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REVIEW
doctoral dissertation
Author: MSc. Ahmed Zubair JAN

Topic of the dissertation: "Method of efficient utilization of digital hydraulic concept in multisource hydrostatic drive systems"

Supervisor: Krzysztof KĘDZIA, PhD, DSc, Eng.

The basis for the review of the doctoral dissertation of Mr. **Ahmed Zubair, MSc, Eng. JAN, was the letter of the** Chairman of the Scientific Discipline Council of Mechanical Engineering of the Wrocław University of Technology, Prof. Zbigniew Gronostajski, PhD, DSc, Eng., dated 26.11.2025.

1. Evaluation of the topicality of the selected topic

The reviewed work concerns the development of a concept for the use of digital hydraulics in drive systems with multiple sources. The concept of digital hydraulics is based on simple two-state hydraulic components. Digital hydraulics is a branch of hydraulics in which components have a limited number of discrete states. Controlling the hydraulic effector with two-position valves with a simple design, instead of the commonly used slider-type proportional valves, can improve the strength of the hydraulic system. However, a single two-position valve often only allows a rough control of the flow rate that causes the actuator to move. One method to improve control efficiency is to use several two-position valves connected in parallel to control a single flow path. A parallel connection allows several different flow rates to be realized depending on the number and size of the valves used, and also increases the failure resistance of the hydraulic system, as the failure of one valve can often be compensated by the other valves.

The aim of the research conducted by the PhD student was to determine whether it is possible to replace traditional hydrostatic transmissions that use expensive and complex multi-piston pumps with variable displacement or fixed capacity pumps with proportional valves, digital hydraulics.

2. The aim of the doctoral dissertation and the justification of the adopted research concept

The material contained in the first chapter of the dissertation entitled "Introduction" on two pages is devoted to the outline of the development of hydraulics, starting from ancient times. On this basis, the justification for the choice of the topic contained in the second chapter "Justification for the Selection of the Topic" is presented. It should be noted that it is presented in a very general way and reads as follows: "As part of the work, it is planned to compare the different methods of flow change used in multi-source drive systems." From such a research hypothesis, it can be concluded that the dissertation is to concern the possibilities and methods of replacing the control of the hydraulic drive with pump speed control, through a series of pumps and solenoid valves controlled in on/off mode, achieving similar efficiency. In the reviewer's opinion, the hypothesis is of a general nature, it does not include selected parameters/parameter of the compared drives.

In the second chapter, the PhD student focuses on the comparison of a classic hydrostatic system, built of axial piston hydrostatic units, with a digital hydraulic system built of gear pumps with different flows, which allows the fluid flow in the system to be changed. In point 2.1 of the dissertation entitled: "Outline of the Current State of Research", the PhD student presents an outline of the current state of research, referring to only two literature items. In section 2.2 of the "PhD Thesis Hypothesis" he formulates a research hypothesis: "It is possible to replace proportional technology in hydrostatic drive systems with digital hydraulics, with multiple sources, providing similar energy recovery efficiency, while reducing the cost of building a multi-source system by 30%."

The hypothesis is not very precise. What does similar efficiency mean? What is the margin of similarity?

Next, the PhD student formulates five research problems. According to the reviewer's assessment, only point 3:

"Will the dynamic parameters e.g. acceleration, rising time, frequency responses of the hydraulic system subjected to such modifications meet the requirements assumed for the systems?"

and point 5:

"How will the replacement of a typical hydraulic system with a system built according to the "digital hydraulics" concept affect the areas of efficiency, reliability, safety, and ecology (carbon footprint, emission of harmful substances, e.g., in the case of using an internal combustion engine: carbon dioxide, nitrogen oxides, solid particles)?"

are research problems related to aspects aimed at determining the impact of dynamic parameters of a hydraulic system operating in a multi-source system, and how will replacing a classic hydraulic system with a system built according to the concept of "digital hydraulics" affect the efficiency, reliability, safety and ecology of the operating system?

