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# NEW TRENDS IN MINING EQUIPMENT DESIGN

József ANDRÁS,[1] József KOVÁCS,[2] Endre ANDRÁS[3]

[1] *University of Petrosani, Faculty of Mechanical and electrical Engineering, Department of Mechanical, Industrial and Transportation Engineering, Petrosani , Romania, iosif.andras@gmail.com*

[2] *PUniversity of Petrosani, Faculty of Mechanical and electrical Engineering, Department of Mechanical, Industrial and Transportation Engineering, Petrosani , Romania, kovacsi@mail.com*

[3] *University of Petrosani, Faculty of Mechanical and electrical Engineering, Department of Mechanical, Industrial and Transportation Engineering, Petrosani , Romania, andrei.andras@gmail.com*

**Abstract**

Mining machinery and equipment have changed little in recent decades, from the point of view of the principle of operation, construction and structure. But in terms of dimensions, performance and stresses they have made a lot of progress, experiencing unprecedented sophistication and complexity. In order to fulfil the new requirements imposed by the increasing productivity and efficiency demands, as well as the economic, environmental and safety constraints, their design and development must comply with the general advance of overall technology. Therefore, recently, modern analytical methods have also been included in the design and development of mining machines. Among other issues, the present paper examines the theoretical and conceptual aspects related to the mining machinery' design requirements involving mechatronics.

**Keywords***: mining machinery, engineering design, mechatronics.*

## 1. Introduction

Throughout the history of mankind, mining has had a significant impact on general social and economic development. Many ground-breaking technological innovations, such as steam engines and pumps, are associated with the golden age of mining. In the following eras, mining, as a supplier of raw materials, has applied the results of technological developments such as compressed air, electric motors, hydraulic drives, etc., contributing through this to their further development.

The current relative stagnation of mining has been caused by severe economic, financial and environmental limitations. In spite of this, mining remains an essential procedure in the supply of energy and basic raw material.

In the present the "green energy" hysteria has cornered coal-based energy production, but "renewable energy" resources carry a potential energy and critical mineral need-induced crisis that we are not yet able to handle.

For this reason, in the near future, mining can expect a new boom, instead of recession.

At the beginning of the third millennium, mining technologies, equipment and technical solutions reached a certain maturity. This can be considered as the trigger of an emerging revolutionary jump that cannot be ignored.

The unprecedented development of manufacturing technologies is supported by the boom of electronics, fine mechanics, automatic control and computing. Its results were incorporated more easily and efficiently in other industry branches. This caused a lag in the development of mining machinery compared to industrial areas at the forefront of technological development.

As a consequence, design and development methods in mining were positioned later on a scientific basis. **[1]**. So, the development of technologies and equipment used in mining present slower progress compared to other industrial branches.

In order to overcome these phenomena, it is necessary to find new solutions for updating knowledge and technological development. It is also necessary to mention here that mining technology development has always resulted from a symbiosis of creativity and traditional solutions. Due to this, innovation in mining presents special peculiarities [2].

Knowing that mining technology is based on three basic operations - wining, loading-hauling, and supporting, the mechanization of these has sometimes evolved independently of each other, none-the-less influencing each other.

A notable peculiarity of the development of mining technologies is that the explosive evolution of one component leads to the rapid development of the other two components. This evolution is cyclical, resulting in the eventually emergence of an entirely new technology.

There exist examples where the development of mechanization requires a new technological process: a significant one is the use of tunnel boring machines (TBM). The fact that mechanization follows and fits the technological process, is another peculiarity of mining machines. Increasing performance requires size and weight increase. The moving workplace requires that the mobility of the mining machine is one of its important features. In some cases this implies that the three operations (functions) require separate execution tools.

The functionality of a particular machine derives from the integration of the assembly of each functional element and the correlation of functionalities [3, 4].

Consequently, the functional analysis is essential for the design of equipment. Based on this, important conclusions can be drawn on the specifics of mining machines and equipment, as well as on the functionality-design interaction.

Thus, when designing a machine, it is necessary to consider the types of interconnections through which functional elements are connected to the whole machine system, as well as the degree of integration of the machine or functional elements into the system.

