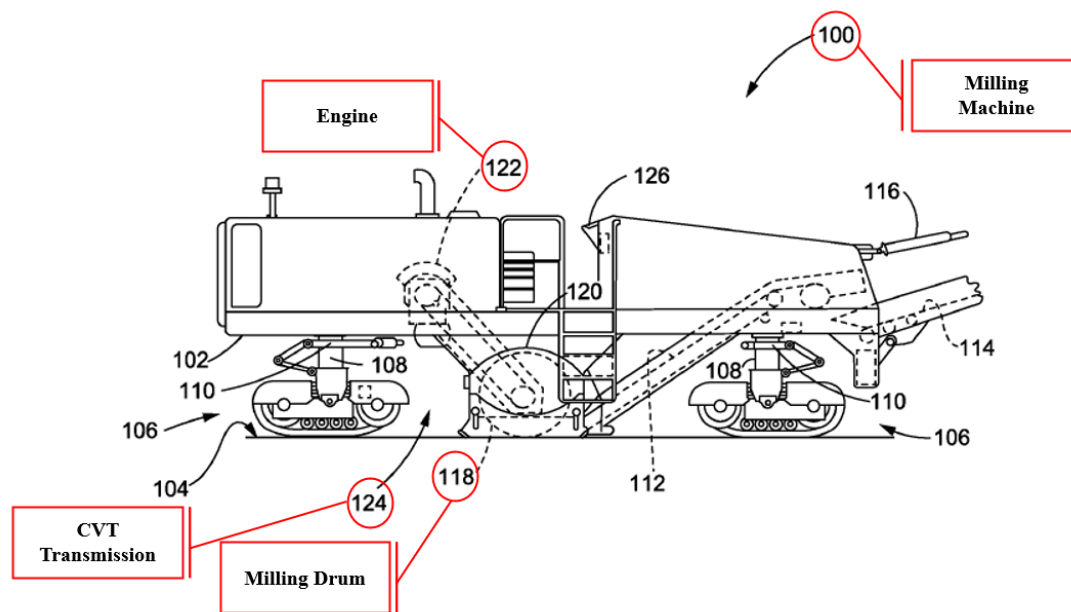


EX1001, Fig. 2

33. These broad embodiments are not limited to any specific type or category of machine or a specific type of rotor, and the specification notes that the disclosure “finds utility in various applications involving the use of machines.” EX1001, 4:48-54. Although they describe generic machines with generic rotors, the specification recognizes a narrower “industrial machines” category and points to specific types of machines as examples, “such as cold planers, pavement profilers, road milling machines, roadway planers, rotary mixers, and the like...for scarifying, removing, mixing or reclaiming material from the surface of bituminous or concrete roadways and similar surfaces.” EX1001, 1:13-17, 4:48-54. The specification selects one specific type of machine—a milling machine—as an example for more detailed description and recognizes that a milling machine uses a specific type of implement which is “a cutter or planning rotor” which is adapted to scarify, remove, mix or reclaim material from the surface of bituminous or concrete roadways and similar surfaces. EX1001, 2:38-46, 4:54-59. But the ’538 Patent’s “disclosure is directed at addressing,” more broadly, “solutions for controlling and maintaining a desired rotor speed of a milling machine, which also takes fuel consumption or efficiency into consideration.” EX1001, 1:41–45.

34. The specification provides that “one exemplary embodiment” of its control system “may be integrated into the milling machine 100 and used to control at least the rotor 118 in response to input received via the operator interface 126.” EX1001,

3:8-12. In my opinion, the structural features of the '538 Patent's milling machine appear to be conventional. For example, Figs. 1 and 2 depict a milling machine and a CVT that are substantially similar in structure to the milling machine and CVT in US Patent No. 8,465,105 to Parker, which the specification describes, in comparison, as conventional.¹ EX1001, 1:34–37.

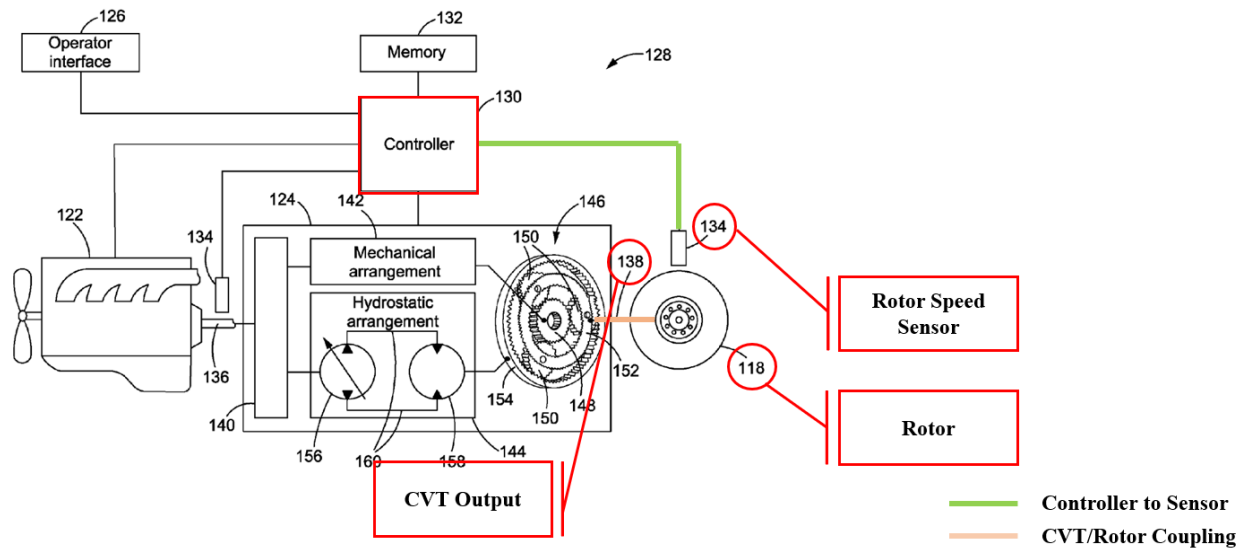


EX1001, Fig. 1 (annotated)

The control system 128 can include controller 130, which can be an electronic control module, an electronic control unit, or any other suitable means for receiving input from the operator interface and for controlling the machine, in electrical communication with at least a memory, an operator interface, and one or more of the

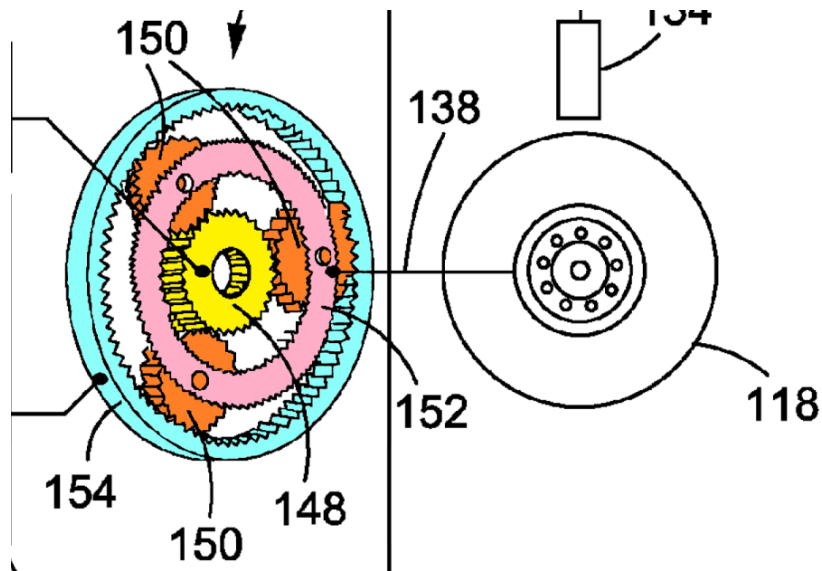
¹ Parker was filed more than eight years before the '538 Patent.

rotor, engine and CVT, as well as sensors for determining engine speed and rotor speed. EX1001, 3:15-29. Controller 130 receives signals from another sensor 134 for determining “rotor speed via a CVT output 138.” EX1001, 3:8-30.



EX1001, Fig. 2 (annotated)

In an exemplary method, “controller 130 communicates with the engine 122 to adjust engine speed based on changes in the engine load and predefined efficiency points 162 for better fuel economy.” EX1001, 4:4-6:9.



EX1001, Fig. 2 (excerpt annotated)

35. The variable transmission is described as a continuously variable transmission (CVT), with a clutch 140, a mechanical arrangement 142, a hydrostatic arrangement 144, and planetary gear set 146 having a sun gear 148 (yellow), planetary gears 150 (orange), a carrier 152 (pink), and a ring gear 154 (light blue). EX1001, 3:30–34. The mechanical arrangement 142 can include any suitable arrangement of pulleys, belts, roller chains, output shafts, to couple the engine output to the sun gear. EX1001, 3:37-40. The hydrostatic arrangement can include a hydraulic motor 158 connected via fluid lines to a hydraulic pump 156 configured to hydraulically couple the engine output to the ring gear 154. As shown in Fig. 2, the planetary gears 150 are mounted on the carrier 152 and coupled to drive the CVT output 138. Planetary gear set 146, which drives CVT output 138, is conventional.

36. As shown in Fig. 3, the planetary gears 150 combine the output of the hydrostatic arrangement through the ring gear and mechanical arrangement through the sun gear in a manner defined by a predetermined relationship. By varying the speed of the hydraulic motor and engine, and thereby the ring gear and sun gear, the controller continuously adjusts the gear ratio, which the specification explains represents the ratio between the engine output 136 and the CVT output 138 provided by the planetary gears and carrier. EX1001, 3:51-4:8. The specification explains that the transmission is “operated [to] continuously adjust the gear ratio, for instance, between the engine output 136 and the CVT output 138, in a manner which substantially maintains the rotor speed at the desired rotor speed specified by the operator irrespective of changes in the engine speed.” EX1001, 3:52–57. The specification explains that the conventional variable transmission in the Parker patent was also able to “allow for variations in the engine speed without affecting rotor speed.” EX1001, 1:34-37.

37. The specification explains that in addition to adjusting the gear ratio to provide a desired rotor speed, the controller adjusts the CVT output 138 in a manner that provides optimum fuel efficiency, or in a manner constrained based on predetermined fuel consumption rates shown in Fig. 4. EX1001, 4:4-8.

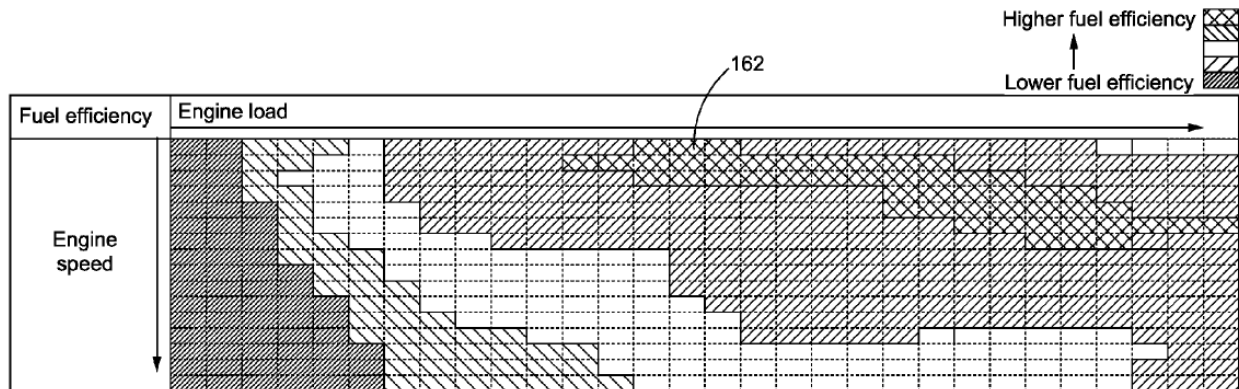


FIG. 4

EX1001, Fig. 4

38. Memory 132 can store information relating to the estimated fuel consumption rates the milling machine and engine achieve at different engine speeds and loads. The loads can include loads due to the rotor 118, the hydrostatic arrangement 144, and other parasitic loads. EX1001, 4:9-14. The memory 132 can also store information regarding efficiency points 162, which relate to the relative fuel consumption rates and combinations of expected engine loads and expected engine speeds that should provide relatively better fuel economy. EX1001, 4:14-23. Using the efficiency points 162 as a reference, the controller 130 controls the engine 122 to a speed at which the engine can achieve the determined engine load and that is the most fuel efficient. EX1001, 4:23-27. The controller 130 also receives from operator interface 126 desired rotor speed inputs from the operator and communicates with the CVT 124 to adjust the CVT's gear ratio based on changes in the engine speed for more consistent rotor speeds. EX1001, 3:8-29, 4:31-44, Fig. 2. Fig. 5

schematically depicts an exemplary algorithm according to this method. EX1001, 4:64-6:9.

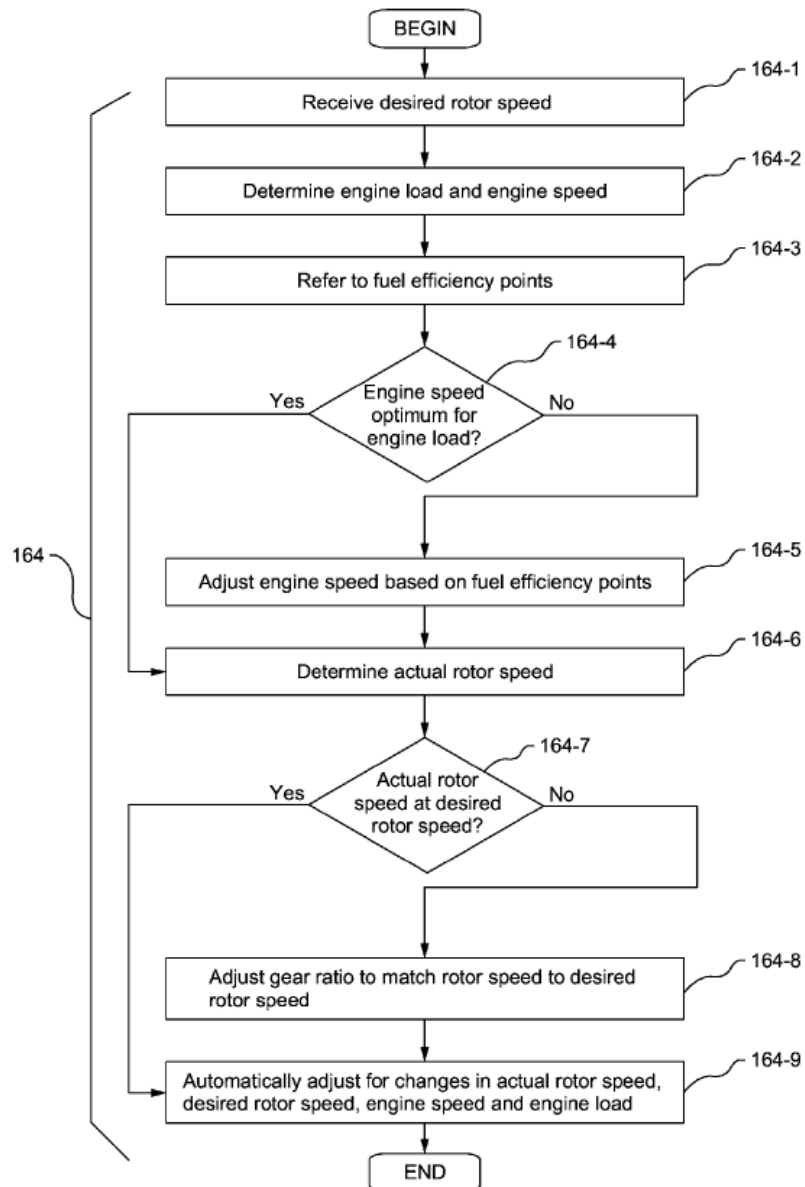


FIG.5

EX1001, Fig. 5

B. File History

39. Filed on May 18, 2015, Application No. 14/715,204, which eventually issued as U.S. Patent No. 9,975,538, included 20 claims of which claims 6-12 were ultimately cancelled. During prosecution, the applicant made various amendments and arguments to distinguish the claims over the prior art which may inform the scope and meaning of the issued claims of the '538 Patent.

40. On December 12, 2017, the applicant responded to one office action in which the examiner challenged the validity of the original pending claims, except claims original 4, 15, and 18, as anticipated by a publication that ultimately issued as the Parker patent. EX1002, 71-77, 92-101. According to the examiner, claims 4, 15, and 18 contained patentable subject matter but were objectionable because they depended from invalid claims. EX1002, 76. Original claims 4 and 18 further specified that the predefined efficiency points of independent original claims 1 and 13 were at least partially based on predetermined fuel consumption rates and providing optimum engine speeds for different engine loads. Claim 15 further specified that the gear set of original claim 14 is a planetary gear set having a sun gear coupled to the engine, a carrier coupled to the rotor, and a ring gear coupled to the hydraulic motor.

41. In its response, the applicant did not contest the examiner's argument that Parker discloses:

a controller-implemented method of controlling a machine having a rotor coupled to an engine through a variable transmission,
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,
and adjusting a gear ratio of the variable transmission based on the engine speed and the desired rotor speed.

EX1002, 99. Instead, the applicant amended original claims 1 and 13 to include allegedly patentable features of claim 4 to specify that predefined efficiency points of were “at least partially based on predetermined fuel consumption rates and providing optimum engine speeds for different engine loads.” EX1002, 100–01.

VII. Technology Background

42. Since at least the early 1970s, mobile machine powertrains have included continuously variable transmissions (CVTs) driven by internal combustion engines and have utilized controllers to control and coordinate their operation. One of the main functions of transmissions in mobile machines has been to convert the rotary output of a power source, such as internal combustion engine, into a form more useable by connected devices that require the power to work. Transmissions have been designed to receive rotational output of an internal combustion engine through

an input shaft and outputting the power at a different speed, torque, or direction, for example. The transmission output shaft is designed to couple the transmission's output and rotate machine components connected to the output shaft.

43. Mobile machine powertrains have included various types of CVTs, such as multi-range hydromechanical transmissions. EX1018, 1–2; EX1007, 2, 23, 27; EX1008, 1:15-22. These mobile machines include vehicles, tractors, milling machines or cold planers, wheel loaders, excavators, backhoe loaders, compactors, feller bunchers, forest machines, forwarders, harvesters, industrial loaders, knuckleboom loaders, material handlers, motor graders, pipelayers, road reclaimers, skid steer loaders, skidders, telehandlers, dozers, tractor scrapers, or other paving or underground mining equipment. EX1008, 2:48-60. In addition to identifying commercially available continuously variable transmissions suitable for motor vehicles and noting CVT use in industrial applications as of its 1979 publication, Beachley described existing systems that used microprocessors to control CVTs and internal combustion engines for optimum efficiency in view of load and desired CVT output speed. EX1007, 13, 23, 26–27. Beachley observed that as early as 1979, the “term continuously variable transmission also usually implies that torque may be controlled independently of speed ratio and vice versa.” EX1007, 1. “For conventional cars, a CVT allows the engine operating condition to be chosen for best economy on a continuous basis. A practical and attractive CVT must have efficiency

approaching that of a gear transmission, good reliability and life, and a satisfactory control system that allows the speed ratio to be set based on a signal from the system controller.” EX1007, 26.

44. Control systems in these mobile machine powertrains could provide for variation in the transmission ratio such that the engine is operated at whatever speed will give the maximum fuel economy and/or minimum emissions for that particular combination of vehicle speed and power demand. The industry recognized that the ability to set engine speed independently of vehicle speed was a significant benefit of CVTs. EX1010, 2153–65, 2154; EX1011, 112–13. The controllers in several of these systems determined engine load, adjusted engine speed based on load and fuel efficiency engine maps, and adjusted transmission ratios based on engine speed and a targeted transmission output shaft speed.

Being infinitely variable...it is possible to program the transmission system so that the engine operates...at some number of preselected speeds which can be varied in accordance with the vehicle power demands.... A further refinement of the control system can provide for variation in the transmission ratio such that the engine is operated at whatever speed will give the maximum fuel economy...for that particular combination of vehicle speed and power demand.

EX1010, 2154. It was well understood prior to May 2015 that these continuously variable powertrains had universal applicability to any of the mobile machines identified above. EX1008, 2:43-61. In my opinion, a POSITA would have found

adapting a powertrain of one mobile machine for use in another would have been considered conventional.

45. A milling machine or cold planer is a work vehicle with a powered rotatable drum mounted underneath the vehicle's chassis, which cuts or grinds away a roadway surface. These and other industrial machines used in construction, mining, agriculture, and transportation—such as vehicles, tractors, harvesters, and road reclaimers—have powertrains which have conventionally consisted of a prime mover, such as an internal combustion engine, and transmission elements that couple the engine output to the end effector or rotor (e.g., wheels, tracks, cutters, or a power take-off device (PTO)). *See, e.g.*, EX1008, 2:43-61, 3:18-35; EX1010, 2153–54; EX1013, 4:50-64; EX1016, ¶¶[0032]-[0034]; Laux, 1:23-32; EX1015, ¶¶[0028]-[0030]; EX1007, 1–4. Their powertrains have utilized hydromechanical transmissions, such as split torque continuously variable transmissions (CVTs). *See* EX1008, 1:15-25; 3:18-35; EX1010, 2153–54; EX1013, 4:50-64; EX1016, ¶¶[0032]-[0034]; Laux, 1:23-32, EX1007, 1–4, 13, 22–23.

