УДК 65.011.56: 378.1

A.V. PUZANOV

TRANSDISCIPLINARY MODELS OF HYDRAULIC DRIVES OF MOBILE MACHINERY

JSC «Special Design Bureau of Instrument Making and Automation»

Modern drive engineering requires a comprehensive analysis of all work processes in hydraulic drives, solving the problems of modeling the technological processes of their production using mathematical and software tools of various physicality.

The article proposes an approach to the development of hydrodrives of mobile equipment based on transdisciplinary models of instruments and control systems. These models are designed to unite in a single information space a methodical and mathematical apparatus of various physicality: mechanics, kinematic, hydromechanics, heat engineering, and methods for their solution. These measures will increase their adequacy, reduce assumptions and reduce the safety factor as a measure of imperfection of the scientific and technical understanding of the facility.

The article gives an example of the use of this approach in the development of volumetric hydraulic drives of mobile equipment - a technique for calculating the indicator diagram of an axial-plunger hydraulic machine at a micro level using the Matlab / Simulink, Autodesk Simulation CFD and Autodesk Simulation Mechanical software complexes. The indicator diagram of the hydraulic machine is a clear characteristic of the dynamic qualities of the product. From the correctness of the calculation of this characteristic, the dynamic properties, reliability and resource of the drive as a whole depend.

Keywords: *transdisciplinarity; multiphysical analysis; CAD; CAE.*

The creation of new generations of hydraulic drives requires an increase in the scientific and technical level of design and production. Increasing the technical and operational characteristics of hydraulic drives dictate the need to implement new development principles with a deeper theoretical analysis of its operating principles.

The actual direction of development of modern production is based on multidisciplinary, multilevel and multistage research based on inter-, multi- and transdisciplinary computer technology [1].

Transdisciplinarity – a way to expand the scientific worldview, which consists in the consideration of a phenomenon outside the framework of any single scientific discipline. In this context, transdisciplinarity is treated as a meta-methodology, since it accepts as the object different methods of different disciplines for their transformation [2].

In relation to the development of the hydraulic actuators are realized by two main approaches: modeling at the macro and microlevel.

At the macrolevel, will use the discretization of space on a functional basis, which leads to the representation of models at this level in the form of systems of ordinary differential equations. In these equations the independent variable is time and the dependent variables constitute the vector of phase variables characterizing the state of the integrated elements of the sampled space. Such variables are force and velocity in mechanical systems, the voltage and current in electrical systems, pressure and flow of liquid and gas in hydraulic and pneumatic systems, etc. The system of ordinary differential equations are universal models at the macrolevel that is appropriate for analyzing both dynamic and steady-state objects.

Feature modeling at the microlevel is a reflection of the physical processes occurring in continuous space and time. The models at the microlevel are differential equations in partial derivatives. They independent variables are the spatial coordinates and time. Using these equations, mechanical stresses and deformations, pressure and temperature, etc.

Modeling at the microlevel problems of heat conduction and stress-strain state of the products is implemented through the finite element analysis for. For modeling of problems of dynamics of liquid and gas, fluid mechanics and heat and mass transfer uses finite-difference and finite-volume solution methods.