As the integration between the elements of the equipment (technical system) is higher, the peculiarity of the equipment for certain conditions of use is greater, the degree of versatility is lower, which requires an optimal compromise between specialization and universality.

Depending on the degree of integration of functional elements into different systems, it can lead to new structural restrictions dictated by the compatibility of functional elements, and the need to perform some new secondary functions may entail changes in structure.

Therefore, the design of any functional element, be it a unique machine or an integrated system, should be carried out in a systemic context, taking into account the effect of the connection of the given element with the others on its functionality (operation in accordance with the requirements). At the same time, the expected stresses, known only in average or maximum values, which can be attributed to the random nature of workflows such as wining, loading, haulage, support, (might) lead to oversizing of the structural components.

## 2. Mechatronics as a design approach

Traditional design of mining machines manages separately the structural-functional parts (mechanical, electrical, hydraulic and control units).

Mechatronics, as a design approach, can offer an innovative procedure for the systematic design of mining machinery and equipment.

The multidomain nature of these machines, in traditional design, may lead to the impossibility of optimal alignment of the structural and functional parts of different varieties. The loads of mining machinery usually result from the prescribed motion of the executive element while it interacts with the working environment.

The traditional mechanical design basically tries to compute the trajectories, velocities and accelerations of parts, in the condition of action of a known force system. (Figure 1)

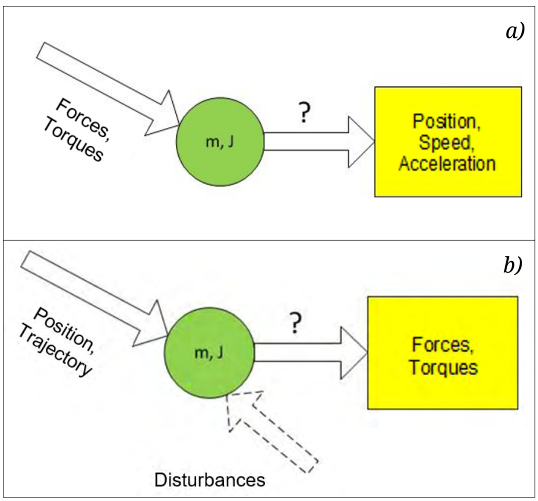


**Figure 1.** *Traditional (a) and mechatronics based (b) design approach.*

In mechatronics, mechanical systems are also essentially complex, but in contrast to the previous one, the subject of the computing becomes the forces and torques needed to maintain a prescribed trajectory, speed and acceleration of the parts. The computed values are provided by continuous measurement-based control. (Figure 2)

Figure 3 refers to the distribution and treatment of flows (energy, material and information) used in mechatronic design. [5, 6].

The processing of information refers to the fact that the operating parameters of mining machines should generally only be adapted to rock cutting factors known in average terms, together with compliance with geometric, desired shape, productivity and energy requirement limitations.

These requirements are imperious for all kind of rock cutting machines, but specially for roadheaders. However, since the direct perception of the different parameters is impossible or in principle complicated, they can be obtained indirectly from the operating parameters only by calculation. Therefore, a drive is required with a complex structure containing embedded sensors for mobile elements. Up to date artificial intelligence methods (fuzzy logic or neural networks) may be used for calculations.

The experimental system developed by Polish researchers [7] is shown in Figure 4. The data of the boom and of the loader plate position sensors are processed by the control unit which properly regulates the parameters of the milling head and loading system.

All this together uses data from the milling head drive torque and the boom swing speed sensors for optimal energy use and productivity, observing the requested shape of the cross section of the cut.