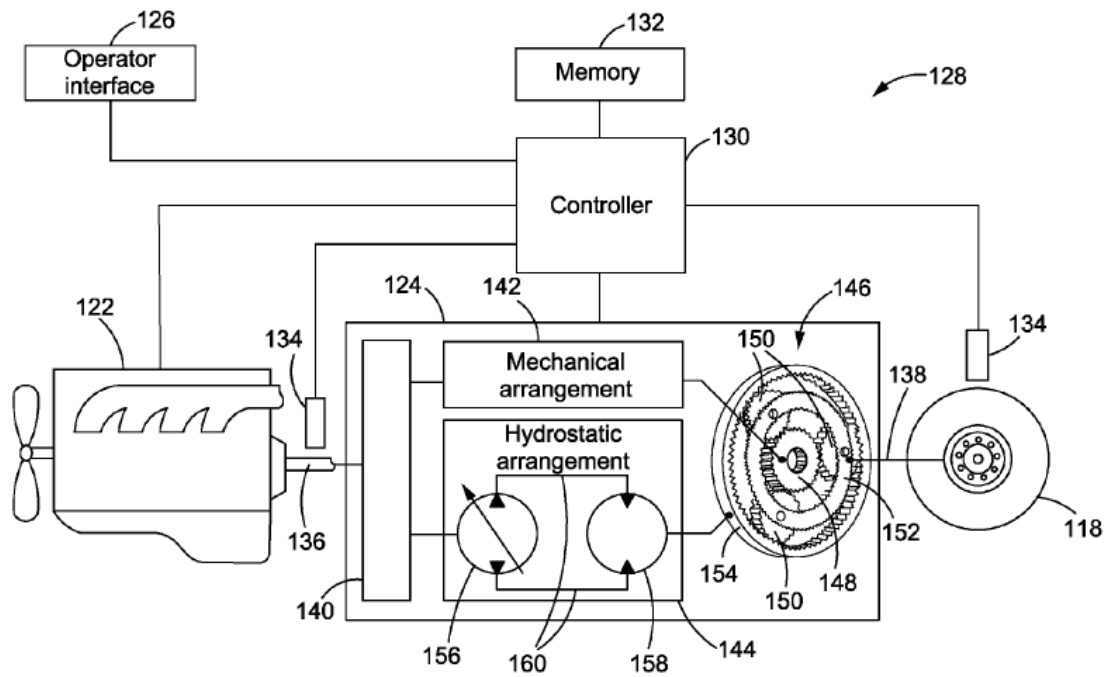
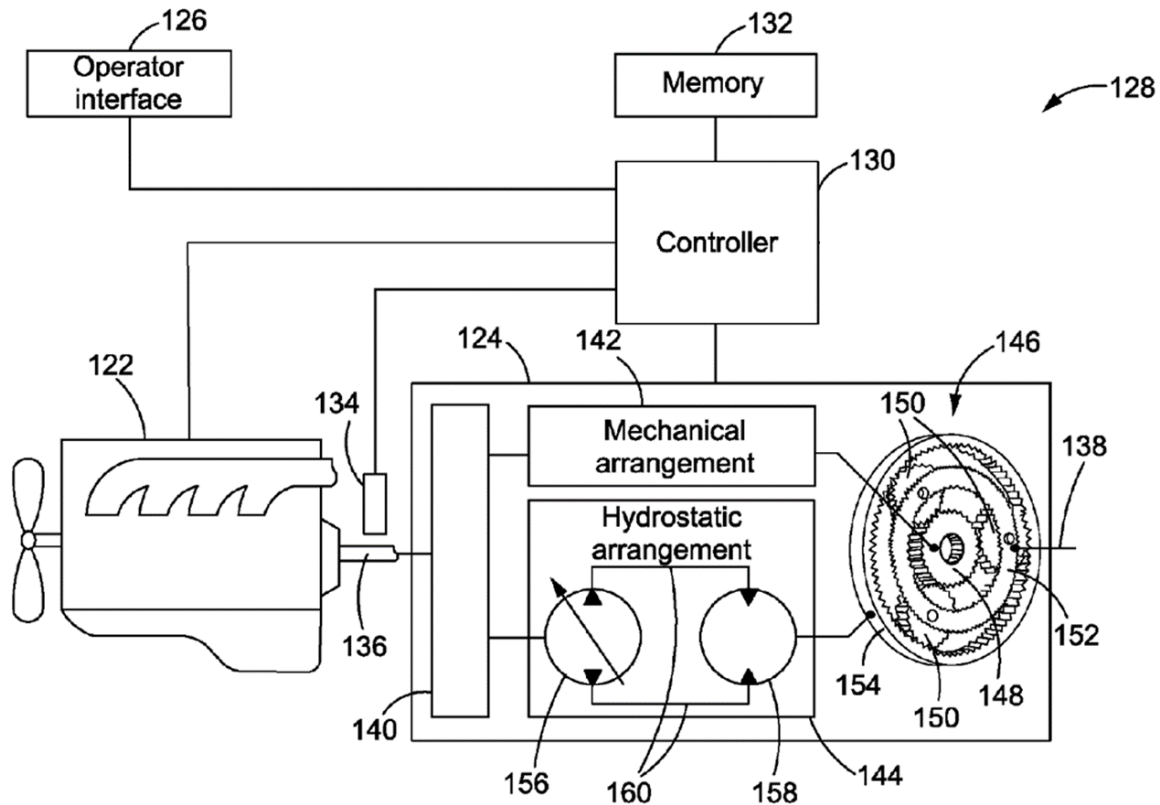


FIG.2

EX1001, Fig. 2

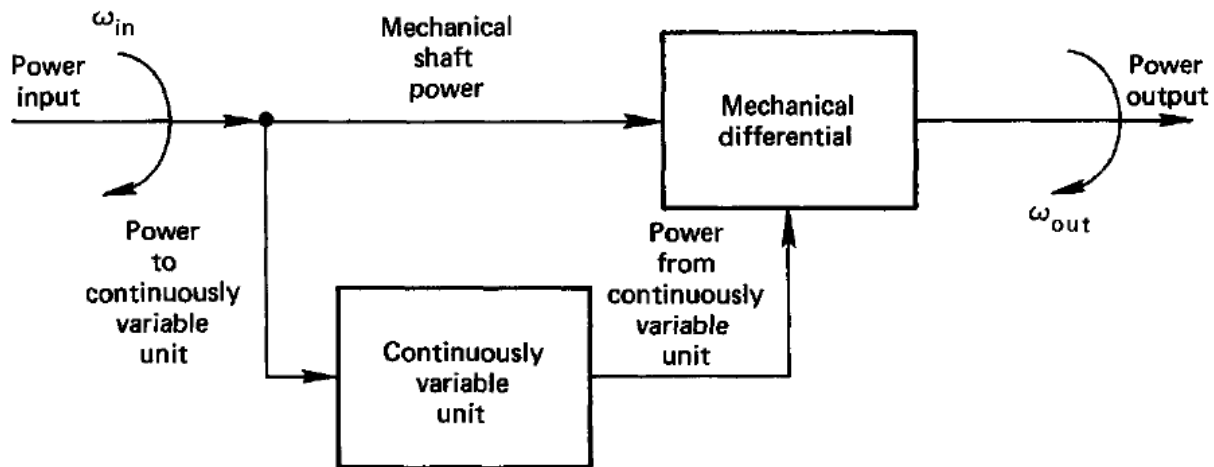
In typical split torque hydromechanical CVT transmissions, the engine is connected via the transmission input shaft and its torque is split to drive hydrostatic and mechanical branches of the transmission. Ex. 1007, 3–5, 13, Figs. 2, 9; EX1010, 2153–54; EX1011, 1–2.



EX1001, Fig. 2

46. The hydrostatic branch couples the engine to the transmission's output via a hydraulic pump which pumps fluid to and thereby drives a hydraulic motor. The mechanical branch is a mechanical linkage such as a gear set which couples the engine to the transmission's output. EX1007, 3–5, 13, Figs. 2, 9; EX1010, 2153–54; EX1011, 1–2. A planetary gear set, differential, or similar system of gears combines the outputs of the hydrostatic branch and the mechanical branch to drive the transmission output shaft. EX1007, 3–5, 13, Figs. 2, 9; EX1010, 2153–54; EX1011, 1–2. The planetary unit typically found in these CVTs is a summation transmission,

which combines the power in each of the hydrostatic and mechanical branches. The planetary output shaft carries the power in each of the hydrostatic and mechanical branches. The rotational speed of the output shaft is defined by the combined speeds of the hydrostatic and mechanical branches. EX1008 1:15-25; 3:18-4:34; EX1016, ¶¶[0008]-[0009], ¶[0034]; EX1007, 3–5, 13, Figs. 2, 9. One of the advantages of this arrangement is that the ratio of the output speed to the input of the hydraulic branch alone can be continuously adjusted. Thus, engine speed and the rotor speed in these machines can be independently adjusted. EX1007, 3–5, 13, Figs. 2, 9; EX1011, 1–2; EX1008, 1:15-25; 3:18-4:34; EX1016, ¶¶[0008]-[0009], ¶[0034]; Laux, 6:1-24; EX1010, 2153–54.



EX1007, Fig. 9

47. Since well before 2015, POSITAs have known that operating milling machines was “comparatively costly,” and customer demand required optimizing machine operation by minimizing milling machines’ fuel consumption whenever

possible, while maintaining desired milling performance. Laux, 1:33-37; EX1013, 3:18-23, 3:54-59. At least since the 1960s, POSITAs understood that an important benefit of coupling hydromechanical CVTs to internal combustion engines was to allow control of engine speed to minimize fuel consumption for a given load, while controlling transmission gear ratios to output desired transmission shaft speeds and maximize machine performance. EX1007, 2, 13–16, 23, 26, 31–34. Accordingly, several milling machines incorporated CVTs, which allowed operators to select, independently of engine speeds, different desired milling rotor speeds to maximize milling production, maximize quality of the milled surface, or to maximize energy efficiency of milling operations. EX1013, 3:18-30, 3:54-59; Laux, 1:45-62.

48. Ordinarily skilled engineers experienced in these mobile machines would have appreciated that the output shafts of the transmissions in these machines were rotors and were designed to be connected to additional components, such as rotary implements, that could be described as rotors. In the field of machine powertrains, rotor is a generic term that can refer to many parts that rotate or revolve. *See, e.g.*, EX1009. A wide variety of rotary components, such as helicopter blades, rotating turbine or compressor blades, vehicle brake disks, ignition system distributors, central rotating member of electric motors, for example, were and are still often described as rotors. In addition, transmission output shafts are generally designed to be connected to a rotatable part of a machine, and many of these mobile machines,

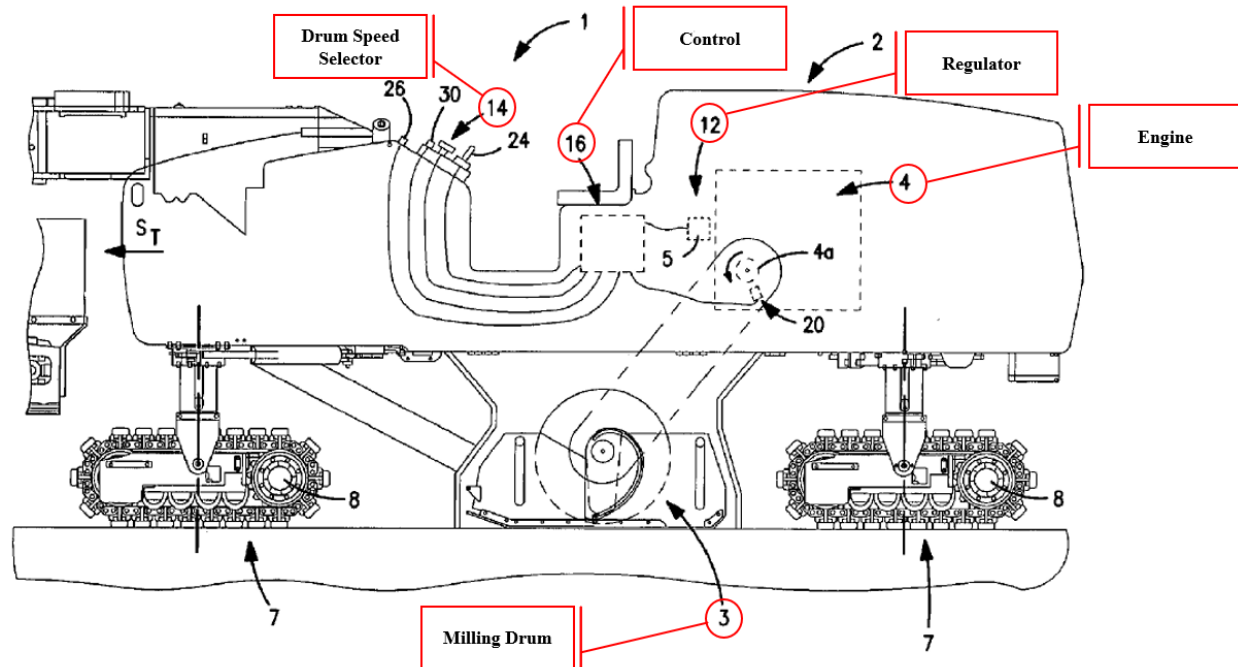
such as tractors and harvesters had rotary implements that could also be described as rotors, which could be connected and powered via their transmission output shafts. So, mobile machines having rotors coupled to an engine through a variable transmission were known well before May 18, 2015. All these machines included rotors. Because POSITAs understood the term “rotor” generically refers to a machine component that rotates, EX1009, a POSITA would have understood the output of the transmissions in these machines could have been and were coupled to rotors including the transmissions’ rotary output shaft and rotating implements. In the case of a milling machine, the rotor would be a milling drum or milling rotor. Machines, such as milling machines, with an engine that drives a rotor through a CVT transmission and with a controller programmed to operate the engine and transmission and adjust the transmission to control the rotor speed received from a user interface were well-known. *See, e.g.*, EX1002, 99–100; EX1007, 3–5, 13, Figs. 2, 9; EX1011, 1–2.

VIII. Overview of the Prior Art

A. Willis

49. U.S. Patent Application Publication No. US2010/0014917 (“Willis”) is entitled “Milling Machine with Cutter Drum Speed Control.” Willis is directed to a milling machine powered by an engine 4. Engine 4 rotates a cutter drum 3 at speed DS to mill a roadway surface. The engine 4 also powers hydraulic pumps 6 and

crawler motors 8 to drive the machine's tracks 7 and propel the machine back and forth. Willis, ¶¶[0003]-[0004], ¶[0017], ¶[0023]. The machine has a control system 10 to control cutter drum speed DS and the machine's propel or travel speed, S_T .



Willis, Fig. 3 (annotated)

50. Control system 10 includes a controller (control 16) that receives operator inputs from a speed selector 14 to select a desired drum cutting speed DS_D . On control 16, each of “buttons 21A, 21B, 21C, 21D...corresponds to a separate desired drum speed.” Willis, ¶¶[0017]-[0018]. Control 16 can also receive a signal from a sensor 20 that can sense or measure the rotational speed of an engine shaft, such as a crankshaft. Willis, ¶[0021]. This engine speed measurement can represent an indirect measure of the rotational speed of cutter drum 3 (or sensed drum speed DS_S)

when the engine is configured to directly drive cutter drum 3. Willis, ¶¶[0021]-[0022]. Control 16 can also directly measure sensed drum speed DS_s by receiving signals from sensor 20 when configured to measure the rotational speed of drum shaft 3a or the drum 3 itself. Willis, ¶¶[0021]-[0022]. Control 16 commands regulator 12 to control the engine or transmission, if present, to adjust the rotational speed of drum 3 so that the sensed drum speed DS_s equals the desired speed DS_D . Willis, ¶[0003], ¶¶[0017]-[0018], ¶¶[0021]-[0022]. The speed selector 14 can include a low idle speed setting that minimizes noise and fuel consumption when the drum is not cutting, a higher speed setting for high torque and low travel speed when cutting through hard material, a standard cutting speed for maximum horsepower, and maximum high cutting speed for shallow cuts at higher travel speeds. Willis, ¶[0019].

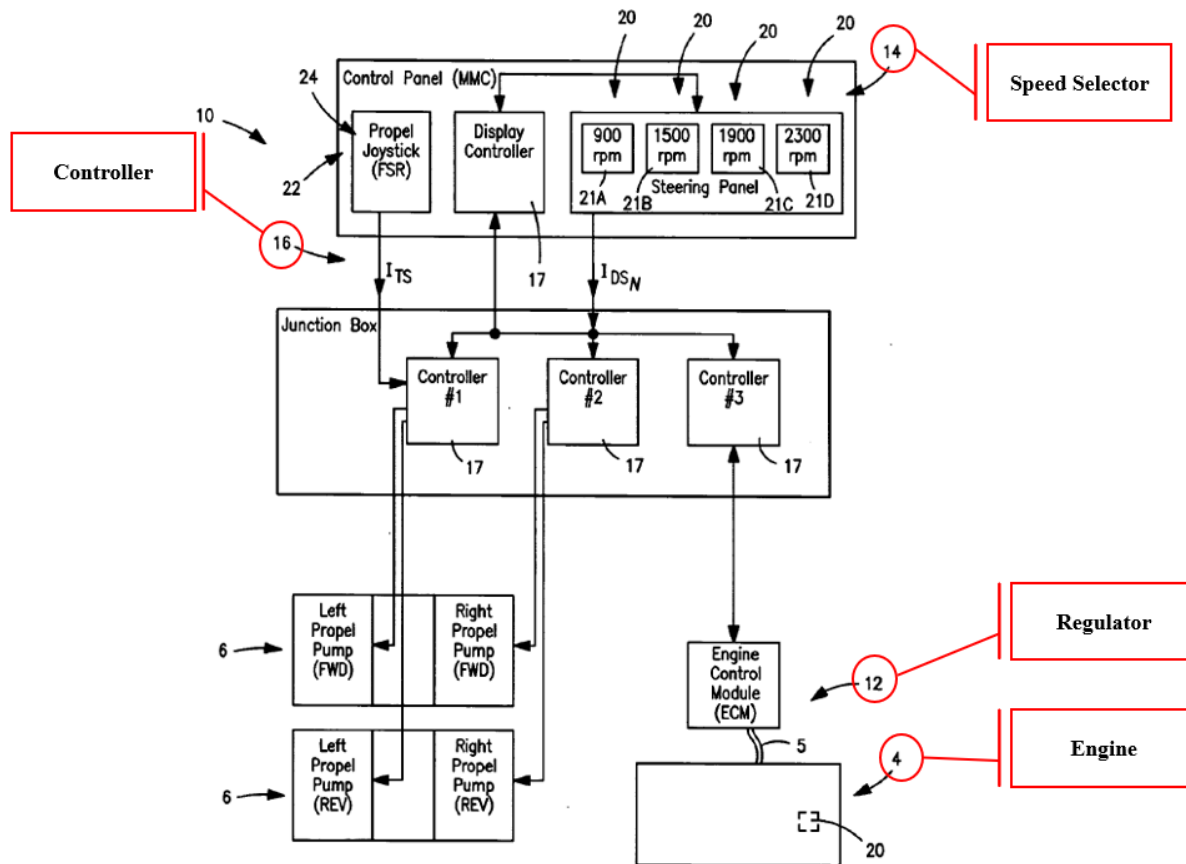


FIG. 1

Willis, Fig. 1

51. Willis describes one milling machine configuration in which engine 4 is directly coupled to and drives drum 3, and an alternate configuration in which engine 4 is indirectly connected to and drives drum 3 via a direct drive train.² Regulator 12

² For clarity, my declaration refers to a “direct drive train” with respect to direct drive systems like those taught by Willis. Absent additional components, a direct drive train transmits power to the rotor at a fixed ratio relative to engine speed. In contrast, when the remainder of my declaration refers to a “transmission” or a

can be operated to control the drum speed by controlling the speed of engine 4 when the engine directly drives drum 3.