Point 2:

"What will be the energy efficiency of the change described above?" and point 4:

"What kinds of savings will result from such a modified system?"

are questions of an economic nature, the answers to which can be formulated after the completion of the work, but it is difficult to qualify them as research problems.

Regarding point 1:

"Will the replacement of a pump with a variable flow rate (e.g., a multi-piston axial pump with a tilting swashplate) and/or throttle control (e.g., realized by a proportional valve) with a system built according to the "digital hydraulics" concept in which a complicated and expensive pump is replaced by a set of simple and inexpensive gear pumps located on one shaft, and/or the proportional valve controlling the flow rate is replaced by simple to build and relatively inexpensive valves (two-stage, two-way) meet the requirements for power supply and control units used to build hydrostatic drive systems?"

It is difficult to determine the meaning of such an extended sentence.

The inclusion of point 2.3 is somewhat surprising. "Contribution of the Expected Results to the Scientific Discipline" at the beginning of the dissertation. Before starting the research, the doctoral student determines what the economic and ecological benefits will be from its implementation.

In section 2.4. "Planned Research Methods" The PhD student states that: "A comprehensive literature review will be conducted before the start of the research program." In the Reviewer's opinion, the conclusions from the analysis of the issue should be the basis for formulating the aim of the paper or the research hypothesis.

The presented course of the work also raises some doubts related to the order in which experimental and simulation research is conducted.

The implementation of the work requires first of all the construction of the station, conducting preliminary tests, the results of which will provide limit values for the construction of the model and conducting simulation tests, and then conducting the validation of the model on the test bench.

Point 2.5. Research Significance describes the importance of digital hydraulics for Industry 4.0. This description, together with a description of the trends supporting the development of digital hydraulics, should be presented as a basis for the research hypothesis.

3. Assessment of the general theoretical knowledge of the PhD student

The reviewed dissertation presents the general theoretical knowledge of Mr. Ahmed Zubair, MSc, Eng. JAN, in the discipline of Mechanical Engineering in the field of power hydraulics. The PhD student presented a dissertation entitled: "Method of efficient utilization of digital hydraulic concept in multisource hydrostatic drive systems". The introductory part of the dissertation, contained on 7 pages of typescript, includes acknowledgments, a table of contents, a list of abbreviations used, and a summary in English. The main part of the dissertation is contained in 156 pages of typescript and is divided into nine numbered chapters including: Introduction, Justification for the choice of topic, Description of the components of digital hydraulic technology, Basic concepts of digital hydraulics, Mathematical and simulation models, Test scenarios, Experimental research results, Simulation test results and Summary. The work ends with the tenth chapter containing a list of analyzed literature (110 items) and

chapter 11 containing three appendices. The structure of the dissertation is poorly organized, but its content is consistent with the title. A certain shortcoming may be introduced by the lack of translation of the title of the dissertation into Polish, and the lack of a summary in Polish.
The analytical part of the dissertation is contained in chapters 3 and 4 entitled "Components of Digital Hydraulic Technology" and "Fundamental Concepts of Digital Hydraulics" respectively. Chapter 3 contains a description of hydraulic components (hydraulic pump, hydraulic cylinders, control valves, tank, hoses and fittings, and hydrostatic transmission) then gives descriptions of hydrostatic drive in open and closed loop, giving the advantages and disadvantages of individual solutions. This is basic information about hydraulic components that are widely known and do not bring anything new to the dissertation.
The chapter ends with a short subsection in which the limitations of traditional hydraulic systems are presented, it does not contain any conclusions that would support the accepted hypothesis.

Chapter 4 is included on 13 pages of typescript and includes a literature review in the field of digital hydraulics conducted by the PhD student. At the beginning, a description of the idea of digital hydraulics and a comparison of the idea of digital systems with the idea of proportional hydraulics is presented. Table 1 "Comparison of digital and analogue hydraulics is very general and contains imprecise formulations, e.g. "energy losses – minimal". In addition, the PhD student focused on the description of parallel connections in hydraulics, presenting a digital control unit, describing methods of modulating control signals and a digital hydraulic system management system. A certain lack of satisfaction is caused by the comparison of conventional and digital hydraulics, as well as the lack of reference in the text to Table 2 and the determination of whether it is the result of the Doctoral student's analyses or taken from the literature.

