17th International Conference
ENGINEERING MECHANICS 2011
Svratka, Czech Republic, 9 – 12 May 2011

# HYDRAULIC SYSTEMS FOR THE FUTURE

J. Tlustoš*

**Abstract:** *Survey of conventional hydraulic systems development and the last progressive trends in hydraulic systems architecture. Aspects of advanced control concepts implementation. Potential of high efficiency systems performance. The foreshadowing of future visions of the "Green hydraulics".*

**Keywords:** ***Hydraulics, control systems, system dynamics, artificial intelligence, fuzzy logic.***

## 1. Introduction

In the last years, a fast development of electronics and mechatronics has caused the replacement of hydraulic and pneumatic systems by these new progressive technologies. Anyway, there is a warranted wide area of applications for fluid systems, especially for hydraulic systems in the age of electronics too. We can also see great progress in the field of hydraulic systems, especially by means of implementation of electronics, cybernetics, mechatronics and new design and development approaches and concepts. The last century development of hydraulic components including pumps, valves and actuators reaches its limits. There is still way ahead, but the focus of up to date activities has to be concentrated on the system architecture. New complex and comprehensive approach to the system design enables to implement general dynamic systems theories and means of the artificial intelligence.

## 2. Hydraulic Systems Performance

Hydraulic systems cannot be replaced by any means of automation for the extremely exposed applications with high forces, torques and velocities. They are produced in different designs related to goal application. In some industrial applications the hydraulic systems are spread on the whole mechanical equipment, only power source with fluid conditioning is mostly centralized. On the other hand, for the installation of hydraulic systems in mobile machines the system has to be adapted and it has to enable effective and optimal usage of the available space. We can name such examples as aircrafts and space shuttles.

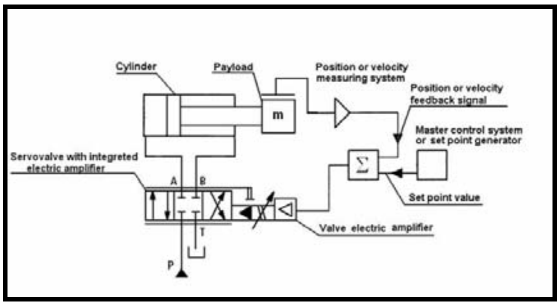


*Fig. 1: Hydraulic Axis fundamental diagram.*

Straight-line motions can be easily executed by means of hydraulics with high efficiency. Closed loop systems enable to control position, velocity and force with high precision (see Fig. 1). These subsystems are called "hydraulic axis". From the point of view of control system architecture, we are dealing with autonomous decentralized control units with self-diagnostics. They are able to communicate in duplex mode with other units on the same control level and also with higher-level automation system via standardized communication interfaces.

* Ing. Bc. Jiří Tlustoš: Hydraulic Systems Department, ŽĎAS Company, Strojírenská 6; 591 71, Žďár nad Sázavou; CZ, e-mail: jiri.tlustos@zdas.cz

## 3. Potential for Improvement

During the last century hydraulic systems have gone through a long process of development, from the primitive hydraulic units with basic functionality, reduced applicability and manual control of the process, through advanced systems with better performance and implementation of basic autonomous control units up to nowadays modern fluid systems with extensive integration of electronics.

### 3.1. Efficiency of Components and System

There are several possibilities how to reach higher efficiency of the system there. The overall efficiency of the system is given as the product of individual efficiencies (see Eq. (1)). The basic hydraulic circuit can be represented by the linear chain of individual efficiencies. It is illustrated in Fig. 2. It is obvious that the first possibility of higher system efficiency achievement is to increase the efficiency of elementary parts of the system.

$$\eta_T = \prod_{i=1}^{n} \eta_i \qquad [\,-\,] \qquad (1)$$

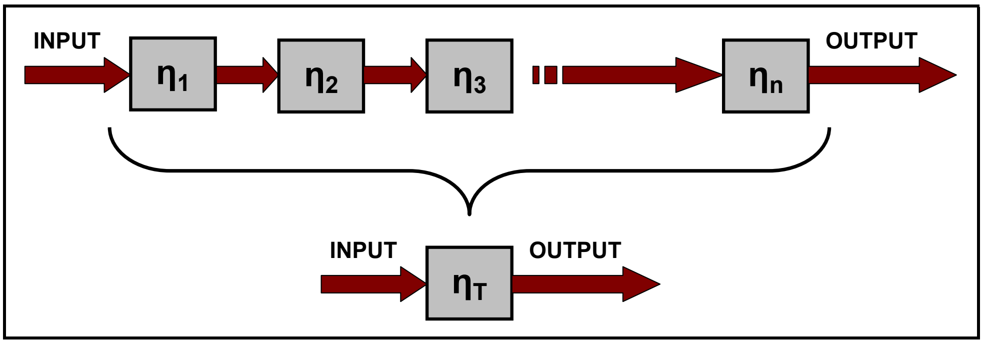


*Fig. 2: Linear Chain Diagram of Individual Efficiencies.*

The efficiency of the power sources and actuators is given by efficiency of energy transformation. The mechanical energy is transformed into pressure energy of the working fluid in pumps (hydraulic generators). In case of the actuators there is the inverse transformation executed. These basic principles are illustrated in Fig. 3 with examples of the real representation of individual blocks.