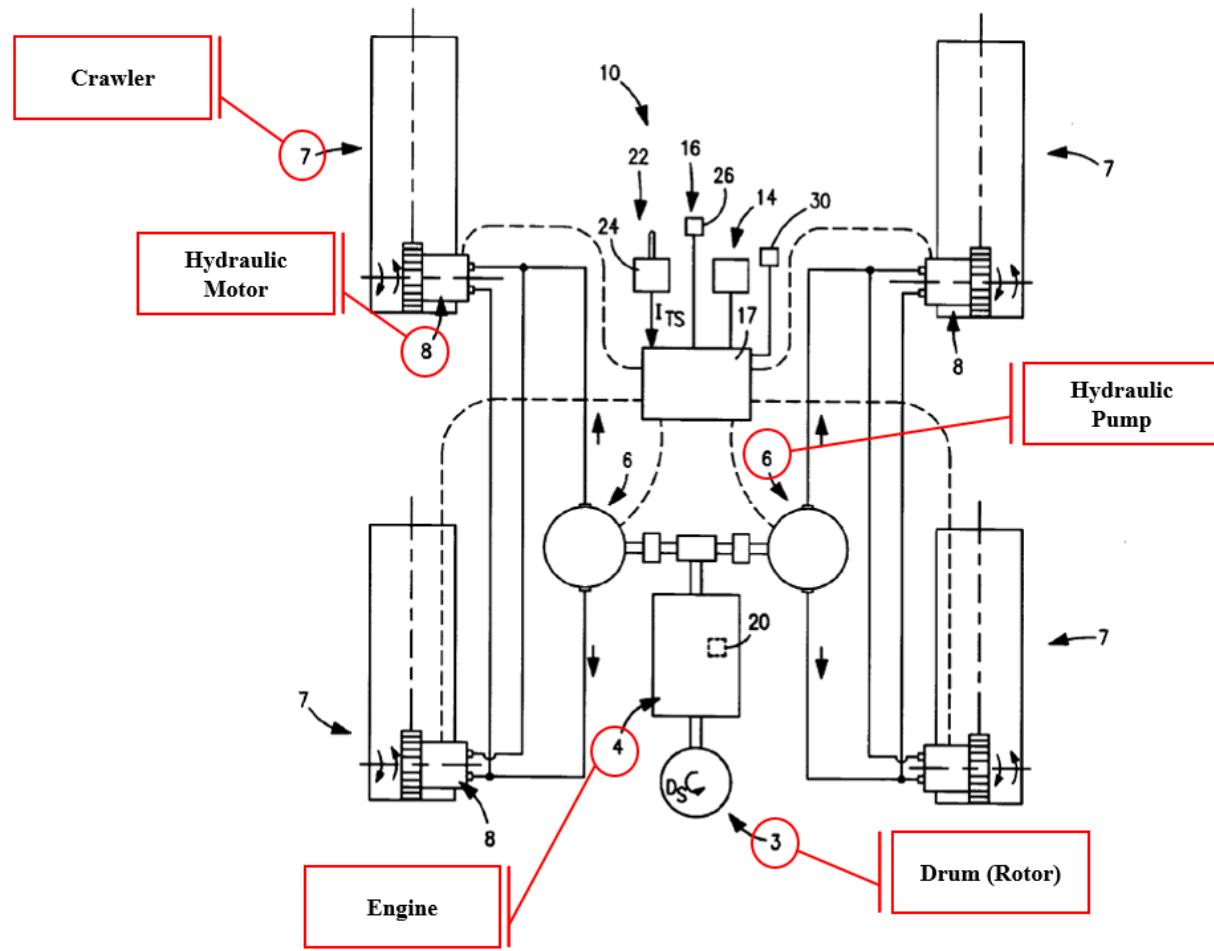


FIG. 4

Willis, Fig. 4

52. Control 16 compares a drum speed measurement signal from sensor 20 with the desired drum speed and operates regulator 12 to adjust the engine speed so that

“variable transmission,” such references are intended to indicate an element of a drive train that may be adjusted to adjust the ratio of rotor speed relative to engine speed.

the sensed drum speed is generally equal to the desired drum speed. Willis, ¶¶[0020]-[0021]. In load control mode (M_1), control 16 also compares the sensed drum speed with the desired drum speed and adjusts pumps 6 to reduce the speed of the crawler motors 8 and slow the machine's travel when the sensed drum speed falls below a predetermined proportion or percentage of the desired drum speed. Willis, ¶¶[0024]-[0028]. In such cases, the lowered sensed drum speed can indicate that the load on drum 3 is greater than desired, such as when drum 3 is cutting a relatively harder material or at relatively greater depth. By correspondingly reducing the machine travel speed, the quality or smoothness of the cut material surface can be maintained. Willis, ¶[0024]. However, in a second control mode (M_2) control 16 permits an operator to drive the milling machine at any desired travel speed via a travel speed input device 22 which can be a shiftable lever or joystick. Willis, ¶[0028].

B. Xing

53. U.S. Patent No. 9,656,656 ("Xing") is entitled "System and Method for Reducing Fuel Consumption of a Work Vehicle" and utilized a controller while maintaining the desired performance and productivity of the work vehicle Xing, Abstract, 1:18-20, 3:48-67. According to Xing, the work vehicle, or machine, can be a tractor, an earthmoving vehicle, a loader, some other type of agricultural or off-road vehicle, or "any other suitable work vehicle known in the art," with a controller 116 that coordinates the operation of an engine 22 and transmission 24. Xing, 2:34-

50, 4:1-27. Controller 116 can include one or more processors and associated memory to store computer-readable instructions that can configure the controller to perform a variety of computer-implemented functions, such as the method shown in Fig. 4, for identifying the optimum target engine speed to operate an engine to minimize fuel consumption for a given load. Xing, 7:33-59, 8:53-59. Xing's controller 116 can correspond to an existing controller of a work machine, such as an existing engine and/or transmission controller, or can correspond to a separate plug-in module that may be installed to allow for Xing's system and method to be implemented without requiring additional software to be uploaded into existing control devices. Xing, 7:60-8:2.

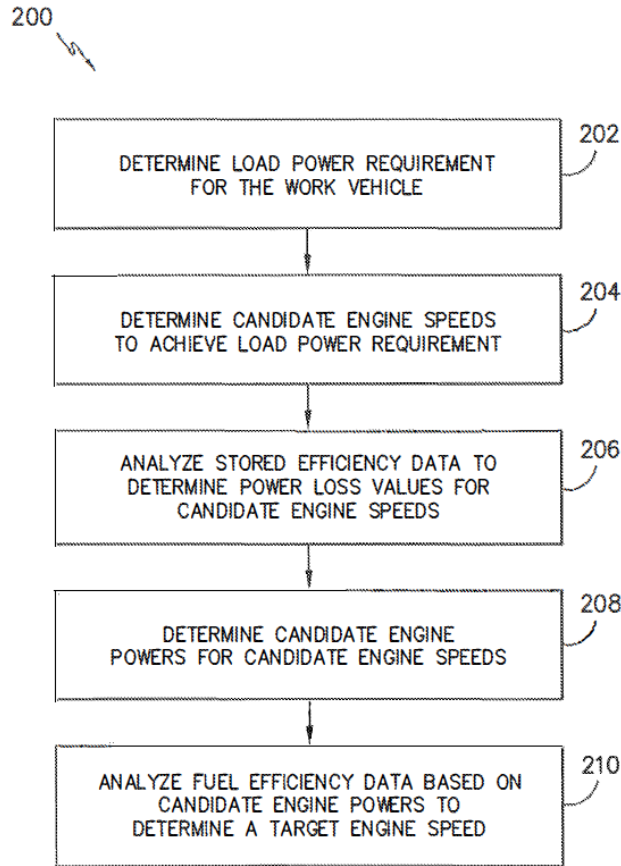


FIG. -4-

Xing, Fig. 4

54. One of Xing's examples is an agricultural tractor with a cab 18 that houses various input devices 20, 21, 120. An operator can use the input devices to control the tractor's operation. Engine 22 is coupled to drive wheels via a transmission 24 and drive axle assembly 26 to form a drive train 28, or power train. Xing, 4:8-21. The drive axle assembly 26 is conventional and can include a differential 102 and half shafts 104 that connect the transmission output shaft 56 to the wheels. Xing, 6:53-58. The powertrain in Xing's machine can also be configured to power any

suitable type of work implement. Xing, 4:33-37. For example, Xing's machine can include a power take-off (PTO) connected to the transmission via a clutch 114 that powers implements through an output shaft 112. Xing, 6:64-7:3.

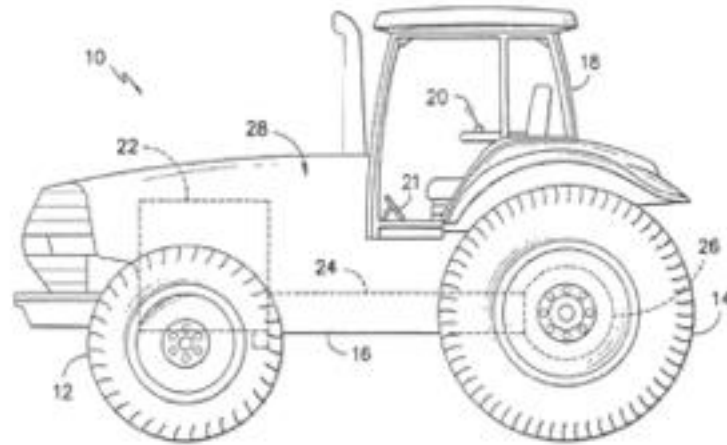


FIG. -1-

Xing, Fig. 1

Thus, the principles of operation in Xing are equally applicable when the transmission is connected to other output shafts, such as those described in Laux and Willis. Indeed, Xing teaches that the principles of operation apply to work vehicles more generally. Xing 1:18-21.

55. Xing's controller adjusts the engine to the most fuel efficient speed for powering the machine's load, and adjusts the transmission's gear ratio and output shaft rotation to drive the machine's wheels to propel the machine at the desired ground speed. Xing 1:25-38, 2:7-21, 4:4-7, 4:16-21, 4:64-5:8, 7:22-32, 9:4-17.

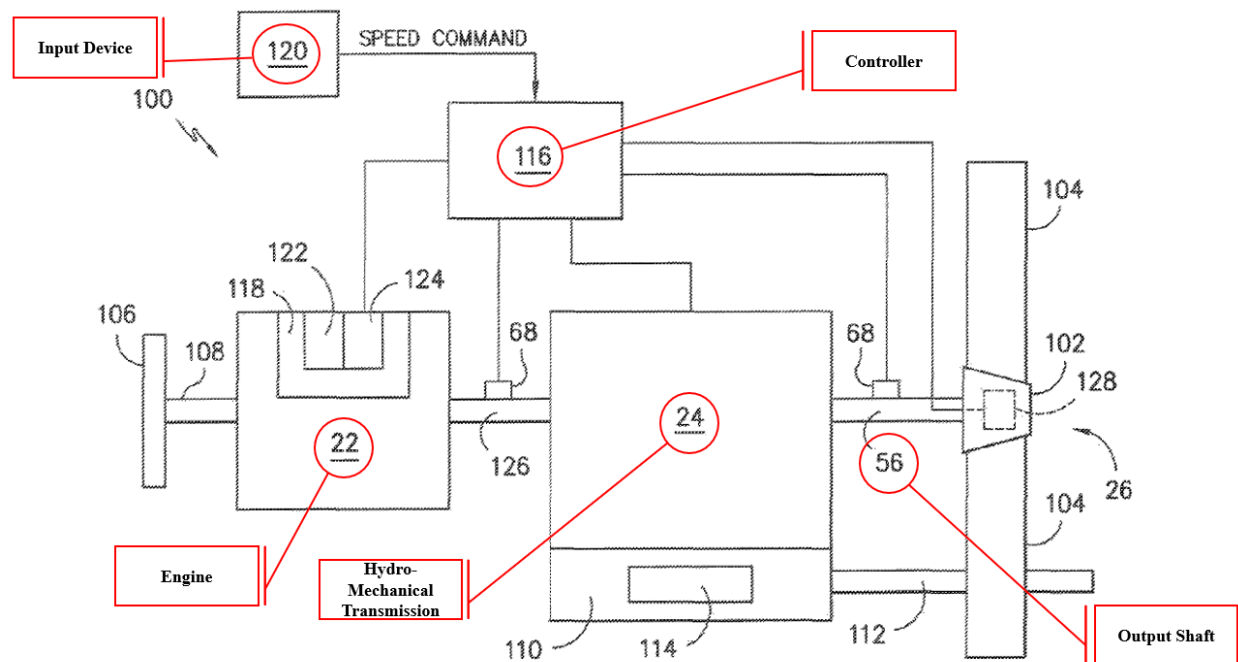
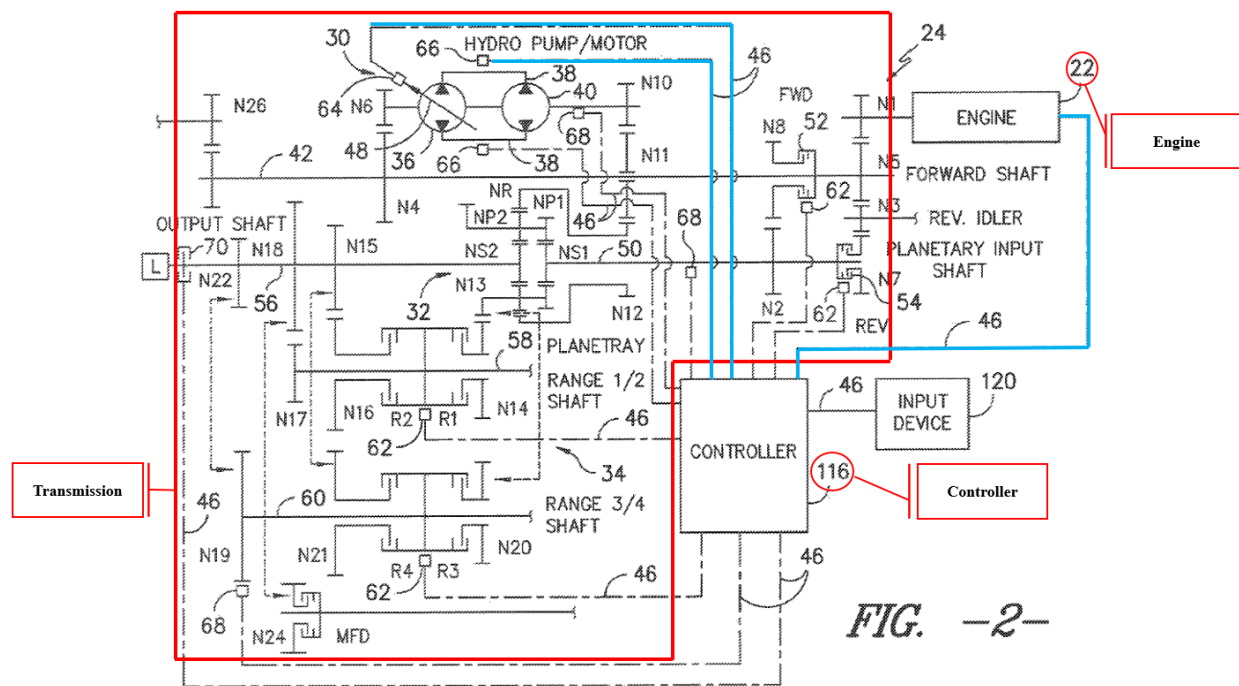


FIG. -3-

Xing, Fig. 3 (annotated)

The transmission in Xing's machine can be a hydromechanical continuously variable transmission. Xing, 4:38-43. Power 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. 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 planetary input shaft 50, which is connected to engine 22, when either the forward or reverse directional clutch 52, 54 is engaged. Xing 5:9-14, 5:65-6:3. In the hydrostatic branch, the ring gear NR of the planetary unit 32 receives power from the output gear N10 of hydrostatic unit 30 through gears N11, N12. Xing 4:54-63. The

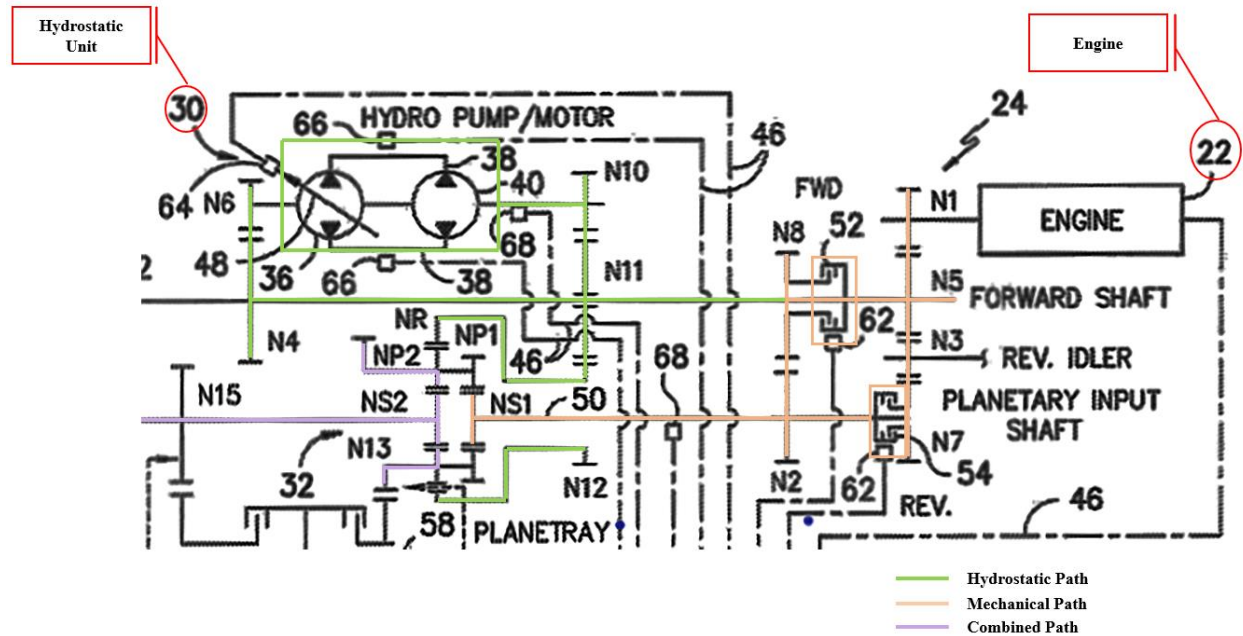
hydrostatic unit 30 includes a variable displacement hydraulic pump 36 which is driven by the engine 22 via forward shaft 42 and which pumps fluid to drive a hydraulically coupled motor 40. Xing 4:54-5:8. Controller 116 controls the motor's output speed by varying the angle of a swash plate 48 in the pump 36, which adjusts the flow of fluid pumped through hydraulic motor 40. Xing 4:42-53, 4:64-5:17, 5:65-6:3. Using control signals to adjust the angle of the pump's swash plate 48, controller 116 controls the speed of the planetary unit's ring gear NR, which is connected to the hydraulic motor's output N10, and thereby adjusts the transmission ratio of transmission 24 in a smooth and continuous manner. Xing 4:58-5:8, 6:6-13.



Xing, Fig. 2 (annotated)

56. Xing Fig. 2 depicts a conventional, power split, summation-type hydromechanical transmission. Xing, 1:25-38, 6:34-45; *see also* Hoff 1:15-25; 3:18-

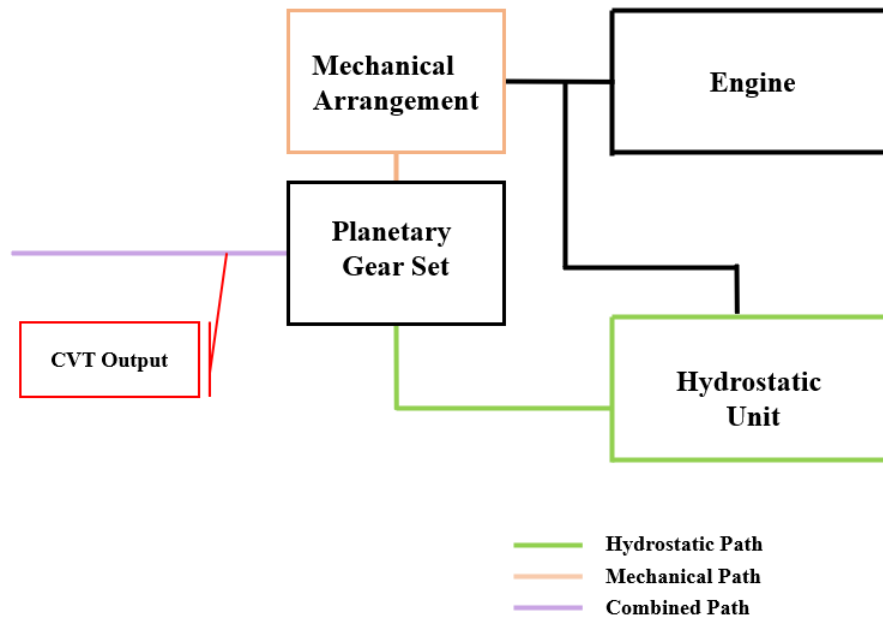
35, 3:59-4:1. Planetary unit 32 can be selectively connected to load L through the transmission's rotary output shaft 56. Xing, 5:14-23.