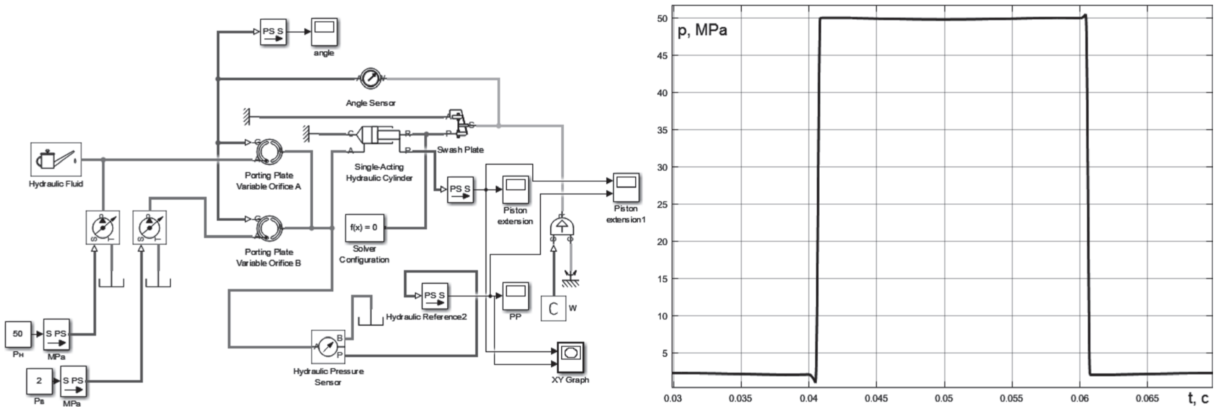

Figure 1. Model and result of calculating the indicator diagram of the hydraulic machine

To ensure the concept of the product life cycle model of the hydraulic actuators should reflect not only current status but also the changes in process operation and design (climatic) performance.

Thus, for a comprehensive analysis of all work processes in hydraulic drives, as well as solving problems of modeling technological and production processes, it is necessary to perform an analysis of problems of different physicality by various mathematical and software tools. The author proposes the development and use of transdisciplinary models of hydraulic drive and its elements. These models are designed to unite in a single information space a mathematical apparatus of a different physical nature: mechanics, kinematics, hydromechanics, heat engineering, levels and methods of solution. These models will reduce assumptions and reduce the safety factor as a measure of the imperfection of the scientific and technical understanding of the facility.

Structural elaboration of the product is carried out on schematic level. At this stage, actively apply software tools for simulation and analysis of circuit decisions on the macrolevel (Matlab/Simulink or other similar, for example, SciLab/SciCos). These programs reflect the characteristics of the whole system and use the description of the test facility and get the results in a familiar user graph form.

As an example of the macrolevel-model, in figure 1 present the model and result of calculation of the indicator diagram of the hydraulic machine.

The indicator chart shows the pressure change in the cylinder during the movement of the piston from the suction cavity – into the injection cavity and back. This dependence is a clear characteristic of the dynamic qualities of the product. From the correctness of the calculation of this characteristic, the dynamic properties, reliability and resource of the drive as a whole depend. The kinematics and hydromechanics of the hydraulic machine, the properties of the working fluid and the performance characteristics are used as model parameters.

The macromodels is usually performed optimization of the system as a whole, traced the mutual influence of system components.

The disadvantages of macrolevel models are inherent in analytical and imitative approaches.

The next stage in the development of the product is a detailed study of its mechanisms and components. The initial data for this stage are the results of modeling at the macrolevel. The range of problems solved: kinematics, strength, fluid dynamics, electromagnetism, heat-mass transfer, etc., as well as their combination.

The task of calculating the indicator diagram at the microlevel, taking into account the geometric features and properties of materials, is solved by means of a complex of programs, including the tools CAD, CFD and CAE.

Adaptive CAD model is required to generate the original geometry and its changes based on simulation results, as well as for subsequent CAM preparation and production [3].

As a result of CFD modeling, the following results were obtained. Figures 2...4 show the distribution of pressure of the working fluid along the channels and gaps of the running part of the hydraulic machine with the flow velocity vectors, as well as the stresses in the structural elements of the running gear of the hydraulic machine caused by the action of the liquid, the mechanical part and the temperature effects.

