Optimizing a four-props support using the integrative design approach

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Abstract. Modern approach to the design process of technical means requires taking into consideration the issues concerning the integration of different sources of data and knowledge, and various methodologies of design. Thus, the importance of integrative approach is growing. The integration itself could be understood as a link between these different methodological solutions. Another problem is the issue concerning the optimization of technical means because of the range of design requirements. The presented issues are the basis for design approach that uses integrative approach as the basis for constructional optimization of designed technical mean. It bases firstly on the concept of integration three main subsystems of a technical mean: structural one, drive one and control one. Secondly it includes the integration of three aspects of a construction: its geometrical characteristics, its material characteristics and its assembly characteristics. One of areas of utilization of the proposed integrative approach to designing process is elaborating the construction of mining mechanized supports. There different systems of mining support characterizing by different sets of advantages and disadvantages. The importance of the design process is considered with the working conditions of mining supports that are closely linked with geological characteristics of mined beds. A mining mechanized support could be treated as the logical union of three mentioned constructional subsystems. The structural one includes among others canopy, rear shield and foot pieces. The drive one includes hydraulic props and its equipment. Finally the control one include the system of hydraulic valves ant their parameters.

1. Introduction
For the underground mining one of the most important method of operation is the longwall one. The second one is the room-and-pillar mining, which is the traditional method in some countries. Longwall mining is the method that is well suited to extracting the relatively flat coalbeds. They are typical for the European mining industry.

Although widely used in different countries, longwall mining has only recently become important for the European hard coal industry. Longwall mining is quite simple techniques of hard coal extraction. A coalbed is divided into panels averaging nearly 250 meters in width, 2000 meters in length, and 2 meters in height, by excavating passageways around its perimeter. A panel of this size contains more than 900 thousand tonnes of hard coal, up to 80% of which will be recovered. During
the mining process, numerous pillars of coal are left untouched. They are placed in certain parts of the mine in order to support the overlying strata. The mined-out area is allowed to collapse. It could cause some surface subsidence.

Nowadays the main mining system is based on the application the powered longwall one. This mining system includes three sub-systems: a shearer one, a conveyor one and a support one. Elements of this system are presented in figure 1.

![Figure 1. Elements of a powered longwall system [1].](image)

The support subsystem consists of a set of powered roof supports which cooperate in the process of supporting strata and in protecting the mining area [2,3,4,5]. In figure 2 is presented the biggest, traditional powered support manufactured for the Indian contractor.

![Figure 2. Typical powered roof support manufactured by Joy [6].](image)

The construction of a traditional powered roof support has some disadvantages. Firstly, the concretion is based on the application of two main hydraulic props. It allows simplifying the design but on the other hand it leads to a reduction of supporting points what results in stresses increasing. Secondly, the construction basing on a pair of parallel placed props is less stable because of a short foot piece. It results in collapsing of a support unit even at weak tremors. And finally the construction of the traditional powered support is characterised by the lack of place designated for equipment location and for miners passages. One of solutions of this problem is modular design [7,8,9,10].
2. Idea of the integrative approach

The designing process of the powered mining support with four-props (legs) was conducted using the integrative approach [11]. In figure 3 is presented the idea of the integrative approach. According to this approach the system of a technical mean is divided into three subsystems according to the main functions fulfilled by them. The first one is called the structural subsystems. It contains representatives of structural elements of a technical mean. In the case of a powered support main structural components are: a canopy, a caving shield and two foot pieces. The second system, the drive one, relates to the drive elements of the designed technical mean. In the case of a support it includes a pair of main props and a number of auxiliary props as well as a hydraulic system. Finally the control system contains information on control elements used in the designed technical means and on control procedure and its implementation. Each subsequent system results from the construction of the previous one and influence on the construction of the following one. In this approach designing process is a cycle of three design sub-processes conducted till the optimal design will be obtained.

![Figure 3. Model of integrative approach (comp. [11]).](image)

Apart from the main cycle, the integrative approach includes also the cycle of selection or designing the constructional features [11]. This three features are: geometrical one (determining the dimensions of a construction), material one (determining the material for a given construction) and assembly one (determining the assembly process).

The another aspect of the proposed approach is the possibility of application the AI technique for improving the design process [12,13,14]. It is particularly related with the optimization process realized during the design one [15,16]. For this purpose it could be utilized the solution established in other technical design areas [17,18,19,20].

3. Design of a mining support

The designing process includes many factors that could be solved during it. For example in the designing process one should determine the most appropriate material [21,22,23] or establish the most economic production approach [24, 25]. The design process is also related with the test approach to analyse details of proposed solutions [26,27]. But in this case the most important was the application of the CAD/CAE environment (Siemens PLM NX program). According analysis, elaborated using the integrative approach framework it has been determined the particular solutions of the designed four-props mining support. The virtual model of this support is presented in figure 4. It was design utilizing
parts of a traditional two-props support. The utilization of the second pair of props allows decreasing the tendency for falling over under the load of a roof.

In figure 5 is presented this support in a mined position, when it is spragged under the roof and in the lowered position (e.g. transport position). In spragged position canopy acts on the roof with the force being the result of hydraulic pressure in props. Simultaneously roof reacts on a canopy with the force equal to the mass of caving stratum what results in stress generating in particular nodes of a support construction. This is why it is important to optimize the construction of a support. It allows improving the strength of the construction and optimizing its weight.

![Figure 4. Powered roof support.](image1)

![Figure 5. Stages of the support spraying.](image2)

Figure 6 presents the distribution of stresses for the two-props, traditional roof support. The concentration of stresses, as it is visible, is observed around the props mounting joints. In figure 7 is presented the distribution of stresses of the analysed support at a vertical load of the roof. The stress concentration takes place mainly at the joints between a canopy and props and a caving shield. But the stress pattern is more uniform.
It should be stated that the stress pattern is strongly depended on the trajectory of a canopy which is not a vertical line (lemniscate curve) and on the direction of particular roof strata.

4. Conclusions
The presented design of the four-props powered roof support was realized as a project used to analyse the module approach in mining support design. It was based on application elements that could be used both in a two-props support and in a four props one. Secondly it was designed to improve the stress pattern resulting from the lower number of supporting props. Additionally this, four-props support, is more stable than a two-props one.

Currently are realized preliminary investigation application the MIAS technology for data constructional data acquisition [28,29,30]. They are related with test of virtual test of newly designed technical solutions [31,32,33].

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