Xing, Fig. 2 (excerpt annotated)

The load L may correspond to the drive wheels of Xing's vehicle driven through a drive axle assembly, or alternatively, to any other suitable load, or even a separate operating system of the work vehicle, such as the PTO 110 which can be connected to output shaft 56 via a clutch 114. Xing, 4:33-37, 4:42-53, 6:47-7:3. Gears N18 and N22 in output shaft 56 mesh with gears N17 on range $\frac{1}{2}$ shaft 58 and N19 on range $\frac{3}{4}$ shaft 60, respectively, of range gear set 34. When engaged, range clutch R1 couples range $\frac{1}{2}$ shaft 58 to gear N13 and range clutch R2 couples range $\frac{1}{2}$ shaft 58 to gear N15. Similarly, when engaged, range clutch R3 couples range $\frac{3}{4}$ shaft 60 to gear N13 and range clutch R4 couples range $\frac{3}{4}$ shaft 60 to gear N15. Planetary gear

NP2 transfers the combined output of the hydrostatic and mechanical branches from sun gear NS1 and ring gear NR to gears N13 and N15, as shown in the simplified version of Fig. 2 below. Xing, 5:9-67, 8:29-41.



Representation of Xing, Fig. 2

Controller 116 can selectively engage output shaft 56 and its associated load L to the engine 22 to rotate at different ranges of speeds relative to the transmission input shaft 126 by selectively engaging range clutches R1, R2, R3, or R4. Additionally, controller 116 can actuate parking brake 70 to further isolate output shaft 56, and its load L, from engine 22.

57. Xing's controller 116 receives various operator inputs through input device 120 including a desired work vehicle ground speed. On receiving the input, controller 116 controls the engine speed and the transmission ratio of the work

vehicle 10 to achieve the commanded ground speed. Xing 8:3-15, 8:64-9:3. Controller 116 can determine the necessary transmission ratio based on the actual engine speed ES and the desired ground speed GS and using the following equation, which describes the relationship between these variables:

$$GS = ES * TR * k.$$

TR is the transmission ratio and *k* is a constant associated with the final drive ratio and the size of the vehicle's tires. Xing, 13:19-35. Because the transmission output shaft 56 is connected to the drive wheels through a subset of drive axle assembly components, such as differential 102 and ½ shafts 104, the rotational speed of output shaft 56 is also related and proportional to the actual ground speed. The specific ratio of the actual shaft speed to the actual ground speed can be represented by a constant determined by the design of the drive axle assembly components and wheels. In adjusting the transmission ratio to maintain a desired ground speed, the controller 116 also controls the rotation of output shaft 56 to maintain a target rotational speed. A POSITA would have understood that as conventionally implemented, controller 116 would be configured to control the transmission ratio of the transmission by receiving and using actual engine speed signals from governor 22 and actual transmission output shaft speed measurements from sensor 68. Xing 5:38-55, 8:29-40.

58. Xing's controller is also connected to the engine's governor 118 and other sensors 122, 124 to monitor the engine speed and torque loads; determine the engine settings that minimize the vehicle's fuel consumption; and control the engine to operate at those settings. Xing 5:52-54, 7:22-32, 8:16-28, 8:53-9:3. The controller can determine the machine's load power requirement (the amount of power required for the vehicle to accomplish useful work) by calculating the engine's current power output from engine speed and torque measurements and estimating the current power loss due to system inefficiencies. Xing 9:18-56. As is generally understood, a plurality of different combinations of engine torque and engine speed may be utilized to meet a specific power requirement. Xing 10:21-24. Controller 116 stores engine fuel efficiency data in the form of fuel consumption maps, data tables and/or mathematical functions and can analyze this data to determine optimal engine settings based on candidate engine speeds and associated engine torques. Xing, 8:53-64, 12:26-54.

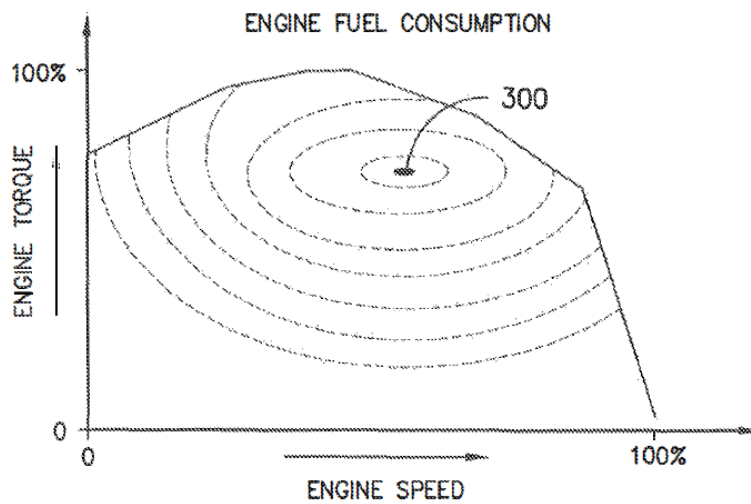


FIG. -11-

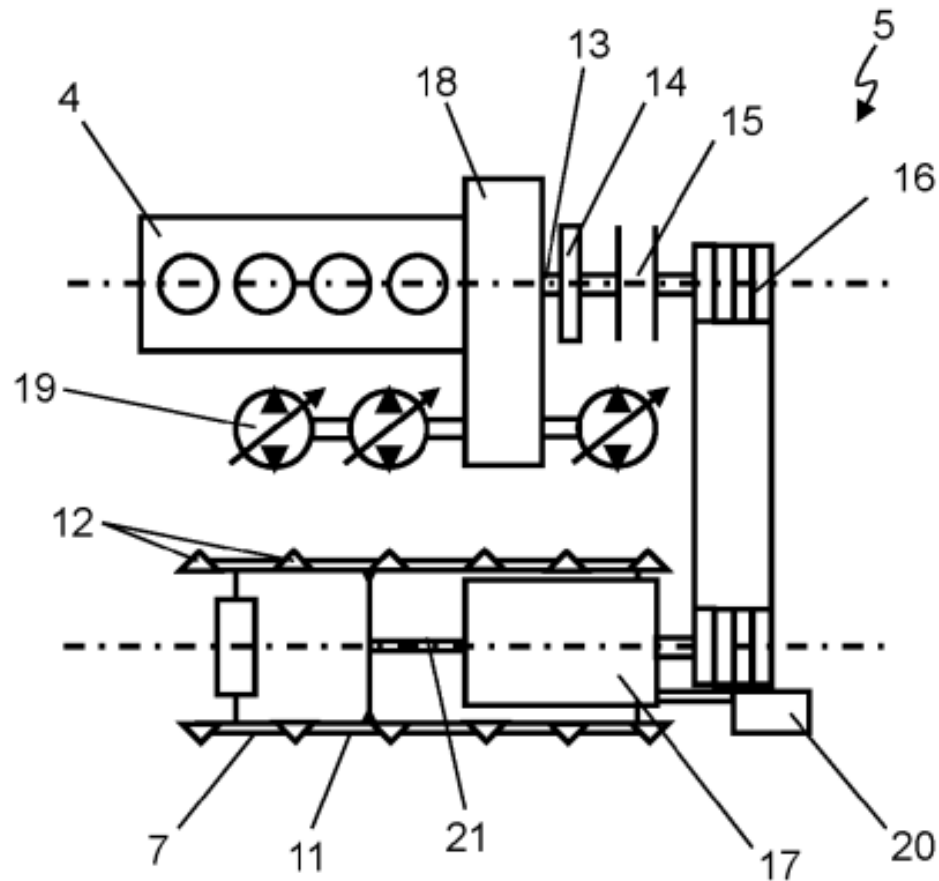
Xing, Fig. 11

59. Using actual or forecast power requirements, controller 116 evaluates several engine speeds and corresponding power losses and identifies the most fuel efficient target engine speed settings at which to operate the engine. Xing, 8:64-9:3, 12:54-63. Thus, Xing's controller coordinates the operation of the engine and transmission of a work machine to select and adjust the engine to the optimum speed to minimize fuel consumption for a measured load. Xing's controller also adjusts the transmission's gear ratio based on actual engine speed to control the transmission output shaft to a desired speed based on inputs from an input device.

C. Laux

60. Laux discloses a milling machine powertrain that includes an engine that drives a rotor via a variable transmission and a controller that coordinates the operation of the engine and transmission to control rotor speed.

Fig. 3



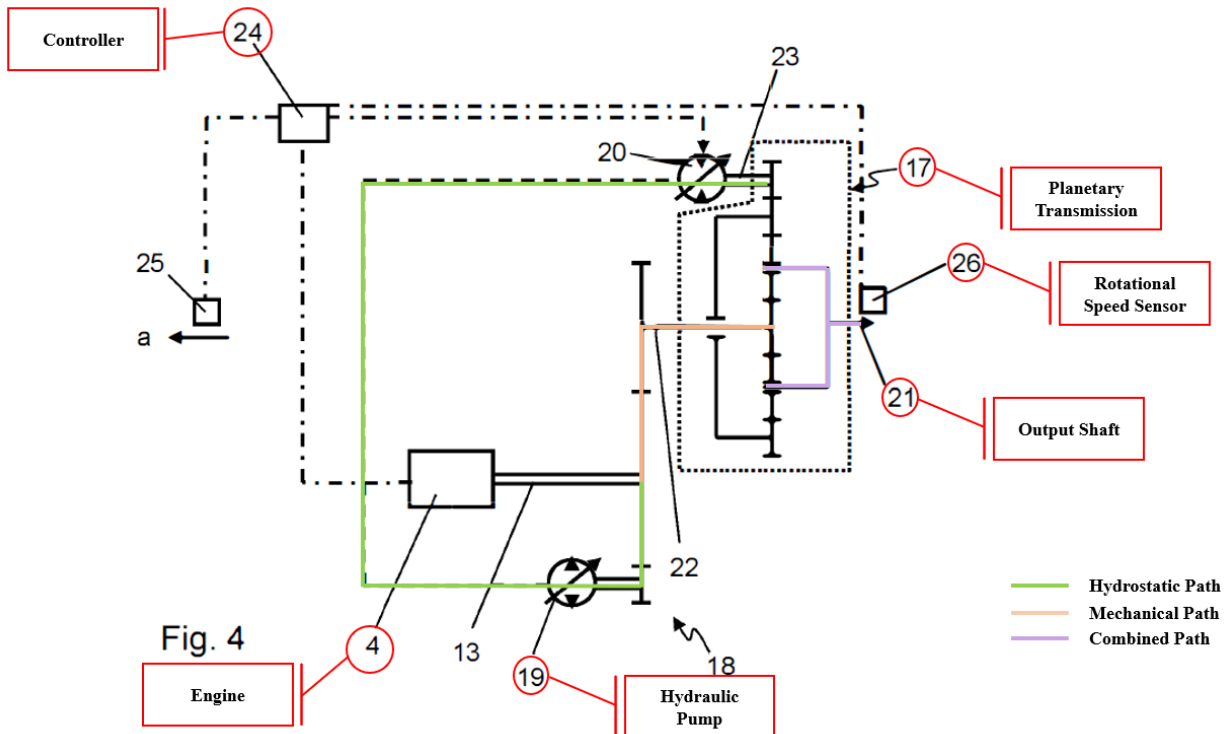
Laux, Fig. 3

Engine 4 is coupled to traction drive 16 via output shaft 13. Laux, 8:60-9:28.

Traction drive 16 is coupled to milling drum 7 via drive transmission 17. Control unit 24, an “essential feature,” is in electrical communication with rotational speed sensor 26 and controllably adjusts the rotational speed of milling drum 7. Laux, 9:29-46.

61. Laux’s drive train utilized a planetary unit to combine two power inputs (hydrostatic and mechanical) to drive a single transmission output. Laux’s drive transmission 17 was a planetary gear summation transmission (i.e., a variable

transmission) that received drive input from engine 4 via shafts 13, 22, and drive input from hydraulic motor 20, via shaft 23, to rotate output shaft 21 based on the summation of the two inputs.

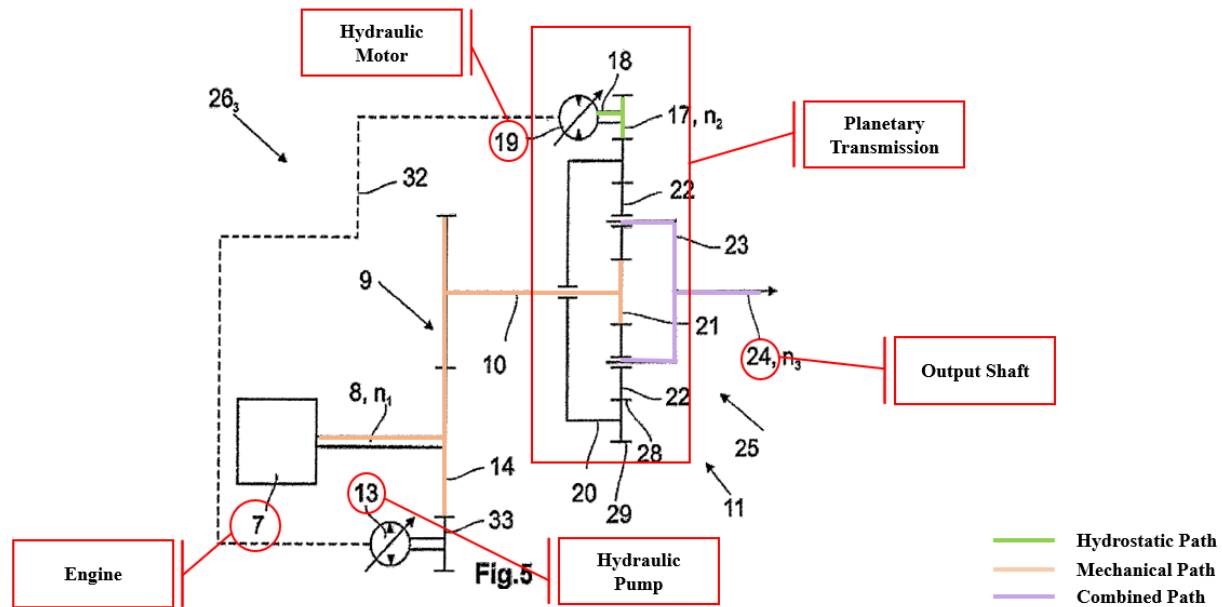


Laux, Fig. 4 (annotated)

By adjusting the speed of the hydraulic motor, controller 24 could continuously vary the speed of transmission output shaft 21 and thereby adjust rotor speed independently of engine speed. Laux, 5:61-6:24.

62. For further details regarding its variable transmission, Laux incorporated Schomaker by reference.³ Laux, 1:38-43, 6:12-14. Schomaker also utilized a planetary unit to combine two power inputs (hydrostatic and mechanical) to drive a single transmission output. EX1016, ¶¶[0033]-[0034]. Schomaker details the well-known arrangement of its planetary gear 25, which combines rotational speeds n_1 (mechanical) and n_2 (hydrostatic) to vary speed n_3 of output shaft 24, which drives milling rotor 6. EX1016, ¶¶[0033]-[0037].

³Counsel informs me that Laux claims priority to German application DE102012006189.7 to Schomaker et al. (“Schomaker”). Schomaker was effectively filed February 12, 2014. Accordingly, Laux constitutes prior art under 35 U.S.C. § 102(a)(2). Laux also incorporates by reference Schomaker and its corresponding PCT application, PCT/EP2013/000686. US Application No. 2015/0091363 is a corresponding English language application that claims priority to and shares its disclosure with these German language Schomaker applications. Laux, 1:8-11, 1:38-43. For ease of reference, this Declaration cites to U.S. Application No. 2015/0091363 (the “363 Application”), which is an English language application corresponding to DE102012006189.7.



EX1016, Fig. 5

63. Laux taught that milling machine operation is “costly,” and customer demand required optimizing machine operation by minimizing milling machines’ fuel consumption whenever possible while maintaining desired milling performance. Laux, 1:33-37. Schomaker likewise taught that the “reduction in fuel consumption as well as the continuous adjustability of the second speed of rotation at which the milling rotor is driven result in more economical, faster, and safer milling of road surfaces compared with prior art construction machines.” EX1016, ¶[0024]. The powertrain system taught by Laux, which incorporated the teachings of Schomaker, allowed independent variation of engine speed and milling drum speed by using a planetary summation transmission to continuously vary rotational speed Laux teaches that this flexibility can be used to optimize the road milling machine

performance that includes accounting for fuel consumption. Laux, 2:5-15, 5:61-6:24, 7:12-27.

IX. Application of the Prior Art to the Claims

A. Ground 1: Claims 1-13 Would Have Been Obvious Based on the Combination of Willis and Xing

64. The '538 Patent claims the combination of known milling machine components and powertrain systems with known controller-implemented methods for optimizing fuel efficiency while maintaining a desired rotor speed. Willis teaches a milling machine with a powertrain that includes an engine coupled to a rotor via a direct drive train. Numerous prior art references, including Parker, Laux, and Schomaker, taught that implementing a variable transmission and control system in a milling machine powertrain system would permit control of rotor speed independently of engine speed to maintain a desired rotor speed, leading to improved fuel efficiency. Xing taught an improved method of controlling a similar powertrain system to maintain a desired transmission output speed while optimizing engine fuel efficiency. Accordingly, a POSITA would have been motivated to modify Willis with the teachings of Xing and Laux and would have had a reasonable expectation of success in modifying Willis with Xing's teachings to arrive at the claimed invention. Willis, in view of Xing, renders all the '538 Patent claims obvious.

1. Reasons and Motivations for Combining the Teachings of Willis and Xing

65. A POSITA would have wanted to include Xing's system and method in Willis's milling machine. Milling machine operators and others familiar with milling machines understood that the operation of "milling machines is comparatively costly." Laux, 1:33-37. They understood that a "demand always exists for the most optimum possible machine operation," and to achieve "lowest possible fuel consumption" while, at the same time achieving "the highest possible milling performance." Laux, 1:33-37; *see also* EX1013, 3:18-20 ("The several embodiments described herein are designed to improve both the time and energy efficiency of a machine such as a cold planer or reclaimer/stabilizer machine."); EX1014, 2:6-11 ("What is needed, therefore, is a new combine harvester drive system for driving the rotor of a combine harvester that will permit the engine speed to automatically change from a high-speed/fuel inefficient region to a lower speed/fuel-efficient region while keeping the rotational speed of the rotor substantially constant."); EX1015, ¶[0003] ("Publication DE 38 10724 makes known an engine control system that is designed to ensure that—when the drive engine is operated in a partial load range at a lower engine speed in order to save fuel..."). Indeed, Willis understood the benefits of fuel efficiency and suggests lowering rotor speed when the machine is not working, or the drum is not cutting and is at partial load to minimize fuel consumption. Willis, ¶[0019].

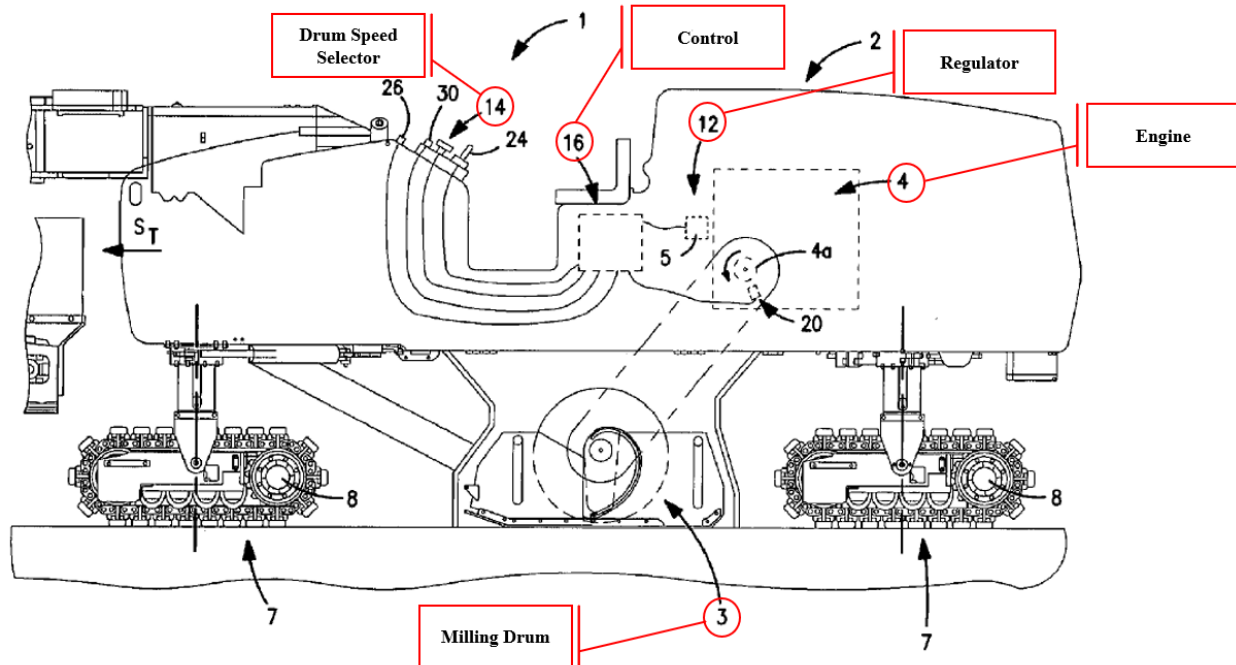
66. Using hydromechanical CVTs with internal combustion engines was a recognized way to independently control an engine in such machines to speeds that minimize fuel consumption for a given load while controlling transmission gear ratios to achieve desired transmission output speeds and maximize machine performance. EX1007, 2, 13–16, 23, 26, 31–34. Indeed, Parker, Laux, and Schomaker taught the advantages of implementing an electronically controlled variable transmission in a milling machine, e.g., a desired rotor speed could be achieved independent of engine speed. In my opinion, a POSITA would have understood that teachings regarding powertrain systems in a wide variety of machines could be universally applied to a wide range of mobile machines, including agricultural tractors and milling machines. EX1008, 2:43-61. Thus, a POSITA would have expected to successfully incorporate Xing's teachings regarding the configuration and operation of its controller, control algorithm, engine, and transmission system, or relevant components into Willis's milling machine. Relevant components would have included Xing's transmission, as well as its engine and transmission control algorithm and associated sensors, to reduce the fuel consumption and improve energy efficiency. For example, a POSITA would have wanted to, and would have expected to be able to incorporate Xing's controller algorithm, associated sensors and circuits, and continuously variable transmission into Willis's milling machine to improve the fuel efficiency of Willis's milling

machine while maintaining machine performance and desired rotor speeds received from an operator. Such a combination would amount to applying a known technique to a known device ready for improvement to yield predictable results.