I believe that the PhD student has general theoretical knowledge in the field of power hydraulics, both proportional and digital. The dissertation lacked an in-depth critical analysis of the possibility of using both types of hydraulics.

4. Evaluation of the research method and the author's original achievements

After conducting a literature review, the PhD student began the implementation of the research program. The first phase of the program included simulation studies using MATLAB/Simulink software. Once the physical model was defined, a mathematical model was developed. On this basis, simulation models of both the proportional hydraulic system and the one built according to the concept of "digital hydraulics" were built.
As part of the doctoral thesis , experimental research was carried out in cooperation with the Institute of Hydraulic and Pneumatic Research INOE 2000 – IHP in Bucharest as part of a mini-research grant obtained by a PhD student entitled: Method of effective use of the concept of digital hydraulics in multi-source hydrostatic drive systems.
After verifying the simulation results using experimental ones, the models of both simulation systems were compared in terms of dynamic and ecological parameters. This comparison was the basis for formulating an answer to the research hypothesis, whether it is possible to replace the classic hydrostatic propulsion system with its digital counterpart. On this basis,

the question of whether it is possible to use it in hydrostatic drives with multiple sources was also answered.

I believe that the proposed research method has been developed based on the methods used in research on digital hydraulics. There is no information in the dissertation whether the PhD student was the designer of the research station used, but his works contribute to the development of knowledge about digital hydrostatic systems, identifying and quantifying the gap between idealized simulation results and complex experimental reality. It shows that while simulation models are an excellent tool for energy assessment, experimental research is absolutely crucial for identifying critical dynamic loads. Therefore, it should be emphasized that both the results of simulation research and the results of experimental research conducted on the basis of research scenarios developed by the PhD student constitute his original achievements and are a contribution to the development of the scientific discipline of mechanical engineering.

5. Assessment of the ability to conduct scientific work independently by a PhD student

On the basis of the doctoral dissertation submitted for review, entitled: "Method of efficient utilization of digital hydraulic concept in multisource hydrostatic drive systems", in which the PhD student included the results of his analytical work, model and experimental research in order to demonstrate the correctness of the research hypothesis that "It is possible to replace the proportional technique in multi-source hydrostatic drive systems with "digital hydraulics", ensuring similar recovery efficiency while reducing the costs of building a multi-source system by 30%", it should be stated that Mr. Ahmed Zubair Jan, MSc, Eng., obtained answers to the research problems posed in Chapter 2 of the dissertation. It showed that:

1. The flow profile "in a digital hydraulic system" faithfully approximates the continuous characteristics of a proportional system over a wide range of loads and cyclic dynamics.
2. The energy efficiency of the digital and classic systems is at a similar level.
3. The digital system enables very high dynamic cycles, with rise times to full output of less than one second. This meets the requirements of many applications.
4. However, there are phenomena that pose a major challenge to this technology. Even in steady state, the system generates significant, high-frequency torque oscillations,
5. The digital system meets the requirements for responsiveness, but introduces dynamic loads (pulsations, shocks) that must be taken into account at the design stage and in the control strategy.

On this basis, it can be assessed that he has demonstrated the skills to conduct scientific work independently.

6. Shortcomings noticed in the dissertation and debatable problems

The dissertation meets all the formal criteria set for doctoral theses, but it also contains some shortcomings. This is especially true for some drawings with very low resolution (Figs. 10, 20).

The author did not avoid understatements and editorial errors in several places. The most common editorial errors include:

- lack of consistency in the use of SI units;
- no dot at the end of the number in the numbering of subsequent work points;
- lack of descriptions of the drawings (Fig. 17) and lack of references in the text to the drawings included in the dissertation;
- no references to the sources of the figures (chapters 2 and 3);
- the numbering of figures, tables and formulas is not linked to the chapter numbers, the numbers are assigned consecutively;
- referring to several literature items at once without individual reference to the wording contained therein.