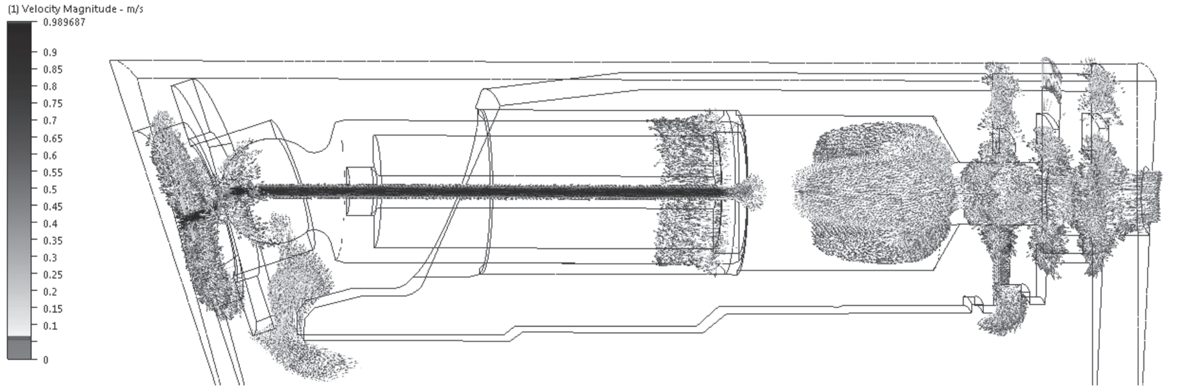

Figure 2. Vector field of flow rates of working fluid in the channels and gaps of the undercarriage of the hydraulic machine

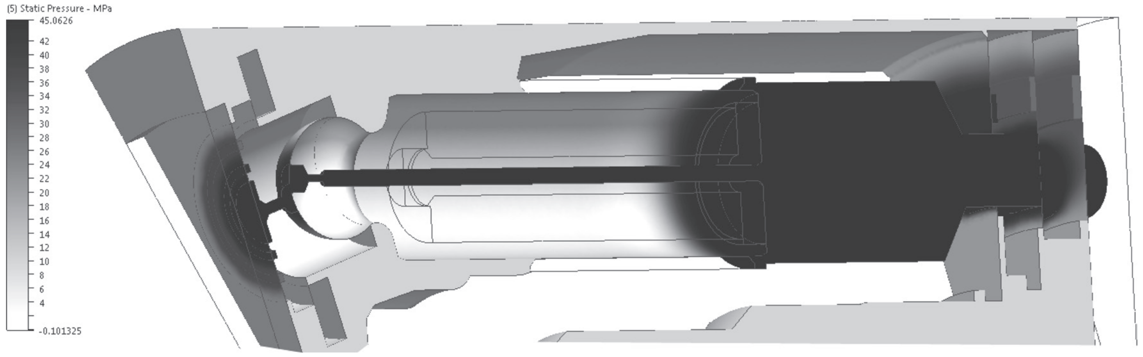

Figure 3. Field of working fluid pressure in the cavities and channels of the hydraulic machine

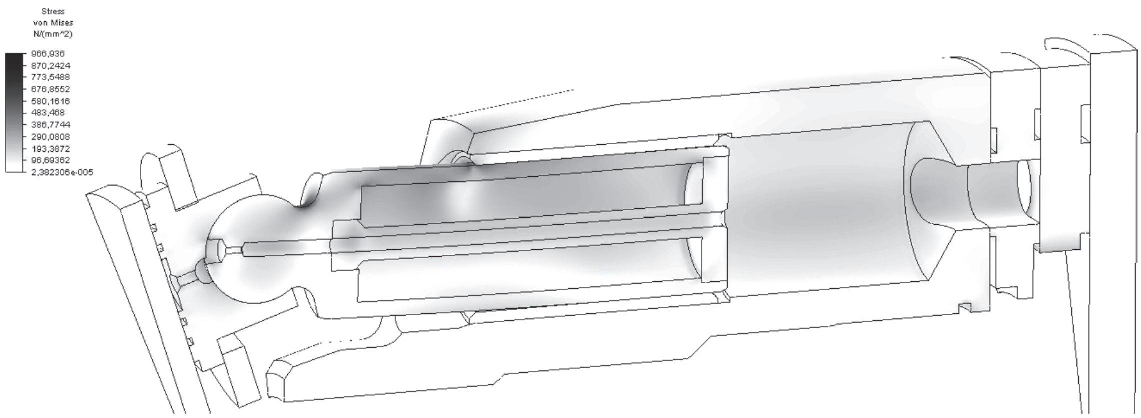

Figure 4 - Stresses of structural elements of the undercarriage of the hydraulic machine from the hydro-mechanical action of the working fluid