2. Independent claim 1

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

67. Willis teaches a milling machine with an engine coupled to a rotor, which is a rotatable cutter drum or milling drum, under control of a drum speed control system. Willis, ¶[0017].



Willis, Fig. 3 (annotated)

68. The drum speed control system includes a controller that receives a desired drum cutting speed input from a speed selector and operates a regulator to adjust the drum cutting speed to the desired speed. Willis ¶[0003], ¶[0017]. Willis taught a direct drive train described as “engine 4 may drive the drum 3 through a transmission, such as a belt-and-pulley system or a gear train.” Willis, ¶¶[0020]-[0021]. The controller, or “the control 16,” is configured “to compare sensed drum speed DS_S with desired drum speed DS_D , and to operate the regulator 12 such that the sensed drum speed DS_S is generally equal to the desired drum speed DS_D .” Willis, ¶[0021]. The regulator can be any regulator capable of adjusting engine speed to correspondingly vary or adjust cutter drum speed DS . Willis, ¶[0020].

69. Willis combined with Xing discloses a milling machine having a rotor coupled to an engine through a variable transmission under control of a drum speed control system. Xing describes a system and method for reducing fuel consumption of a work vehicle by controlling a transmission. Xing, 1:18-20. Xing’s system and method is implemented in a work machine that has an internal combustion engine coupled to a hydromechanical CVT type variable transmission. Xing, 4:38-53, 4:64-5:8, 7:22-32. Xing’s transmission includes an output shaft 56, which is a part of Xing’s machine and is designed to rotate. Xing’s transmission can also be coupled to additional parts of the machine, such as PTO shaft 112 and implements, which are also designed to rotate. Xing, 4:49-53, 6:59-7:3. A controller connected to Xing’s

engine and transmission controls the engine speed and transmission ratio to optimize the machine's efficiency and minimize engine fuel consumption. Xing, 2:9-15, 7:4-32. The controller includes a processor that carries out instructions representing an algorithm. Xing, 7:33-59. Based on the algorithm, the controller determines engine load and controls the engine speed to minimize fuel consumption. In view of the engine speed, the controller adjusts the transmission gear ratio to control the rotational speed of the transmission output shaft speed based on user inputs setting machine desired performance, such as the desired ground speed. Xing, 4:38-53, 7:4-21, 7:33-59, 8:3-40.

70. Xing is directed to a system and method for reducing the fuel consumption of a work vehicle. Xing teaches that its system and method “may allow for a work vehicle 10 to be controlled in a manner that minimizes fuel consumption while maintaining the desired vehicle performance/productivity.” Xing, 8:54-9:3; *see also* Xing, 3:48-67 (“Specifically, the disclosed system and method may be utilized to minimize fuel consumption while maintaining the desired performance and productivity of the work vehicle.”), 12:26-13:50 (teaching that, “by considering the various individual component efficiencies, engine settings may be selected that minimize fuel consumption without impacting vehicle performance and/or productivity”). Xing evaluates power losses from the transmission and various other power consuming components at different speeds, work output demanded of the

machine, and independently sets engine speeds and transmission ratios to minimize fuel consumption while achieving desired performance. Generally, internal combustion engines can meet a machine's specific power demands or requirements within the engine's capability using different engine settings. Xing, 10:21-24. Xing teaches using engine maps to identify speeds at which an engine can achieve needed power requirements at improved engine fuel efficiency. Xing, 1:55-67, 10:21-24, 12:37-41. Although Xing applies its teachings to an agricultural tractor in specific examples, "in other embodiments, the work vehicle 10 may be configured as any other suitable work vehicle known in the art, such as various other agricultural vehicles, earth-moving vehicles, loaders and/or various other off-road vehicles." Xing, 4:2-7. Moreover, Xing teaches that its system "relates generally to work vehicles and, more particularly, to a system and method for reducing the fuel consumption of a work vehicle," and recognizes these vehicles as machines. Xing, 1:18-20, 4:64-5:2. Thus, a POSITA would have understood that Xing's teachings are broadly applicable to different machines that use an engine to power a load through a transmission.

71. Xing teaches that its system and method can be adapted for use in different machines. Xing teaches that its engine, transmission, and controller not only control and propel the work machine via its transmission output rotor shaft but also controls and powers various power consuming components and implements of the machine.

Xing, 4:14-16, 4:33-37, 4:42-46, 6:59-7:3. Although Xing's described embodiment of the transmission output shaft is coupled to and powers the drive wheels of Xing's work machine, which represent a load, the output can be connected to any other suitable load, including "separate operating system of the work vehicle 10 (e.g., a power-take off (PTO))." Xing, 4:49-53. Through a PTO shaft, the PTO can be configured to transfer power from the engine to one or more implements. Xing 6:59-7:3. Also, Xing explains that its controller and algorithms can be conveniently used in other machines, either by installing software or using plug in modules. Xing, 7:60-8:2. Thus, a POSITA would have had a reasonable expectation of successfully adapting Xing to use its transmission, controller algorithms, associated sensors and control circuits, or optionally larger subcomponents of Xing's machine, such as its engine, transmission, and controller in other work machines to power the machine's drive wheels/tracks or other components and implements, such as the milling drum in Willis's milling machine.

72. In my opinion, a POSITA would have been motivated to modify Willis's milling machine to include Xing's control algorithm, transmission, and other relevant components of Xing's system, such as Xing's associated sensors and circuits, so that at least one of the transmission output shafts would drive Willis's milling rotor to achieve the desired rotor speed received from Willis's operator

interface. Associated sensors and circuits could have included Xing's rotational shaft speed and torque sensors, and engine governors.

b) [a] "receiving a desired rotor speed;"

73. In the proposed combination, Willis's controller modified to include Xing's algorithm would have implemented the step of receiving a desired rotor speed. Willis teaches that its controller receives a desired rotor speed input from a milling drum speed selector. Willis, ¶[0003], ¶[0005], ¶[0017]. The drum speed selector is an operator interface that is electrically connected to the controller through which an operator can input different desired drum cutting speed commands the interface transmits to the controller. Willis ¶¶[0017]-[0019]. For example, Willis Fig. 1 discloses an exemplary interface where the operator may select the desired drum speed. Willis, ¶[0017].

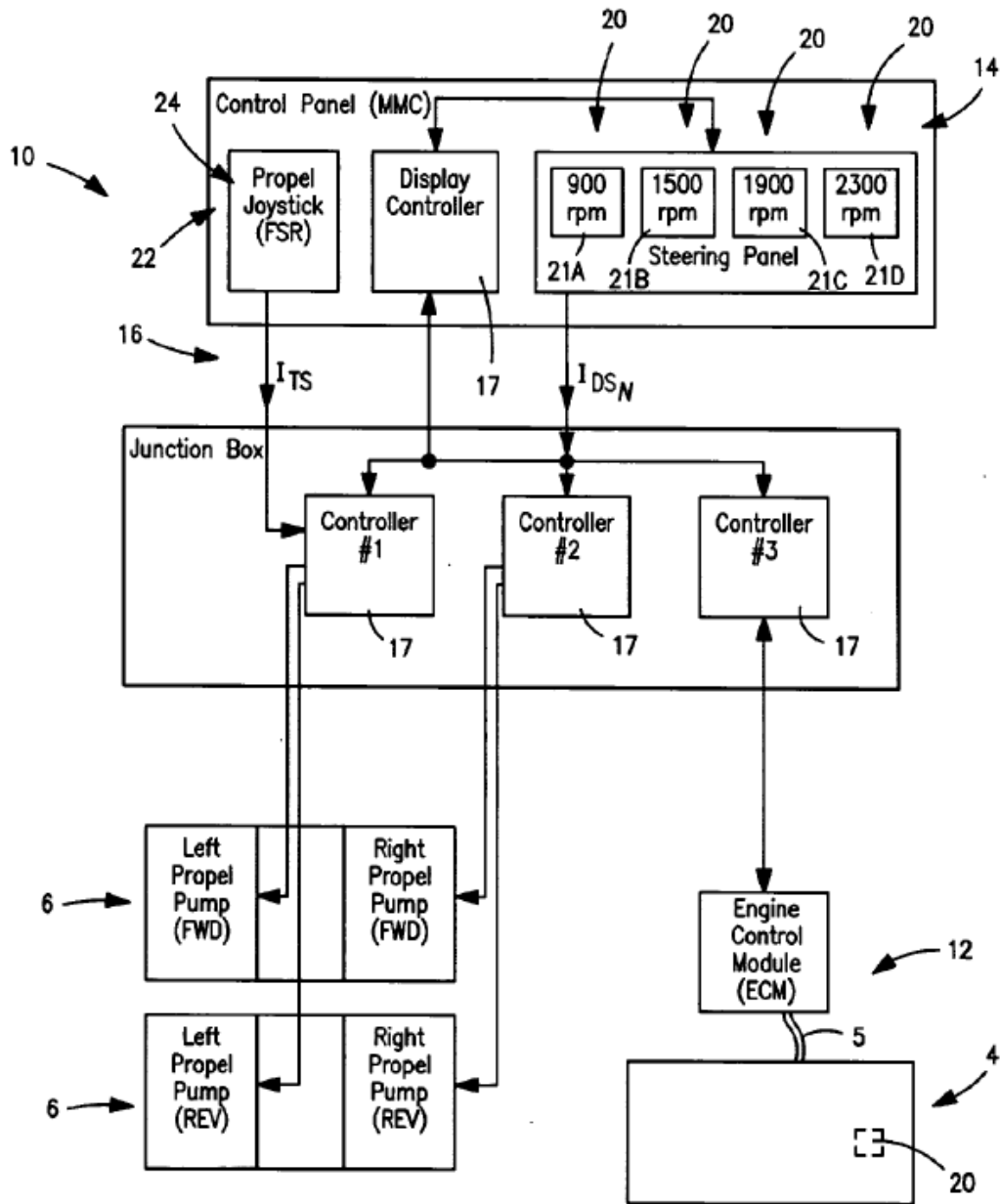


FIG. 1

Willis, Fig. 1

This interface transmits the input from the interface to control 16. Willis, ¶[0017].

Willis designated this input as I_{DS} , “corresponding to a desired drum cutting speed

DS_D.” Willis, ¶ [0017]. The controller, or “the control 16,” is configured to receive the desired drum speed and “to compare sensed drum speed DS_S with desired drum speed DS_D, and to operate the regulator 12 such that the sensed drum speed DS_S is generally equal to the desired drum speed DS_D.” Willis, ¶[0021]. The controller receives sensed drum speed signals from sensors that directly measure the actual rotational speed of the milling drum and/or that measure the rotational speeds of shafts connected to the milling drum. Willis, ¶[0017], ¶[0021]. The regulator can be any regulator “capable of adjusting engine speed and transmission to correspondingly vary or adjust cutter drum speed DS.” Willis, ¶[0020].

74. When incorporating Xing’s CVT transmission to drive Willis’s milling drum, as Xing and Laux teach, the engine would be coupled to the transmission input shaft. Xing, 2:34-50, 4:1-27; Laux, 8:60-9:28. Further, when incorporating Xing’s CVT, a POSITA would have understood that either Xing’s output shaft 56 or Xing’s power take off shaft 112 should be connected to rotate Willis’s milling drum at a desired speed. Willis, ¶[0020]; Xing, 4:46-53, 5:11-14, 6:53-7:3, 8:33-37.

75. Further, when adapting Willis’s controller to run Xing’s algorithm, a POSITA would have expected to successfully modify Xing’s algorithm to receive a desired rotor speed input from Willis’s speed selector, rather than the desired ground speed that Xing teaches. See Willis ¶¶[0020]-[0022]; Xing 5:42-55, 8:2-28. The CVT’s output shaft speed in the proposed combination would remain proportional to and

determine the rotational speed of Willis's milling drum, a POSITA would have understood how to modify algorithm parameters to account for changes in the coupling design. EX1008, 2:43-61. A POSITA would have understood that Xing's powertrain was universally applicable to a wide range of work machines including milling machines. As taught by Parker, Laux, and Hoff, POSITAs knew how to adapt Willis's controller to implement different control algorithms, such as Xing's control algorithm, to control Willis's desired milling drum rotor speed. EX1013, 6:55-67, 8:9-23; Laux, 2:5-9; EX1008, 2:43-61.

76. Although, in Xing's agricultural tractor, the rotational speed of the CVT's output shaft is generally proportional to and determines working vehicle ground speed when connected in Xing's machine, the CVT's output shaft speed in the proposed combination is connected to Willis's milling drum and is therefore proportional to and determines the rotational speed of Willis's milling drum. Xing 4:64-66, 6:53-58, 13:24-35.

77. A POSITA would have expected to successfully adapt Willis's controller to run Xing's algorithm to use the desired rotor speed DS_D (corresponding a desired rotor speed) input (I_{DS}) received by Willis's controller from Willis's speed selector rather than the desired ground speed that Xing teaches. Willis, ¶¶[0020]-[0022]; Xing, 5:42-55, 8:2-28. In Willis, the rotor is coupled to the output of the direct drive train. In Xing, the drive shaft for the wheels is coupled to the output of the CVT

transmission. The proposed modification would couple Willis's rotor to the output of Xing's transmission. Thus, in my opinion a POSITA would have understood that a desired rotor speed, like Xing's desired ground speed, would be dictated by the speed of Xing's output shaft 56. POSITAs knew how to adapt algorithms such as Xing's algorithm to convert the output shaft rotational speed to Willis's milling drum rotor speed. It was well-known that powertrain control systems were universally applicable to a wide range of work machines including milling machines. For example, as discussed with respect to Parker and Laux, POSITAs knew how to adapt milling machine controllers to control rotor speed based on a desired milling drum rotor speed. EX1013, 6:55-67, 8:9-23; Laux, 2:5-9; EX1008, 2:43-61.

c) [b] “determining an engine load of the engine;”

78. In the proposed combination, a POSITA would have implemented the step of determining an engine load of the engine from Xing's algorithm. Xing discloses a controller adjusting the engine speed to minimize fuel consumption based on the current load on the engine. Xing 2:9-12, 3:50-67, 11:65-12:11. To do this, the controller determines engine load using sensors communicatively coupled to controller, such as torque sensors coupled to the engine for monitoring the engine torque loads. Xing 8:16-40. A POSITA 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. The processor implementing the

algorithm 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}). Xing 9:37-56. The controller calculates the power load requirement for the proposed combination using the equation: $P_{engine} = P_{load} + P_{loss}$. Xing 9:53-56.

79. To implement Xing’s algorithm, a POSITA would have been motivated to incorporate engine torque sensors into Willis to provide the controller with the inputs necessary to execute Xing’s algorithm. Including these sensors would have been within the skill of a POSITA. Willis’s controller already communicated with a sensor to measure engine speed. Therefore a POSITA would have expected to successfully add additional sensors. Willis, ¶[0021].

d) [c] “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”

80. In the proposed combination, a POSITA would have implemented the step of adjusting an engine speed of the engine based on engine load and engine maps that provide optimum engine speeds for different engine loads. Configured with Xing’s algorithm, the machine’s controller adjusts the engine to run at one of the speeds at which the engine can produce sufficient power to meet the current load and at which

the engine and the speed at which the engine minimizes fuel consumption. Xing 3:50-67, 9:37-40, 10:33-37, 11:65-12:11, 12:26-47. As explained with respect to claim limitation 1[b], Xing's algorithm determines the engine load to calculate the machine's load power requirement. Xing 9:37-56. For example, in blocks 204 to 208 of Fig. 4, controller 116 calculated a plurality of candidate engine settings (i.e., pairs of specific engine speeds and engine torques) based on the power load requirements and the estimated power loss due to the machine's components. Xing, 3:58-63, 10:16-12:25, 12:12-47.

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
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.

FIG. -5-

Xing, Fig. 5

To determine the fuel consumption of each pair of candidate engine speeds and torques, the controller references the fuel consumption map or other suitable fuel efficiency data (as shown in Fig. 11). Xing 12:48-58.

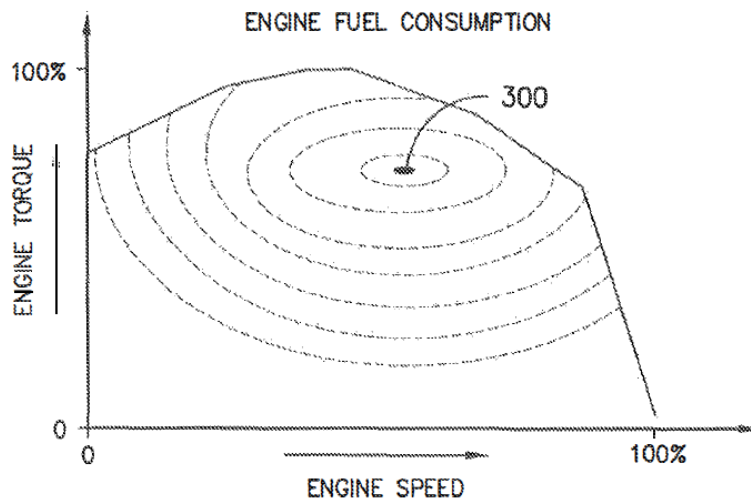


FIG. -11-

Xing, Fig. 11

The controller then selects the candidate engine speed/torque pair that minimizes fuel consumption (i.e., the pair intersecting closest to the optimal fuel efficiency point) as the target engine speed and target engine torque. Xing, 12:58-63. The controller may then set the engine to operate based on the target engine speed. Xing, 3:58-67, 8:64-9:3.

81. To implement Xing's algorithm and obtain the fuel efficiency benefits that Xing teaches, a POSITA would have been motivated to incorporate Xing's engine map to utilize the engine load data from the sensors such that the controller could

execute the algorithm and select engine settings to achieve an optimized engine speed. Storing the engine data to the controller or associated memory for reference by the controller would have been within the skill of a POSITA using standard data structures.

e) [d] “adjusting a gear ratio of the variable transmission based on the engine speed and the desired rotor speed.”

82. In the proposed combination, a POSITA would have implemented the step of adjusting a gear ratio of the variable transmission based on engine speed and the desired rotor speed. For example, Xing’s algorithm directs the controller to adjust transmission gear ratio based on the engine speed and the desired ground speed. Xing, 3:58-67. As noted with respect to claim element 1[c], Xing’s controller selects a candidate engine speed/torque pair that maximizes fuel efficiency (i.e., the pair intersecting closest to the optimal fuel efficiency point) as the target engine speed and target engine torque, and operates the engine at the selected engine settings. Xing 8:64-9:3, 12:48-63. The controller then adjusts the transmission ratio of the transmission 24 to ensure that the machine maintains the desired ground speed, representing an operator input received in the controller from an input device, is maintained. Xing 4:16-19, 8:3-15, 13:19-29.

[T]he controller 116 may be communicatively coupled to an engine governor 118 in order to control and/or monitor the speed of the engine 22. Similarly, as indicated above, the controller 116 may be coupled to various components of the transmission 22 (e.g., the clutch actuators 62

and/or the swash plate actuator 64) in order to control the transmission 24 in a manner that provides a continuously variable transmission ratio.

Xing, 7:25-31.

The candidate engine settings may then be analyzed to determine the specific engine settings the specific settings at which the vehicle's fuel consumption is minimized. The engine operation may then be set to the specific engine settings and the transmission ratio may be adjusted such that the desired vehicle performance/productivity is maintained.

Xing, 8:64-9:3. To adjust the transmission ratio so that the machine maintains the desired ground speed, the controller bases its transmission ratio measurement on the actual engine speed.