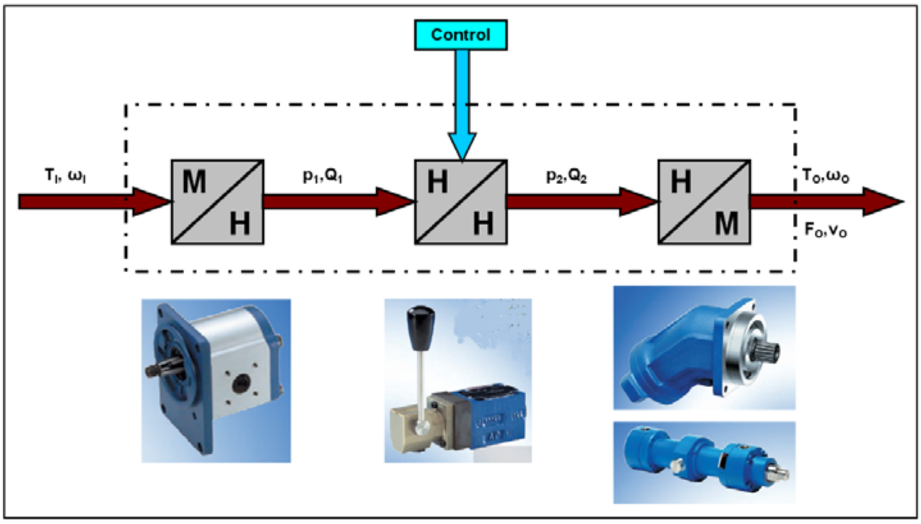


*Fig. 3: Block Diagram of Basic Hydraulic System.*

High quality materials and high quality of production processes are used during the production of the hydraulic components. New approaches of the quality management are implemented in the production of hydraulic components. Better performance parameters of the components can be achieved and the lifetime is also longer. The conclusion is that there is no significant possibility for improvement in the optimalization of the hydraulic components, e.g. valves, pumps, hydraulic cylinders and motors.

### 3.2. Design of the Hydraulic System

The designing of the hydraulic system is a key activity, which has to be done based upon all system requirements and options with respect to control system implementation. The system architecture, which means how the system is composed and designed, is a very important factor. Hydraulic systems enable wide flexibility and there can be a lot of possibilities how to design system for the specific application. We have to observe many criteria of the system performance. Economical criteria are operating cost, maintenance cost and cost of the equipment. Technical criteria are especially the precision of the system performance, safety operation, and also reliability of the system. We can design several options of the specific circuit, they can accomplish the initial requirements but the solution can be totally different. Fast development of information technologies and their implementation into engineering processes enables to increase productivity, quality and effectiveness of the design. CAE tools are widely used in the design of hydraulic components and manifolds. There are also a lot of CAD tools for design of circuit diagrams and system function simulations. The example of the software which supports both functions is in the Fig. 4. Nevertheless the circuit design is still the matter of creativity, knowledge and intuition (Rao, 2000).

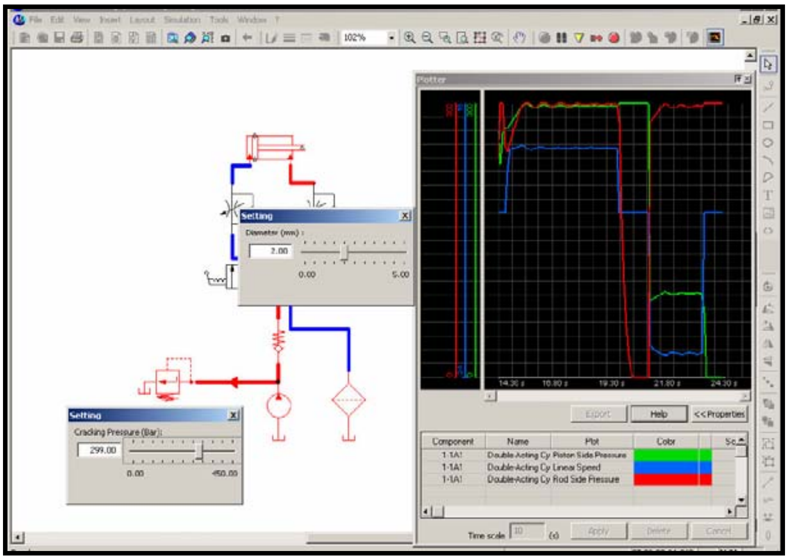

*Fig. 4: Hydraulic Circuit Design and Simulation.*

Energy efficiency of the system is defined by the selected components and especially by the circuit and system architecture. The effective usage of energy plays the fundamental role in nowadays technology. Design of new machines and equipment requires high degree of automation and low energy consumption. The main reasons are economical aspects, which mean reducing of operational costs, and in wider perspective also environmental aspects. The energy efficient and environment friendly hydraulic systems are sometimes called the “Green Hydraulics”