Based on the generalization of the results presented in figures 2...4, we obtain the graph of the indicator diagram (figure 5) of one of the variants of the design of the distribution node (as an example of the effect of design features on the form of the graph) [4].

The figure reflects the effect of micro-level parameters-the design features and properties of the working fluid, its gas saturation and pollution.

On the graph of the indicator diagram, positive results of the design work of the distribution center are seen: the smoothness of the line of entry into the zone of injection.

The oscillatory process at the beginning of the injection zone reflects the content of dissolved gas in the working fluid and the self-stabilization of the hydrostatic support of the plunger.

Analysis of the results presented in Figure 5 shows that the pressure drop and the transient process have a negative impact on the dynamics of the hydraulic drive, especially for mobile equipment.

Conclusion

The transdisciplinary approach allows for a limited number of objects to conduct their compre-

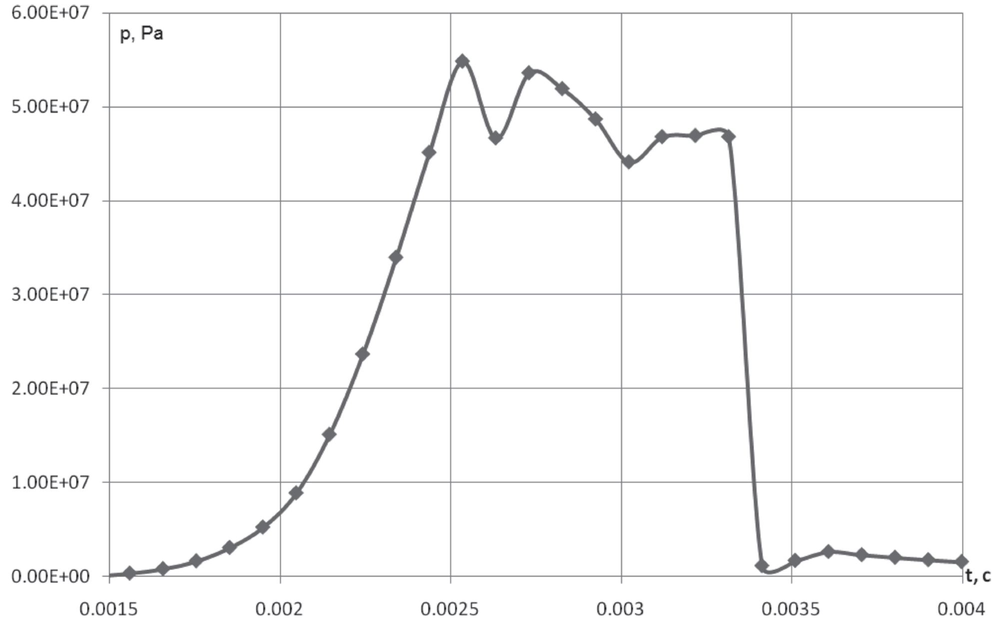

Figure 5. Indicator diagram of the axial-plunger hydraulic machine

hensive analysis, to study the properties of the target object more deeply and in detail, and to explore the mutual influence of the system and design parameters of the product and the parameters of the external environment.

The proposed approach to the development of hydraulic drives of mobile equipment allows to increase the adequacy of design models, reduce assumptions and increase the reliability of both hydraulic drive and mobile equipment.