83. Xing's controller 116 can receive various operator inputs through input device 120 including a desired work vehicle ground speed. On receiving the input, controller 116 can control the engine speed and the transmission ratio of the work vehicle 10 to achieve the commanded ground speed. Xing 8:3-15, 8:64-9:3. The controller is coupled to "various components of the transmission 22 (e.g., the clutch actuators 62 and/or the swash plate actuator 64) in order to control the transmission 24 in a manner that provides a continuously variable transmission ratio." Xing 7:28-32.

wheels. In controlling the angle of swash plate 48 using actuator 64 to adjust the transmission ratio and maintain a desired ground speed, the controller 116 also controls output shaft 56 to maintain a target rotational speed. The transmission ratio is based on the actual engine speed, *ES*, and the target speed of output shaft 56 dictated by the desired speed the controller 116 receives from the operator input device. Xing 5:38-55, 8:29-41.

85. In the proposed combination, a POSTIA would have utilized the desired rotor speed in place of the ground speed. Like Xing's desired ground speed, Willis's desired rotor speed is dictated by the rotary speed of Xing's output shaft 56. Thus, to control the transmission gear ratio in the proposed combination, a POSITA would have used the desired rotor speed in place of the desired ground speed. A POSITA would have expected to be able to successfully adapt a controller in Willis's machine that is running Xing's algorithm to use the desired rotor speed input from Willis's speed selector to maintain the desired rotor speed because this is a simple substitution consistent with Xing teachings and well within POSITA's background. Willis, ¶¶[0020]-[0022]; Xing 5:43-55, 8:3-28.

86. As in Parker and Laux, the modification would have coupled the output of the variable transmission to Willis's rotor so as to maintain a desired rotor speed in Willis's milling machine. And implementing Xing's control system in Willis's

milling machine would confer Xing's stated benefit of minimizing fuel consumption while maintaining desired machine performance, i.e., constant rotor speed.

87. A POSITA would have had a reasonable expectation of successfully making such a modification. Parker already taught a milling machine wherein the engine is coupled to the rotor via a variable transmission. A POSITA would have understood that installing a CVT between Willis's engine and milling rotor requires using a different coupling between the transmission output shaft and the milling rotor than between the output shaft and wheels of Xing's work machine. Although the CVT's output shaft speed in the proposed combination would remain proportional to and determine the rotational speed of Willis's milling drum, a POSITA would have understood how to modify algorithm parameters to account for changes in the coupling design. EX1008, 2:43-61; Xing, 4:33-37. A POSITA would have understood that Xing's powertrain was universally applicable to a wide range of work machines including milling machines. Xing, 4:33-37. POSITAs knew how to adapt controllers of Xing's work machine to control Willis's desired milling drum rotor speed. EX1013, 6:35-7:8, 8:9-23; Laux, 2:5-9; EX1008, 2:43-61. Accordingly, a POSITA would have expected to be able to successfully adapt a control system like that taught by Xing to Willis's machine to use the desired rotor speed input from Willis's speed selector.

3. Claim 2

88. The combination of Willis and Xing renders this claim obvious.

a) “The controller-implemented method of claim 1,”

89. The combination of Willis and Xing renders obvious the method of claim 1.

Supra IX.A.2.

b) “wherein the desired rotor speed is received through an operator interface of the machine.”

90. A controller in Willis’s milling machine modified to include Xing’s algorithm for reducing fuel consumption would have implemented the step of receiving a desired rotor speed through an operator interface of the machine. Willis teaches that its milling machine controller receives a desired rotor speed input from a milling drum speed selector. Willis, ¶[0017]. The drum speed selector can include buttons such as those shown in Fig. 1 (21A-D), an operator can press to generate different inputs, or a knob that an operator can turn to generate different inputs, each of which represents a different desired milling drum rotational speed. Willis, ¶¶[0017]-[0019].

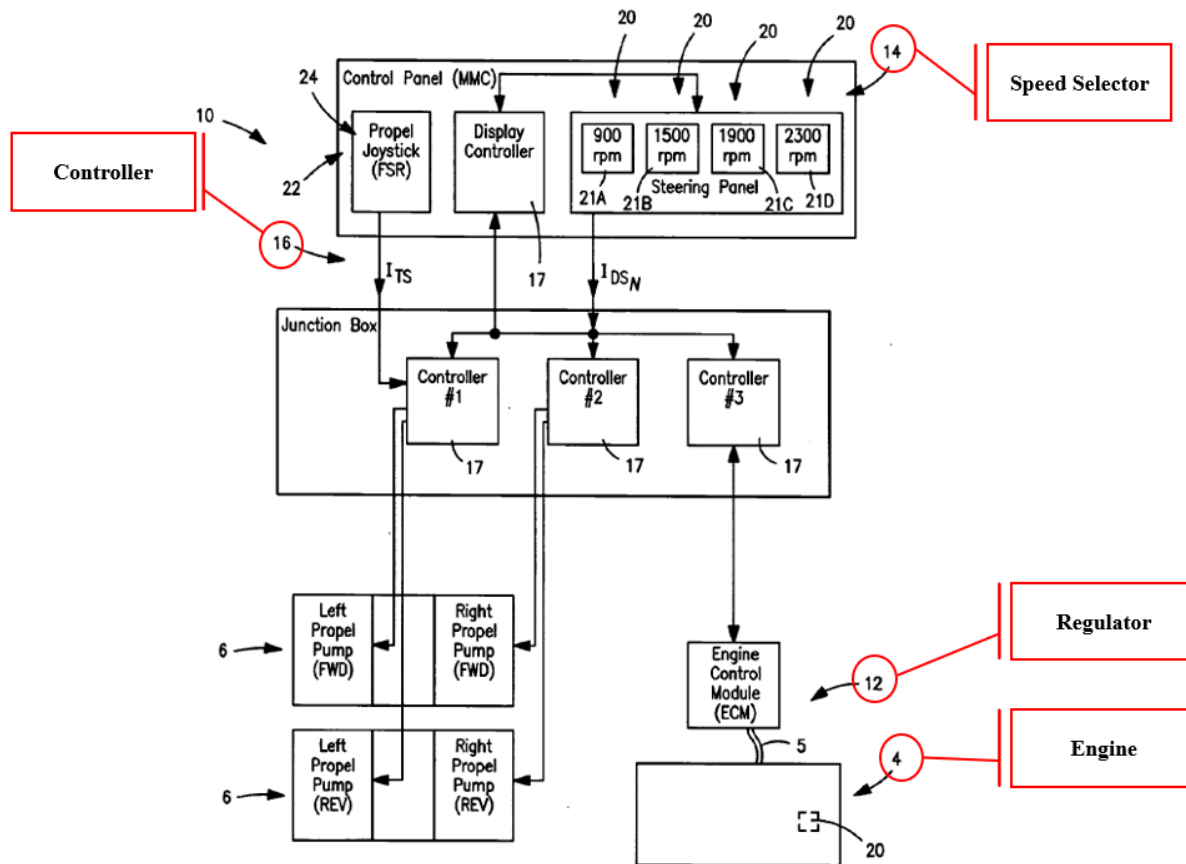


FIG. 1

Willis, Fig. 1 (annotated)

91. Willis's controller is electrically connected to the speed selector and to the regulator. Willis, ¶[0017], ¶[0021]. The controller receives the desired milling drum speed input from the drum speed selector. *See supra* IX.A.2.b.

4. Claim 3

92. The combination of Willis and Xing renders this claim obvious.

a) “The controller-implemented method of claim 1,”

93. The combination of Willis and Xing renders obvious the method of claim 1.
Supra IX.A.2.

b) “wherein the engine load includes loads due to at least the rotor and a hydrostatic arrangement.”

94. A controller in Willis’s milling machine modified to include Xing’s algorithm for reducing fuel consumption would have implemented the step of determining engine load wherein the engine load includes loads due to at least the rotor and a hydrostatic arrangement. Willis discloses that the engine drives the milling drum (cutter drum 3), hydrostatic pumps 6, and the motors that “operatively drive” power the machine’s travel motors, crawler motors 8. Willis ¶[0004], ¶[0017], ¶[0023], Fig. 4. As Willis teaches in Fig. 4 and in the specification, the engine drives pumps which are connected to hydraulic crawler motors. The pumps and connected hydraulic motors represent a hydrostatic arrangement. Willis ¶[0004], ¶[0017], ¶[0023], Fig. 4.

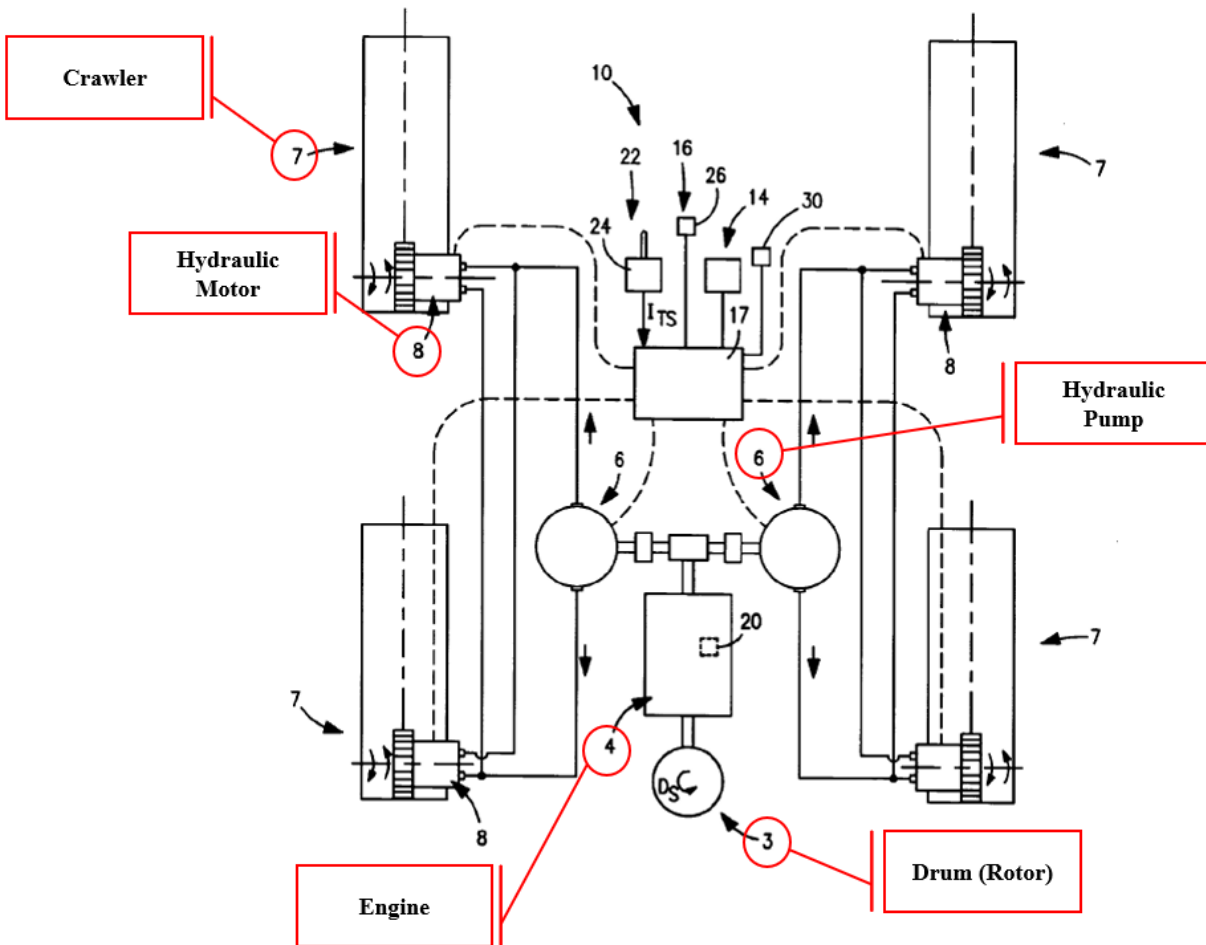


FIG. 4

Willis, Fig. 4 (annotated)

95. A POSITA would have understood that another source of the load on the engine for driving the rotor in the proposed combination would have been Xing's CVT transmission which includes a combination of both a CVT mechanical arrangement and a CVT hydrostatic arrangement. As explained above with respect to claim 1 limitations 1[p] and 1[a], Willis teaches that the milling machine's engine can be configured to drive the milling drum such that the engine load includes loads due to the rotor. Willis, ¶[0020]. And a POSITA would have wanted to incorporate

Xing's CVT into Willis's milling machine coupled between Willis's engine and milling drum. See, e.g., *supra* IX.A.1, 2.a. In this configuration, Xing's CVT includes both an output shaft 56 and a hydrostatic unit. Xing, 4:42-53. A POSITA would have understood that the hydrostatic unit is a hydrostatic arrangement and generally includes a hydraulic pump coupled by fluid conduits in a closed loop to a hydraulic motor. See Xing, 4:54-56. The hydraulic unit is connected at one end to a load on the transmission's output and, at its other end, connected to and exerts a load on the engine. Xing, 4:42-53, Fig. 2.

96. Xing's controller can determine the total load on the engine through torque and speed sensors on the engine. Xing teaches that the controller is "communicatively coupled to various sensors, such as a torque sensor 122 and/or a speed sensor 124, mounted on and/or within the engine 22 for monitoring the engine torque loads and/or the engine speed." Xing, 8:17-28. A POSITA would have understood that these load measurements from the torque load sensors would have included engine loads resulting from the components connected to and receiving power from the engine. This would include the hydrostatic arrangement in Xing's CVT and loads on output shaft of the CVT due to the pump and crawler motor hydrostatic arrangement and the loads from the rotor (milling drum rotor).

97. For example, Xing taught that the controller could determine a power loss value (P_{loss}) based on the sum of the individual "parasitic power losses associated

with the various drivetrain components and/or other power consuming components of the work vehicle 10,” as exemplified by the following equation “ $P_{loss} = P_{transmission} + P_{PTO} + P_{drive\ axle} + P_{fan} + P_{other}$.” Xing, 10:43-11:64. By accounting for $P_{transmission}$, Xing taught accounting for the losses due to the mechanical and hydrostatic arrangements in the CVT.

5. Claim 4

98. The combination of Willis and Xing renders this claim obvious.

a) “The controller-implemented method of claim 1,”

99. The combination of Willis and Xing renders obvious the method of claim 1.

Supra IX.A.2.

b) “wherein the engine speed is automatically adjusted based on detected changes in the engine load according to one or more predetermined relationships providing a plurality of the predefined efficiency points.”

100. A controller in Willis’s milling machine modified to include Xing’s algorithm for reducing fuel consumption would have implemented the step of adjusting engine speed wherein the engine speed is automatically adjusted based on detected changes in the engine load according to one or more predetermined relationships providing a plurality of the predefined efficiency points. Xing teaches an algorithm where a controller of the resulting modified milling machine would have automatically adjusted engine speed based on changes in detected load according to one or more

predetermined relationships providing a plurality of predefined efficiency points. Xing, 9:4-64, 10:16-12:11, 12:26-63.

101. Xing describes instructions representing an algorithm that a controller performs to adjust the engine to run at a speed that minimizes fuel consumption based on the current load on the engine. Xing, 2:9-12, 3:50-67, 11:65-12:11. Specifically, as Xing Fig. 4 depicts, the controller determined the current engine load by “continuously monitor[ing] the engine speed and the engine torque.” Xing 9:37-56, Fig. 4. As explained with respect to claim limitation 1[b] above, Xing’s algorithm measures and determines the current engine power (P_{engine}) needed to meet the machine’s combined current load power requirement (P_{load}) and current power loss due to system inefficiencies (P_{loss}). Xing, 9:27-44. In addition, using efficiency data stored in memory, Xing’s algorithm estimates current power loss (P_{loss}) based on current vehicle operating parameters. Xing, 9:44-53. Then, having determined the current engine power and estimated current power loss, the algorithm calculates the machine’s current load power requirement (P_{load}). *Supra* IX.A.2.c; Xing 9:53-56. Based on the continuously monitored engine loads, the controller calculates a plurality of candidate engine settings using efficiency data such as fuel consumption maps. Xing 3:58-63, 12:12-25, 12:48-58.

102. Having determined the machine’s current load power requirement (P_{load}), the algorithm seeks other candidate settings at which the machine can achieve similar

load power requirement (P_{load}) more efficiently. Xing, 8:53-9:3. The algorithm determines candidate power loss values for a range of candidate engine speeds (as shown in Fig. 5) using suitable efficiency data for one or more of the components of the work vehicle. Xing, 10:42-11:47. By adding the candidate power loss values to the current power load requirement at each candidate speed, the algorithm calculates candidate engine powers necessary for the engine to meet the power estimated load power requirement and power losses at each of these candidate speeds. Xing, 11:65-12:11. This search for candidate settings can be global and can consider every possible combination of engine speeds, torques, and transmission ratios within the working ranges of the machine. Xing, 12:12-25. The algorithm further analyzes fuel efficiency data to determine a target engine speed based on the candidate engine powers. For example, the controller 116 can determine a candidate engine torque (as shown in Fig. 5) for each pair of candidate engine powers and speeds (e.g., by dividing each candidate engine power by its associated engine speed). Each set of engine torques and engine speeds may then be utilized to determine the most fuel efficient engine settings for achieving the desired load power requirement. Xing, 12:26-35, Fig. 11.

103. Based on the load power requirement, the controller calculates a plurality of candidate engine settings (e.g., pairs of specific engine speeds and engine torques). By referencing fuel consumption maps, tables, or other suitable fuel efficiency data,

the controller determines which candidate engine settings may be used as the target engine settings for minimizing fuel consumption while maintaining the desired vehicle performance/productivity. Xing 3:58-63, 12:12-25, 12:48-58. The controller, which is communicatively coupled to an engine governor, then selects one of the candidate engine speed/torque pair that maximizes fuel efficiency as the target for producing the engine power necessary to achieve the load power requirement and controls the engine to meet the target. Xing 3:58-67, 7:25-31, 8:13-16, 8:64-9:3, 12:58-63. Because Xing teaches that the controller can determine candidate engine speeds based on the current load power requirement (which it derives from current engine power load and torque measurements), changes in current detected engine load automatically result in changes in the adjusted engine speed. Xing, 9:7-17, 9:37-56, 10:33-37.

6. Claim 5

104. The combination of Willis and Xing renders this claim obvious.

a) “The controller-implemented method of claim 1,”

105. The combination of Willis and Xing renders obvious the method of claim 1.

Supra IX.A.2.

b) “wherein the gear ratio of the variable transmission is automatically adjusted to maintain a rotor speed of the rotor at the desired rotor speed irrespective of changes in the engine speed.”

106. A controller in Willis’s milling machine modified to include Xing’s algorithm for reducing fuel consumption would have implemented the step of adjusting a transmission gear ratio wherein the gear ratio of the variable transmission is automatically adjusted to maintain a rotor speed of the rotor at the desired rotor speed irrespective of changes in the engine speed. Xing’s algorithm instructs the controller to adjust the gear ratio of the CVT to maintain the rotor speed at the desired speed irrespective of the engine speed. Xing, 8:54-9:3, 13:26-35. Specifically, having controlled the speed of the machine’s engine based on the currently determined engine load, the controller “adjust[s] the transmission ratio of the transmission 24 to ensure that the desired ground speed is maintained,” under command of Xing’s algorithm. Xing, 13:4-22.

107. With Xing’s transmission incorporated into Willis, as described above (with respect to parent independent claim 1), Xing’s output shaft 56 would be coupled to and dictate the rotational speed of Willis’s milling drum rotor. A POSITA would have expected to be able to successfully adapt a controller in Willis’s machine that is running Xing’s algorithm to use the desired rotor speed input from Willis’s speed selector. Willis ¶¶[0020]-[0022]; Xing, 5:43-55, 8:3-28. As taught by Parker, Laux, and Hoff, POSITAs knew how to adapt controllers of Xing’s work machine to

control Willis's desired milling drum rotor speed. EX1013, 6:55-67, 8:9-23; Laux, 2:5-9; EX1008, 2:43-61

7. Independent Claim 6

108. The combination of Willis and Xing renders this claim obvious.

a) [p] “A machine, comprising:”

109. The combination of Willis and Xing discloses a machine. Both Willis and Xing are directed to work machines. Willis teaches a milling machine with an engine coupled to a rotatable cutter drum, or milling drum rotor, under control of a drum speed control system. The drum speed control system includes a controller that receives a desired drum cutting speed input from a speed selector and operates a regulator to adjust the drum cutting speed to the desired speed. Willis, ¶[0003], ¶[0017].

110. Xing describes a work machine that has an internal combustion engine coupled to a hydromechanical CVT transmission. Xing 1:18-28, 2:34-38, 4:38-53, 7:22-32.

b) [a] “an engine;”

111. The combination of Willis and Xing discloses a machine with an engine. *See supra* IX.A.2.a, 7.a.

c) [b] “a variable transmission operatively coupled to an output of the engine;”

112. The combination of Willis and Xing discloses a variable transmission operatively coupled to an output of the engine. Willis teaches that its milling machine can include an engine which drives the machine’s milling drum through a direct drive train as well as a regulator configured to controllably vary the engine speed and thereby adjust the rotational speed of the milling drum. Willis, ¶[0020].