In addition, notes on the spotted errors:

1. Str. 18 Dynamic Characteristic: The main engineering challenge and compromise for potentially higher efficiency is a different dynamic characteristic. The discrete, stepped nature of the control inherently generates phenomena in the system such as pressure and torque pulsations and, as shown by experimental studies, shock load spikes at the moments of switching [32],[33],[34],[35],[36]
2. Pg. 23 Generally, engine volumetric and hydraulic-mechanical losses are represented by the same or similar dependencies as pump losses [45], [46], [47], [48], [49], [50], [51], [52], [53], [54]. Practice demonstrates that engine volumetric losses are lower than pump losses because of the higher filling of the engine working chambers.
3. Page 33 "Figure 16" – it is stated that the drawing comes from item [72], the presented drawing was not found in the above-mentioned item. In addition, Figure 17 does not have the references described.
4. Figure 30 Experimental stand of digital fluid power transmission scheme. - not very legible. In addition, there is no reference of photos of real objects (Figures 31 – 34) to the diagram (Fig. 30)
5. p. 61. "The presented below set of four graphs (Fig. 32 to Fig. 35) " should be "The presented below set of four graphs (Fig. 34 to Fig. 37)"
6. Pg. 61. [AV] is not a unit of active power. The unit of active power is [W], while [VA] is the unit of apparent power.
7. Included in "Table 7. Comparison of the costs of building a classic and digital hydrostatic transmission."

Reading the dissertation revealed some understatements, which, in the reviewer's opinion, need to be supplemented and raised some problematic remarks that I would like to discuss during the defence.

Comments on which I expect written answers and discussions during the defence:

1. With regard to point 2.2, I would like to ask you to specify the research hypothesis and to substantiate its in-depth justification that it is possible to replace proportional (continuous) control in a multi-source hydrostatic drive with a discrete one.

2. Listing the benefits of the research on page 15 of the dissertation, the PhD student stated that: "Reducing the possibility of exclusion for financial reasons and/or a suitably developed technological background." I would like to ask you to elaborate on this issue. Who is to be excluded for financial reasons,
3. Pg. 23 – "Generally, engine volumetric and hydraulic-mechanical losses are represented by the same or similar dependencies as pump losses [45], [46], [47], [48], [49], [50], [51], [52], [53], [54]. " please elaborate on this thought in relation to each of the authors.
4. Pg. 28 - Are discrete signals as shown in Figure 11 used in control systems in hydraulics?
5. On the basis of Chapter 4, please make a summary in terms of the selection of elements of the research stand.
6. Is the statement in point 9.2 'Yes, it is possible to effectively replace the proportional technique with "digital hydraulics."' Not too generic? Shouldn't it be narrowed down, for example, to the type of application (mobile or stationary hydraulics), the required precision of the drive, etc.?

The above remarks do not capture the substantive value of the dissertation, especially against the background of the interesting and innovative, commercializable results of scientific and technical research presented in the dissertation.

7. Final evaluation of the work

The reviewed doctoral dissertation of **Ahmed Zubair JAN, MSc, Eng., falls** within the scientific discipline of mechanical engineering. My assessment of the work is positive, despite a certain number of editorial comments. The work contains a number of new interdisciplinary cognitive results. In this respect, they complement the state of knowledge in the field of "digital hydraulics". This dissertation primarily draws original conclusions as applied to implementation practice.

The reviewed dissertation meets the conditions for doctoral dissertations set out in Article 187(1) and (2) of the Law on Higher Education and Science of 20 July 2018 (Journal of Laws of 2024, item 1571). Therefore, I request that the doctoral dissertation of Mr. **Ahmed Zubair JAN, MSc, Eng., be admitted** by the Discipline Council of Mechanical Engineering of the Wrocław University of Technology for further proceedings.

1.06.2026 r.