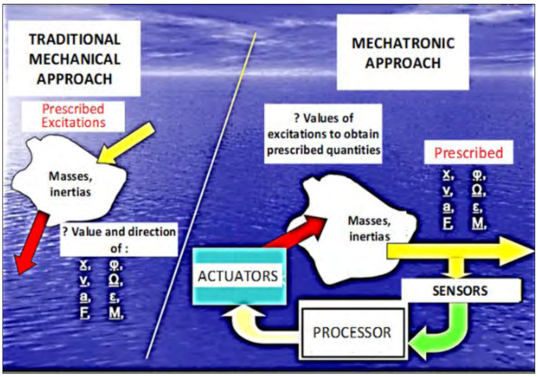


**Figure 2.** *Comparison of traditional / mechatronic design.*

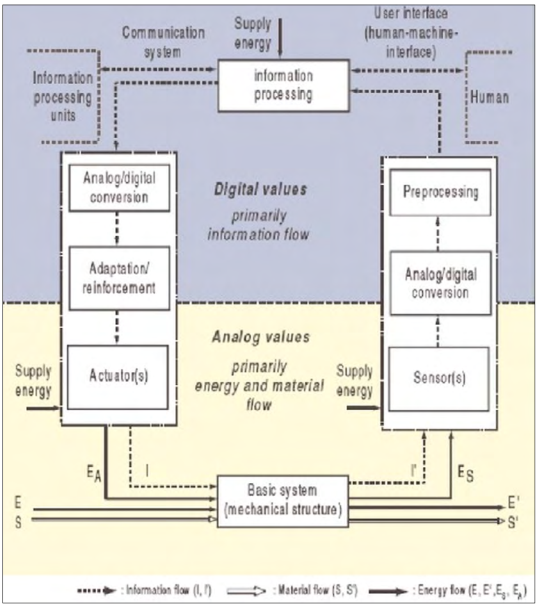


**Figure 3.** *Flows used in mechatronic design*

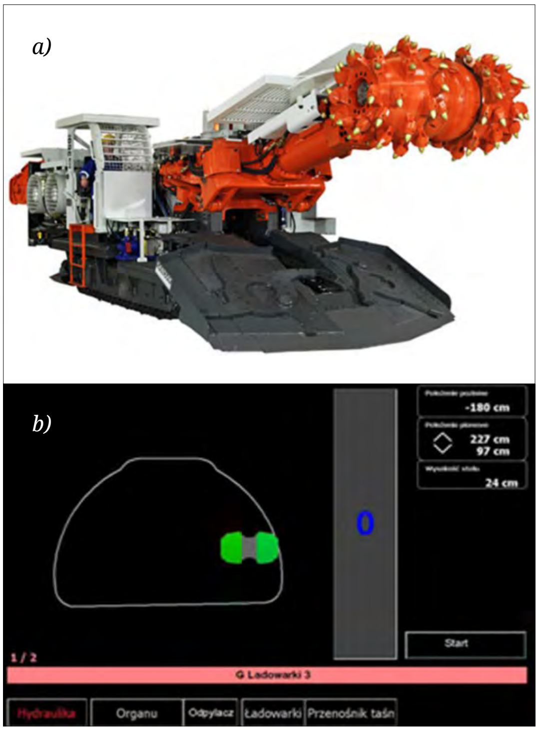


**Figure 4.** *Roadheader designed on the basis of a mechatronic approach, (a) display screen observing the shape of the cross-section of the cut (b).*

Another example also applies to drilling carriages (jumbos) used in cutting drives (**Figure 5**) which are an essential tool for drilling-blasting technology.

In this case, compliance with the prescribed drilling scheme (**Figure 6.a**) is the main issue. The appropriate position of the drill rod end and the direction of the conductive rail (**Figure 6.b**) for each borehole is calculated on the basis of data from built-in sensors and made by the displacement of the hydraulic actuators. With the help of a software, one can display the state of the process on a screen(**Figure 6.c** ).

**Figure 5.** *Drilling jumbo*


**Figure 6.** *The prescribed drilling scheme (a), the boom with the conductive rail (b), the display screen (c).*

## 3. Conclusions

Modern analysis methods have recently been used in the design and development of mining machines.

They are not just tools, but rather an approach.

The specificity of mining machinery allows to fulfil this requirement under certain conditions.

The multidomain nature of these machines, in traditional design, may lead to the possibility of optimal alignment of the structural and functional parts of the separate parts.

Mechatronics as a design approach can offer an innovative approach to the regular design of machinery and equipment used in mining, which has been illustrated by examples.

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