113. A POSITA would have been motivated to modify Willis to include a variable transmission, sensors for determining current rotor speed, engine speed, and engine load, and a control algorithm designed to optimize fuel efficiency based on rotor speed, engine speed, and engine load, such as the transmission, sensors and algorithm disclosed in Xing to improve fuel consumption and machine energy efficiency. Willis teaches that minimizing fuel consumption is desirable and suggests lowering rotor speed when the machine is not working, or the drum is not cutting and is at partial load. Willis, ¶[0019]. This teaching reflects the general well-established desire in industry to minimize milling machine operating costs by minimizing milling machines’ fuel consumption while achieving desired milling performance. Laux, 1:33-37; EX1013, 3:18-20; EX1014, 2:6-11; EX1015, ¶[0003]. Using hydromechanical CVTs with internal combustion engines was a recognized way to enable independent control of an engine in such machines to speeds that minimize fuel consumption for a given load while controlling transmission gear

ratios to achieve desired transmission output speeds and maximize machine performance. EX1007, 2, 13–16, 23, 26, 31–34.

114. Xing describes a work machine that has an internal combustion engine coupled to a hydromechanical CVT transmission. Xing, 4:38-53, 7:22-32. Xing's work machine has a controller connected to the engine and transmission which controls the engine speed and transmission ratio to optimize the machine's efficiency and minimize engine fuel consumption. Xing, 2:9-15, 7:4-32. The controller includes a processor that performs functions and carries out instructions representing an algorithm. Xing, 7:33-59. Using the algorithm, the controller determines engine load, measures current engine and transmission output shaft speeds, and controls engine speed and transmission output shaft rotational speed to achieve the desired performance (ground speed) while minimizing engine fuel consumption in view of loads from the machine's rotor, hydrostatic drive system, and ancillary devices that the engine powers. Xing, 4:38-53, 7:4-21, 7:33-59, 8:3-40.

115. Xing teaches that its engine, transmission and controller not only control and propel the work machine via various transmission output rotor shafts but also controls and powers various power consuming components and implements of the machine. Xing 4:14-16, 4:33-46, 6:59-7:3. Thus, a POSITA would have expected to be able to successfully modify Xing to use its engine, transmission, and controller in other work machines that power both drive the machine's propel system as well

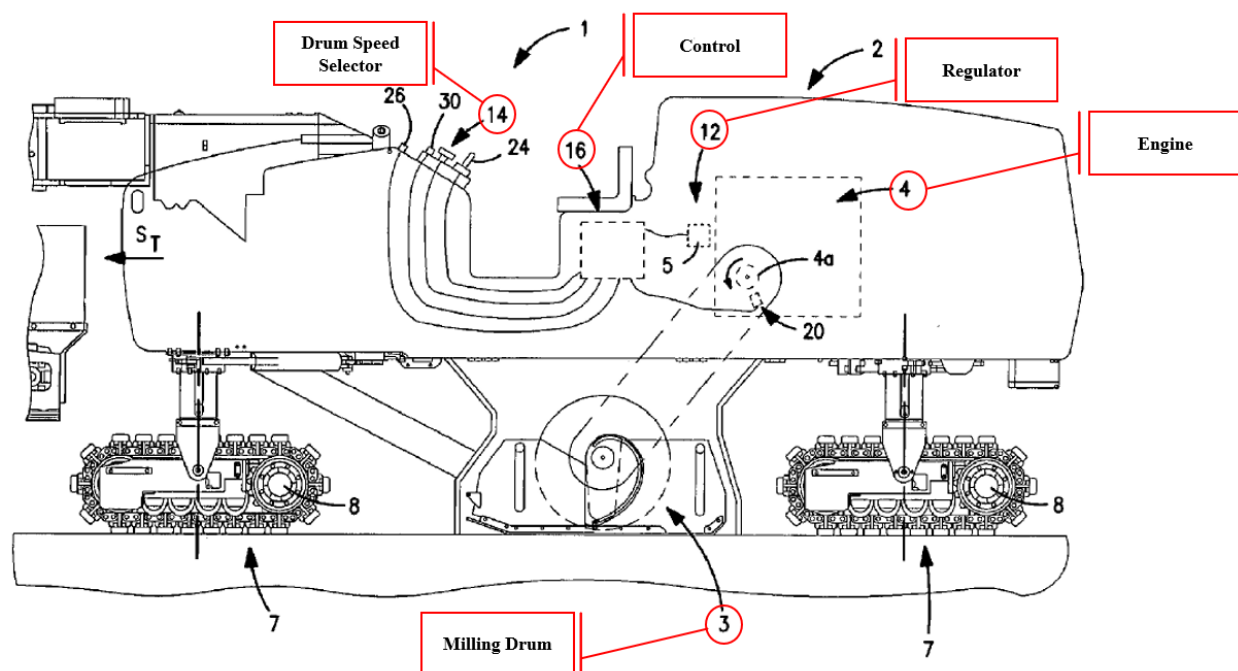
as other components and implements, such as Willis's milling machine, without undue experimentation.

116. A POSITA would understand that Willis's milling machine could be modified to include relevant components of Xing's engine, transmission, and controller, so that at least one of the transmission output shafts would drive and determine the speed of Willis's milling rotor to achieve the desired rotor speed received from Willis's operator interface. Relevant components can include Xing's CVT, the engine and transmission control algorithms used in Xing's controller, as well as relevant sensors such as rotational shaft speed and torque sensors, and engine governors. A POSITA would have wanted to make such a modification. A POSITA would have understood, based on Xing, that additional efficiencies could be achieved by operating the machine's engine at low engine speeds with corresponding gear ratio changes to achieve both desired milling rotor speeds and most fuel efficient engine speeds possible given the measured load. Also see claim 1 above. *See supra* IX.A.1, 2.a.

d) [c] “a rotor operatively coupled to an output of the variable transmission; and”

117. The combination of Willis and Xing discloses a rotor operatively coupled to an output of a variable transmission. Willis teaches a milling machine with an engine coupled to a rotatable cutter drum, or milling drum rotor, under control of a drum speed control system. Willis, ¶[0003], ¶[0017]. Willis teaches that the engine can

drive the drum through a direct drive train, and the regulator can be configured to controllably vary the drum speed. Willis, ¶[0020]. Willis further teaches that its milling machine can include a regulator configured to “controllably vary the drum speed DS.” Willis, ¶[0020].



Willis, Fig. 3 (annotated).

118. Xing teaches a work machine with a variable transmission operatively coupled to an output of the engine. Xing, 4:8-54, Figs. 2, 3. Xing teaches that its engine, continuously variable transmission and controller not only control and propel the work machine via various transmission output rotor shafts but also control and power various power consuming components and implements of the machine, represented as a load L on the transmission output shaft. Xing 4:14-19, 4:33-53,

5:14-23, 6:59-7:3, 7:28-32, Figs. 2, 3. Thus, a POSITA would have reasonably expected to be able to successfully adapt Xing's transmission and control algorithm for use in other work machines to power and control the machine's travel or propulsion system, as well as to power and control other components and implements driven from the transmission, such as the milling drum in Willis's milling machine. *See supra* IX.A.1, 2.a, b, e.

119. In implementing Xing's CVT in Willis's milling machine, a POSITA would have been motivated to modify Willis's milling machine so that the output of the CVT (e.g., Xing's transmission output shaft 56) drives Willis's rotor and would have had a reasonable expectation of success in doing so. A POSITA would have understood from Parker and Laux that the variable transmission could be implemented at different locations within the drive train. *Supra* VIII, IX.A.1, Laux, 6:45-7:5. Accordingly, a POSITA would have understood that the rotor could be coupled to the variable transmission at least either (1) directly via the CVT output shaft or (2) indirectly to the CVT via a PTO, PTO clutch, and PTO shaft.⁴ This

⁴ Xing teaches alternative ways a load, such as a machine's drive system or implements such as a rotor, can be coupled to the variable transmission so that implements can be isolated from all engine power for added safety and efficiency when unused, while other machine components remain selectively connected to engine hydraulic or mechanical power. Xing, 2:34-50, 4:1-27, 4:33-37, 6:59-7:3. Xing teaches that such powertrain systems can be implemented in any "suitable work

modification would have resulted in a milling machine having “a rotor operatively coupled to an output of the variable transmission.”

120. A POSITA would have expected to be able to successfully modify Willis in view of Xing’s teachings with reasonably minimal effort. For example, Xing teaches that the engine, transmission, and controller may be used in various work machines to power and control their propulsion system, as well as to power and control other components and implements driven from the variable transmission. Considering the prior-art teachings regarding implementing variable transmissions in milling machines, a POSITA would have recognized that the rotor in Willis’s milling machine constitutes one of those other components or implements.

vehicle known in the art” to power any work implement and POSITAs understood how to adjust the designs for competing benefits of safety and convenience. Xing 4:1-27, *supra* VIII.B, IX.A.1. Based on Xing, a POSITA would have modified Willis’s machine to couple rotor to Xing’s variable transmission either (1) directly via the CVT output shaft or (2) indirectly to the CVT via a PTO, PTO clutch, and PTO shaft. This modification would have resulted in a milling machine having “a rotor operatively coupled to an output of the variable transmission.” Although my opinion focuses on the variable transmission’s output shaft, but unless otherwise noted, such discussions apply equally to the PTO shaft.

e) [d] “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.”

121. The combination of Willis and Xing discloses a controller in electrical communication with one or more of an engine a variable transmission and a rotor. For example, Willis teaches that its control system includes a controller that communicates using transmitted signals with sensors in one or more of the engine and milling drum rotor and operates a regulator to control engine speed. Willis, ¶¶[0020]-[0022]. Xing teaches “the controller 116 may be communicatively coupled to an engine governor 118 in order to control and/or monitor the speed of the engine 22. Similarly, as indicated above, the controller 116 may be coupled to various components of the transmission 22 (e.g., the clutch actuators 62 and/or the swash plate actuator 64) in order to control the transmission 24 in a manner that provides a continuously variable transmission ratio.” Xing, 7:21-31. The controller can also be communicatively coupled to various sensors on or in the engine and transmission to measure the torque and speed of various engine and transmission shafts, including the transmission output shaft and drive axles. Xing, 8:16-51.

122. The combination of Willis and Xing discloses a controller that would have been configured to determine an engine load. *Supra* IX.A.2.c.

123. The combination of Willis and Xing discloses a controller that would have been configured to 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. *Supra* IX.A.2.d.

124. The combination of Willis and Xing discloses a controller that would have been configured to adjust a gear ratio of the variable transmission based on the engine speed to maintain a desired rotor speed. *Supra* IX.A.2.b, e.

8. Claim 7

125. The combination of Willis and Xing renders this claim obvious.

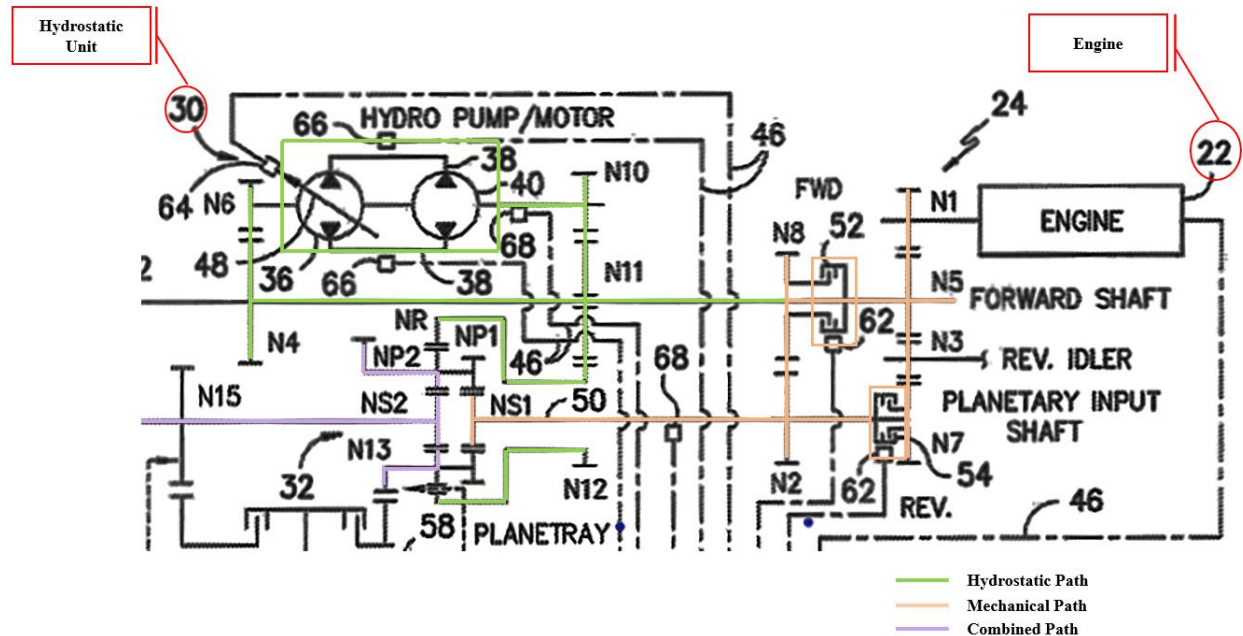
a) “The machine of claim 6,”

126. The combination of Willis and Xing renders obvious the machine of claim 6. *Supra* IX.A.7.

b) “wherein the variable transmission includes a gear set and a hydraulic motor configured to adjust a rotor speed of the rotor.”

127. Modifying Willis’s milling machine to include a variable transmission with a gear set and a hydraulic motor configured to adjust a rotor speed of the rotor would have been obvious in view of Xing. Xing’s variable transmission includes a gear set

(planetary unit 32) and a hydrostatic unit 30 comprising a hydraulic pump 36 coupled to a hydraulic motor 40. Xing, 4:42-56.



Xing, Fig. 2 (excerpt annotated)

The hydrostatic unit 30 and the planetary unit 32 are coupled to an output shaft 56 of the transmission. Xing, 6:6-13. The controller 116 controls the hydrostatic unit 30 to adjust the gear ratio of the planetary unit 32, which in turn adjusts output shaft 56 rotational speed using the hydraulic motor 40.

[T]he controller 116 may be communicatively coupled to the pump 36 via a suitable communicative link 46 so that the angle of a swash plate of the pump 36 (the swash plate being denoted by a diagonal arrow 48 through pump 36) may be adjusted through a range of positions, thereby adjusting the transmission ratio of the transmission 24.

Xing, 5:2-8. For any given engine speed, the adjustment of the transmission ratio adjusted the rotational speed of the output shaft 56. This allowed the engine speed

to be selected for maximum fuel efficiency while allowing the output shaft speed to be controlled to achieve desired rotational speed of the load. In Xing, the desired rotational speed was the rotational speed of the drive wheels, whereas, in Willis, the desired rotational speed was the milling rotor speed. Thus, Willis, as modified by Xing, would have had a variable transmission that included a gear set and a hydraulic motor configured to adjust a speed of the rotor.

128. As explained above with respect to claims 1 and 6, a POSITA would have been motivated to incorporate Xing's transmission into Willis's milling machine so that the transmission's output shaft is coupled to Willis's milling drum rotor, and would have reasonably expected to succeed in doing so. *See supra* IX.A. 1, 2, 7.

9. Claim 8

129. The combination of Willis and Xing renders this claim obvious.

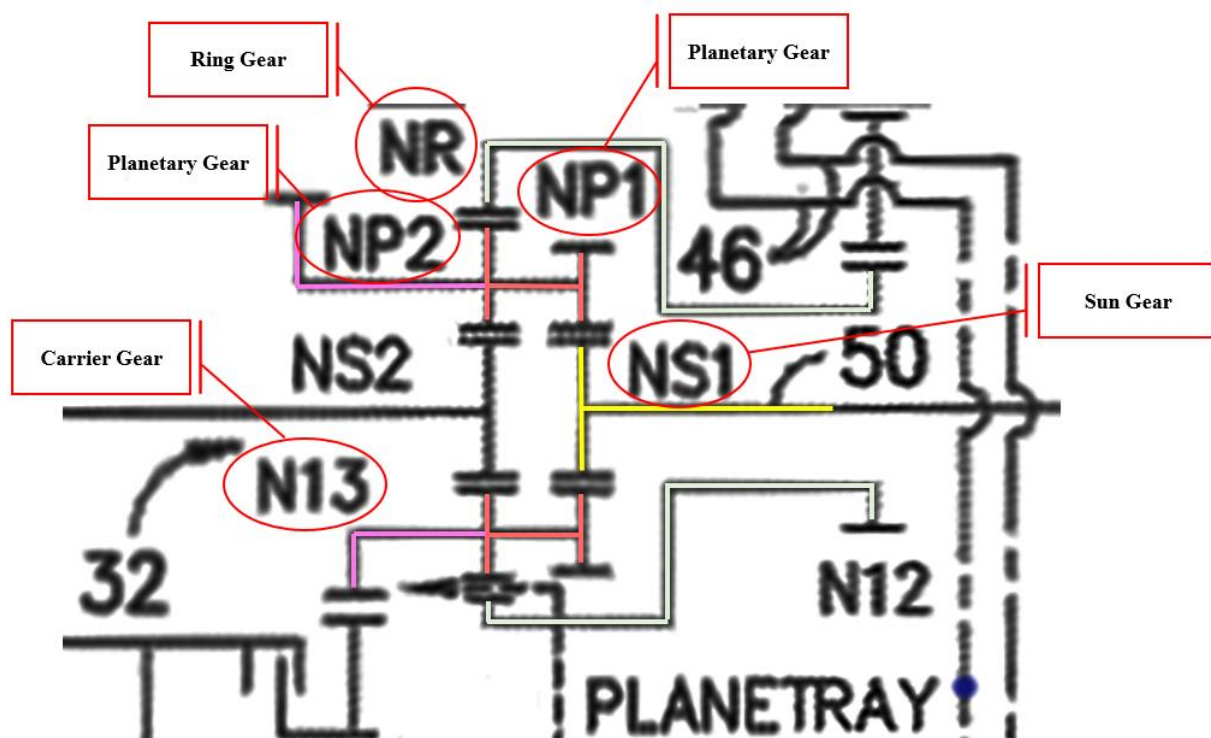
a) “The machine of claim 7,”

130. The combination of Willis and Xing renders obvious the machine of claim 7. *Supra* IX.A.8.

b) “wherein the gear set is a planetary gear set having a sun gear coupled to the engine, a carrier coupled to the rotor, and a ring gear coupled to the hydraulic motor.”

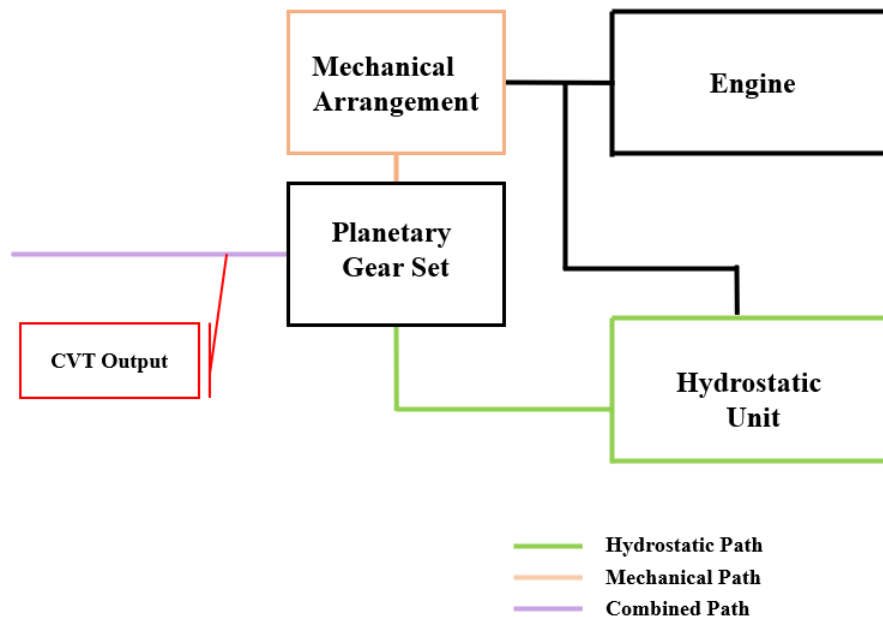
131. Modifying Willis's milling machine to include a variable transmission with a planetary gear set having a sun gear coupled to the engine, a carrier coupled to the rotor, and a ring gear coupled to the hydraulic motor would have been obvious. Xing

discloses a transmission with a planetary unit 32 that includes a sun gear NS1 mounted on the planetary input shaft 50 that is coupled to the engine. Xing, 4:42-53, 4:61-63, 5:9-11. The planetary unit 32 includes a ring gear NR coupled to the hydraulic motor 40. A carrier N13 in the planetary unit 32 connects to planetary gears NP1 and NP2 and is coupled to the rotor via range gear set 34. Xing 4:23-36, 4:61-63, 5:9-37, Fig. 2. The planets revolved together with the carrier gear N13 about the sun gear at a speed depending on the relative rotational speeds of the “sun” and the “ring gear.” Xing, Fig. 2.