REFERENCES

1. **Sovremennoe** inzhenernoe obrazovanie : ucheb. posobie / A. I. Borovkov [i dr.]. – SPb. : Izd-vo Politehn. U, 2012. – 80 p.
2. **Transdisciplinarity:** Stimulating Synergies, Integrating Knowledge Division of Philosophy and Ethics UNESCO, 1998, pp. 37–38.
3. **Puzanov, A. V.** Metodika formirovanija CAE-modelej na primere konstruktorsko-tehnologicheskoj prorabotki plunzhera forsirovannoj gidromashiny / A.V. Puzanov // Informatika – 2017, № 2, pp. 37–44.
4. **Puzanov, A. V.** Modelirovanie indikatornoj diagrammy aksial'no-plunzhernoj gidromashiny / A. V. Puzanov, E. A. Ershov // Vestnik Brjanskogo gosudarstvennogo tehnicheskogo universiteta. 2017, № 3 (56), pp. 29–35.

ЛИТЕРАТУРА

1. **Современное** инженерное образование : учеб. пособие / А. И. Боровков [и др.]. СПб. : Изд-во Политехн. ун-та, 2012. 80 с.
2. **Transdisciplinarity:** Stimulating Synergies, Integrating Knowledge Division of Philosophy and Ethics UNESCO, 1998, pp. 37–38.
3. **Пузанов, А. В.** Методика формирования CAE-моделей на примере конструкторско-технологической проработки плунжера форсированной гидромашины / А. В. Пузанов // Информатика – 2017, № 2. – С. 37–44.
4. **Пузанов, А. В.** Моделирование индикаторной диаграммы аксиально-плунжерной гидромашины / А. В. Пузанов, Е. А. Ершов // Вестник Брянского государст-венного технического университета. 2017, № 3 (56). – С. 29–35.

Поступила *22.03.2018* *После доработки* *06.06.2018* *Принята к печати* *30.11.2018*

Пузанов А.В.

ТРАНСДИСЦИПЛИНАРНЫЕ МОДЕЛИ ГИДРОПРИВОДОВ МОБИЛЬНОЙ ТЕХНИКИ

Современное приводостроение требует проведения комплексного анализа всех рабочих процессов в гидроприводах, решения задач моделирования технологических процессов их производства с использованием математических и программных средств различной физической природы.

В статье предложен подход к разработке гидроприводов мобильной техники на основе трансдисциплинарных моделей приборов и систем управления. Эти модели призваны объединить в едином информационном пространстве методический и математический аппарат различной физической природы: механику, кинематику, гидромеханику, теплотехники, а также методы их решения. Эти мероприятия позволят увеличить их адекватность, сократить допущения и снизить коэффициент запаса как меру несовершенства научно-технического представления об объекте.

Увеличение мощности гидроприводов определяет повышение точности методик расчета при проектировании их элементов и систем на их основе. Наглядной характеристикой динамических качеств изделия является индикаторная диаграмма гидромашины. От корректности расчета этой характеристики зависят динамические свойства, надежность и ресурс привода в целом.

В статье приведен пример использования данного подхода при разработке объемных гидроприводов мобильной техники – методика расчета индикаторной диаграммы аксиально-плунжерной гидромашины на микроуровне с использованием программных комплексов Matlab / Simulink, Autodesk Simulation CFD и Autodesk Simulation Mechanical.

Представлены результаты моделирования индикаторной диаграммы гидромашины на макро- и микроуровнях, в том числе поле давления и векторов скорости потока рабочей жидкости в каналах проточной части гидромашины и напряжения в конструкции элементов ходовой части гидромашины. Выполнена верификация результатов моделирования макро- и микромоделей.

Ключевые слова: *трансдисциплинарность; мультидисциплинарный анализ; CAD; CAE.*

Пузанов Андрей Викторович, к.т.н.
Помощник Генерального директора по науке ОАО «Специальное конструкторское бюро приборостроения и автоматики».
601919, Россия, Владимирская обл., г. Ковров, ул. Крупской, 55.
Телефон рабочий: (49232) 9-37-84
avp@oao-skbpa.ru