### 3.3. Control System Design

When we see the Fig. 3 the transformation block which converts hydraulic energy to the hydraulic energy with different parameters, is controlled by some kind of the control unit. In this case the control action is done manually via a hand lever. The advanced concept of control system is illustrated in Fig. 1. In the most cases hydraulic systems are more forked and complex. The principal Drive &Control pyramidal diagram is visible in the Fig. 5. We can see that design of the hydraulic system has to be done with respect of the electrical control system.

## 4. New System Approach

The new mechatronics approach applied during component designing is not sufficient for the design of vast spread systems. Hydraulics is not only connected via appropriate interfaces with control electronics but it is an integral part of whole control system as far as new automation systems are concerned (Kalman, 1960). In this case we have to apply the cybernetic principles and dynamic systems theories (Forrester, 1968).

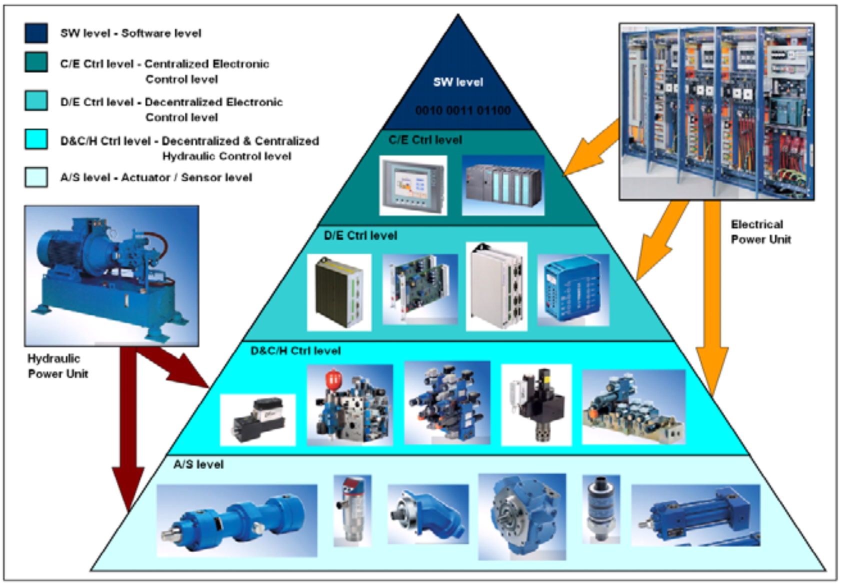


*Fig. 5: Hydraulic & Electronic Drive & Control System Architecture.*

## 5. Implementation of Artificial Intelligence

Hydraulic systems are multiple-parametrical and the optimal operating point is hardly accessible with conventional control algorithms. Very good results can be obtained using the means of artificial intelligence (AI), especially using self-tuning control system with fuzzy logic and neural networks. Knowledge-based system can be implemented in the diagnostic or the failure prediction (Muto, 2003).

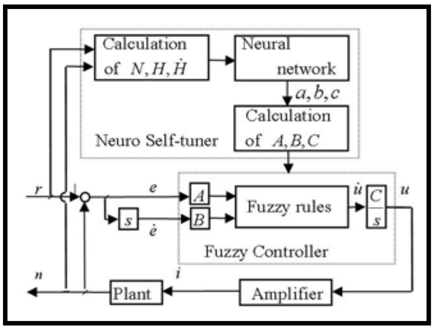


*Fig. 6: Control Algorithm using means of AI.*

## 6. Conclusions

It is obvious from all the mentioned facts, that there is still a significant potential for future progress in hydraulic systems, especially for the advanced system architecture and for new control concepts implementation. The synergic action of the heterogenous parts benefits integration will lead to the system performance excellence and will help us to create safer and energy efficient world.


## Acknowledgement

The survey and research of future potential of hydraulic systems is fully supported by the management of the ŽĎAS Company and it has an impact on various grants and technical development projects solved by the Company. This support is gratefully acknowledged.


## References


Forrester, Jay W. (1968) Principles of Systems, (2nd. ed.). Waltham, MA: Pegasus Communications, 391 pp.

Kalman, R. E. (1960) On the General Theory of Control Systems. In: Proceedings of the First Triennial World Congress of IFAC, Moscow.

Muto, Takayoshi. (2003) Self-tuning Fuzzy Control of Electro-hydraulic System, Journal of Fluid Power, Japan

Rao A.K.& Subash B.A. (2000) Industrial Dynamics to Systems Thinking, Indian Institute of Technology, Bombay, 33 pp.