Xing, Fig. 2 (excerpt annotated)

132. In making the combination, a POSITA would have understood that, by implementing Xing's CVT in Willis's milling machine, a carrier of the planetary gear set would have been coupled to the rotor via the output shaft of the variable transmission, as shown in the simplified version of Xing, Fig. 2 below.



Representation of Xing, Fig. 2

133. As explained above with respect to claims 1, 6 and 7, a POSITA would have been motivated to incorporate Xing's transmission into Willis's milling machine and would have reasonably expected to succeed in doing so.

10. Claim 9

134. The combination of Willis and Xing renders this claim obvious.

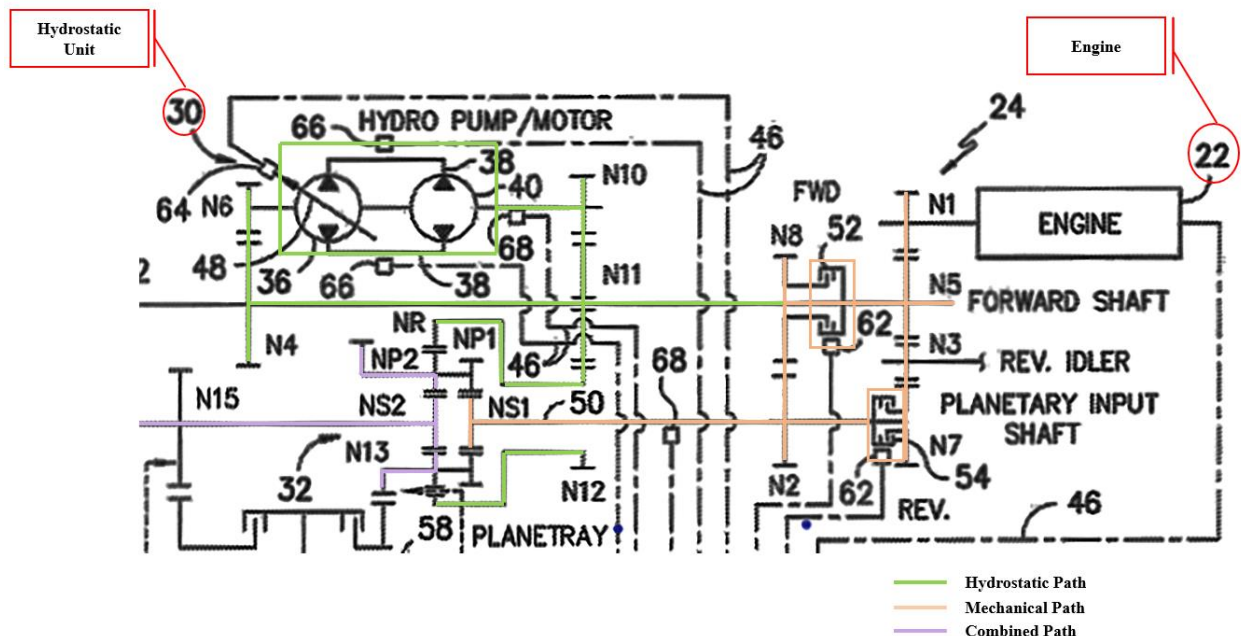
a) “The machine of claim 7,”

135. The combination of Willis and Xing renders obvious the machine of claim 7.

Supra IX.A.8.

b) “wherein the controller is configured to adjust the gear ratio through control of the hydraulic motor.”

136. Modifying Willis's milling machine to include a controller configured to adjust the gear ratio through control of the hydraulic motor would have been obvious. Xing's variable transmission includes a gear set and a hydrostatic unit comprising a hydraulic pump fluidly coupled to a hydraulic motor. Xing, 4:42-56. The hydrostatic unit and the planetary unit are coupled to an output shaft of the transmission. Xing 4:42-56.



Xing, Fig. 2 (excerpt annotated)

Xing's controller adjusts the pump's output to the hydraulic motor and, thereby, the transmission's gear ratio as explained regarding claim 7. Xing, 4:64-5:8, 6:6-13.

137. As explained above with respect to claims 1, 6, and 7, a POSITA would have been motivated to incorporate Xing's transmission into Willis's milling machine and would have reasonably expected to succeed in doing so.

11. Claim 10

138. The combination of Willis and Xing renders this claim obvious.

a) "The machine of claim 6,"

139. The combination of Willis and Xing renders obvious the machine of claim 6.

Supra IX.A.7.

b) wherein the controller is configured to determine the engine load as a sum of loads due to at least the rotor and a hydrostatic arrangement.

140. As shown with respect to claim 4 above, modifying a controller in Willis's milling machine to determine an engine load that includes loads due to at least the rotor and a hydrostatic arrangement would have been obvious in view of Xing. *See supra* IX.A.5.b.

141. As explained above with respect to claim 6, a POSITA would have been motivated to incorporate Xing's CVT and control algorithm in Willis's milling machine and would have had a reasonable expectation of success in doing so. *Supra* IX.A.1, 2, 7. Accordingly, Willis, in view of Xing, renders claim 10 obvious.

12. Claim 11

142. The combination of Willis and Xing renders this claim obvious.

a) “The machine of claim 6,”

143. The combination of Willis and Xing renders obvious the machine of claim 6.

Supra IX.A.7.

b) “wherein the controller is configured to automatically adjust the engine speed based on changes in the engine load according to one or more predetermined relationships providing a plurality of the predefined efficiency points.”

144. Modifying a controller in Willis’s milling machine based on detected changes in the engine load according to one or more predetermined relationships providing a plurality of the predefined efficiency points would have been obvious in view of Xing. *See supra* IX.A.5.b. As described for limitation 1[c], Xing’s controller was configured to adjust engine speed based on load and predetermined efficiency points. And as described above for claim 4, Xing’s controller was configured to automatically adjust the engine speed based on changes in the engine load according to one or more predetermined relationships providing a plurality of the predefined efficiency points. As explained above with respect to claims 1 and 6, a POSITA would have been motivated to incorporate Xing’s control algorithm and transmission into Willis’s milling machine and would have expected to succeed.

13. Claim 12

145. The combination of Willis and Xing renders this claim obvious.

a) “The machine of claim 6,”

146. The combination of Willis and Xing renders obvious the machine of claim 6.
Supra IX.A.7.

b) “further comprising an operator interface configured to at least receive the desired rotor speed from an operator of the machine, the controller being configured to receive the desired rotor speed from the operator interface.”

147. Modifying a controller in Willis’s milling machine to receive a desired rotor speed through an operator interface would have been obvious in view of Xing. *See supra* VI.A.2.b, 3. As discussed for claim limitation 1[a] and claim 2, Willis’s milling machine, modified to include Xing’s algorithm and CVT, would have resulted in a milling machine having an operator interface configured to receive a desired rotor speed from an operator of the machine, wherein the controller was configured to receive the desired rotor speed from the operator interface. As explained above with respect to claims 1 and 6, a POSITA would have been motivated to incorporate Xing’s controller, engine and transmission into Willis’s milling machine and would have reasonably expected to succeed in doing so.

14. Claim 13

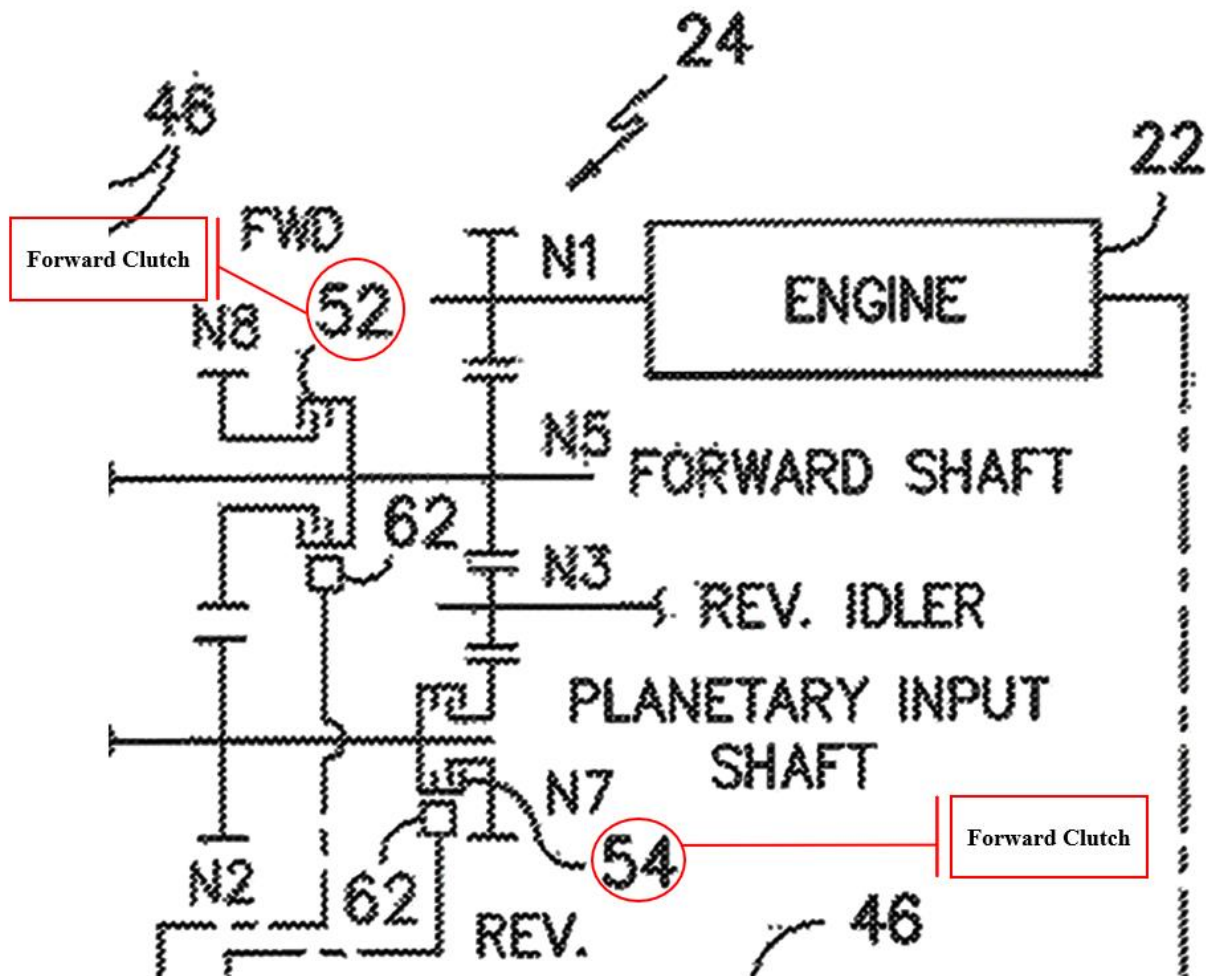
148. The combination of Willis and Xing renders this claim obvious.

a) “The machine of claim 6,”

149. The combination of Willis and Xing renders obvious the machine of claim 6.
Supra IX.A.7.

b) “further comprising a clutch disposed between the engine and the rotor, the controller being configured to selectively disengage the rotor from the engine through the control of the clutch.”

150. In my opinion, a POSITA would have found obvious modifying Willis’s milling machine to include a variable transmission with a clutch disposed between the engine and the rotor, and a controller configured to selectively disengage the rotor from the engine through the control of a clutch. Xing, 5:11-17, 6:53-7:3. 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.



Xing, Fig. 2 (excerpt annotated)

Xing taught that forward directional clutch 52 and reverse directional clutch 54 selectively couple the engine to its planetary gear. Xing, 5:11-17, 6:3-6. Controller 116 could disengage both directional clutches 52, 54 from planetary unit 32. Xing, 6:3-6. By actuating parking brake 70, output shaft 56 and its connected load remained mechanically isolated and disengaged from the engine. Xing, 6:14-34.

151. Alternatively, 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. Xing, 4:42-53, 5:38-55, 6:47-7:3, 7:22-24, Fig. 3. A POSITA 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. In this arrangement, PTO clutch 114 would have connected PTO shaft 112—and Willis's milling drum—to Xing's transmission output shaft 56 and the engine. Willis ¶[0020]; Xing 4:33-37, 4:42-53, 6:47-7:3. As additional support for this combination, Laux teaches connecting a transmission in this manner. Laux, 6:45-7:3.

152. In either arrangement, a POSITA would have modified Willis's milling machine so that the output of Willis's engine was coupled to the input shaft of Xing's CVT transmission and the transmission's output was coupled (directly or indirectly) to Willis's milling drum, because these are the methods Xing teaches for coupling its engine to a load via its CVT. Willis, ¶[0020]; Xing, 4:46-53, 6:53-7:3, Fig. 2 (showing load on shaft 56). The proposed combination includes two alternative ways of selectively disengaging the engine from a load exerted by a rotor by disengaging the clutches in Xing's transmission. Xing 5:14-17, 5:32-37, 6:3-6.

153. As explained above with respect to claims 1 and 6, a POSITA would have been motivated to incorporate Xing's CVT and control algorithm in Willis's milling

machine and would have had a reasonable expectation of success in doing so. *Supra* IX.A.1, 2, 7. Accordingly, Willis, in view of Xing, renders claim 12 obvious.

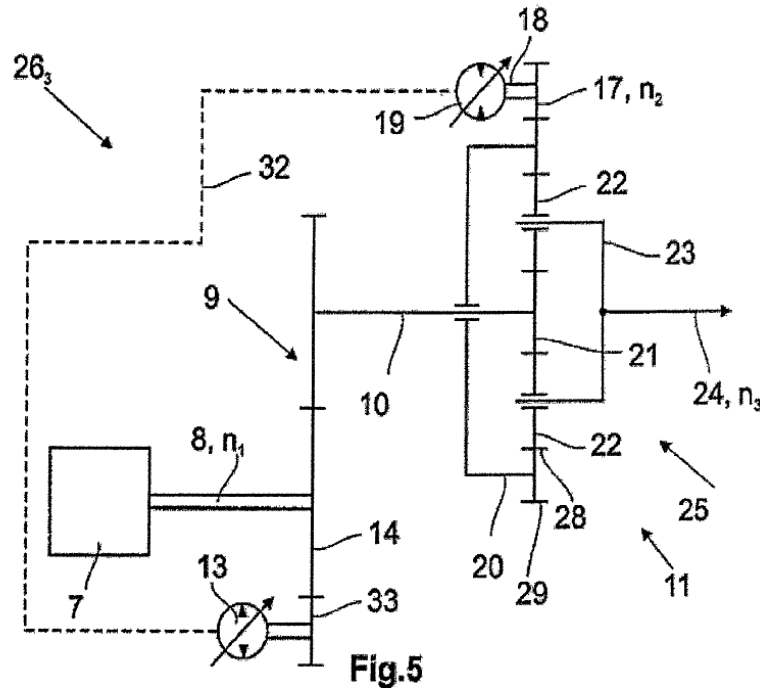
B. Ground 2: Claims 8 and 13 Would Have Been Obvious Based on the Combination of Willis in View of Xing, and Further in View of Laux.

154. As detailed below, Willis, Xing, and Laux together teach every limitation of claims 8 and 13, and these claims would have been obvious over the combination of the Willis, Xing, and Laux.

1. Claim 8: “The machine of claim 7, wherein the gear set is a planetary gear set having a sun gear coupled to the engine, a carrier coupled to the rotor, and a ring gear coupled to the hydraulic motor.”

155. As noted *supra* IX.A.9, Willis combined with Xing teaches this arrangement. However, to the extent a POSITA would have found Xing’s teaching regarding how to support gears NP1 and NP2 of the planetary unit 32 and harness their orbital motion to drive the transmission’s output insufficient, Laux, by referencing and incorporating Schomaker, taught a solution that was commonly used in planetary transmissions. In my opinion, the modification would have been obvious and simply involved combining prior art elements according to known methods to yield predictable results. Schomaker’s planetary gears were mounted on carrier 23, which coupled planetary gears 22 to output shaft 24. Ring gear 20 is also engaged with the planetary gears and is driven by, for example, controllable hydraulic engine, 19. The first driving unit (e.g., an engine) drives sun gear 21. Carrier 23 transferred the

orbital motion of planetary gears 22 around sun gear 21 to output shaft 24, thereby rotating output shaft 24. EX1016, ¶[0035], ¶[0037].



EX1016, Fig. 5.

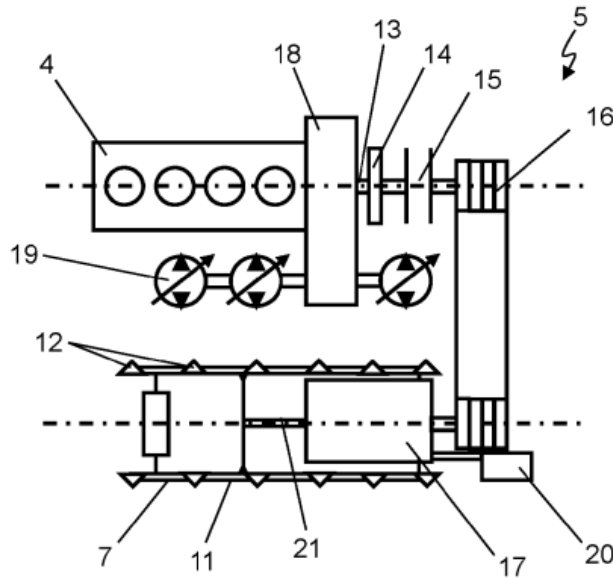
Thus, the combination of Willis, Xing, and Laux teach all the limitations of claim 8. 156. As discussed *supra* IX.A.8, Willis, in view of Xing, renders claim 7 obvious. To the extent the combination of Willis, in view of Xing, failed to render obvious the additional limitation of claim 8, a POSITA would have been motivated to incorporate Laux's carrier into Xing's planetary unit 32 to harness the planetary gears' orbital motion and couple the planetary unit's output to the transmission's output shaft 56 either directly or via Xing's range gears. Indeed, Xing's CVT was designed to use a planetary gear to combine the power output from the CVT's mechanical and hydrostatic paths to rotate output shaft 56. Laux's planetary gear

arrangement provided a known way to do so. A POSITA would have had a reasonable expectation of success in doing so because Xing's CVT already included the necessary components to provide such an arrangement. Accordingly, and for the reasons provided *supra* IX.A.1, 2, 7, and 8, claim 8 would have been obvious over Willis, in view of Xing, and in further view of Laux.

2. Claim 13: “The machine of claim 6, further comprising a clutch disposed between the engine and the rotor, the controller being configured to selectively disengage the rotor from the engine through the control of the clutch.”

157. As noted *supra* IX.A.14, Willis combined with Xing teaches this arrangement. However, 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. *Supra* VIII.C (describing Laux's drive train). Engine 4 was coupled to traction drive 16 via output shaft 13 and shift clutch 15. Laux, 9:3-10.

Fig. 3



Laux, Fig. 3

Clutch 15 could disengage engine 4 from belt drive 16, drive transmission 17, and rotor 7. Laux, 9:3-10. Thus, the combination of Willis, Xing, and Laux teaches all the limitations of this claim.

158. A POSITA would have been motivated to incorporate Laux's clutch into Willis's milling machine that has been modified to include Xing's CVT and algorithm. Milling drum tools 12 frequently wear down during milling and, are typically replaced manually by machine operators. Conventionally, POSITAs understood that, for safety reasons, the milling drum needed to be disengaged from the engine to avoid unexpected startup and possible injury. *See, e.g.*, EX1017, 1:34-47. In such milling machines, this was conventionally achieved using a clutch between the rotor and the engine. *See, e.g.*, EX1017, 3:66-67, Fig. 2. Because a

POSITA would have wanted to retain this safety feature from conventional milling machine, a POSITA would have been motivated to incorporate Laux's clutch. A POSITA would have had a reasonable expectation of success in doing so because clutches were well-known and Laux taught a successful way to implement a clutch in a milling machine wherein the engine was coupled to the rotor via a CVT. Thus, the proposed combination combines prior art elements according to known methods to yield predictable results. Accordingly, and for the reasons provided *supra* VII.A.1, 2, 7, and 14, claim 13 would have been obvious over Willis, in view of Xing, and in further view of Laux.

X. Other Evidence Relevant to Obviousness

159. As I noted above, I understand that the obviousness inquiry requires me to consider whether there is any "objective evidence of non-obviousness." Wirtgen America's counsel has informed me that this type of evidence helps guard against what the courts have called "hindsight bias" when looking backwards in time at a purported invention. Counsel has informed me that the types of evidence that fall into this category are commercial success, long-felt but unmet need, failure by others to solve similar problems facing a POSITA, and the like.

160. Counsel also has informed me that for any such evidence to be applicable, the evidence must also bear some "nexus" to a claim, and in particular, to what is purportedly novel about the claim. I am not currently aware of any objective

evidence of nonobviousness that could apply to the purported invention set forth in the '693 patent and that would also meet the nexus requirement. I reserve the right to reconsider my opinions, as set forth above, if any such evidence is brought to my attention.

XI. Conclusion

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

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

Executed on this 10th day of August 2022.

A handwritten signature in blue ink, appearing to read "Jeffrey L. Stein", is written above a horizontal line.

Jeffrey L. Stein, Ph.D.