Estimation of strength properties of the UWZ-1 device for withdrawing the powered roof support

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Abstract:

The concept of a device for withdrawal of a powered roof support during the liquidation of a longwall panel is presented. This device is a part of the system developed by KOMAG for the withdrawal of a roof support from a row and its transportation in the liquidated longwall. The suggested solution significantly improves efficiency and safety of this process. The basic parameters of the device, a description of the design and principle of operation are presented. Strength properties of its basic components were estimated, taking into account the way the device operated during the withdrawal of the roof support. The paper describes the problems faced by engineers when designing the non-standard mining device, which is the UWZ-1 device. The advantages of the discussed device are also presented.

Streszczenie:

W publikacji przedstawiono koncepcję urządzenia do wybudowy sekcji obudowy zmechanizowanej w procesie likwidacji ściany wydobywczej. Urządzenie to jest elementem opracowanego w ITG KOMAG systemu do wybudowy sekcji z szeregu i jej transportu w likwidowanej ścianie. Zaproponowane rozwiązanie poprawia w zdecydowany sposób efektywność i bezpieczeństwo tego procesu. Przedstawiono podstawowe założenia urządzenia, opis konstrukcji oraz zasadę działania. Oszacowano właściwości wytrzymałościowe jego podstawowych elementów uwzględniając sposób pracy urządzenia w czasie wybudowy sekcji. W publikacji opisano problemy z jakimi spotykają się inżynierowie przy projektowaniu konstrukcji nietypowego urządzenia górniczego jakim jest urządzenie UWZ-1. Przedstawiono także zalety jakie posiada przedmiotowe urządzenie.

1. Introduction

The process of disassembling the technical equipment in the liquidated longwalls and its transportation to new workings is one of the most difficult processes with a significant accumulation of factors favoring the disturbance of this process [1]. Operations related to the withdrawal of the powered roof support from a row and its transportation to the main transport roadway are of particular importance due to the weight and number of transported components. Machines and devices used in Polish hard coal mines are presented in [2, 3, 4, 5].

Based on the experience gained during operating the equipment used for withdrawal [6, 7, 8], chain broaching machines [9] and mine operation [10, 11], KOMAG developed a concept of a new system for the withdrawal of a powered roof support from a row and its transportation in a liquidated longwall panel [12]. UWZ-1 device designed for withdrawal of a powered roof support from the row is the key component of this system. This device has to fulfill the following three basic tasks:

− support the roof in the transportation area of the cross-cut entry in the area of the roof support withdrawal,

- enable the roof support to be moved from the row and relocated to the transportation area of the cross-cut entry and loading it onto a transportation platform using the set of hydraulic cylinders and roof support advancing system,
- move along the cross-cut entry using its own advancing system,
- as well as to meet the requirements of regulations [13, 14, 15, 16, 17, 18].

The issues of estimating the strength properties of basic components of the UWZ-1 device at the concept stage are presented.

2. Description of the device's design and principle of operation

The UWZ-1 device with a transportation platform onto which the withdrawn roof support is pulled, is shown in Fig. 1.
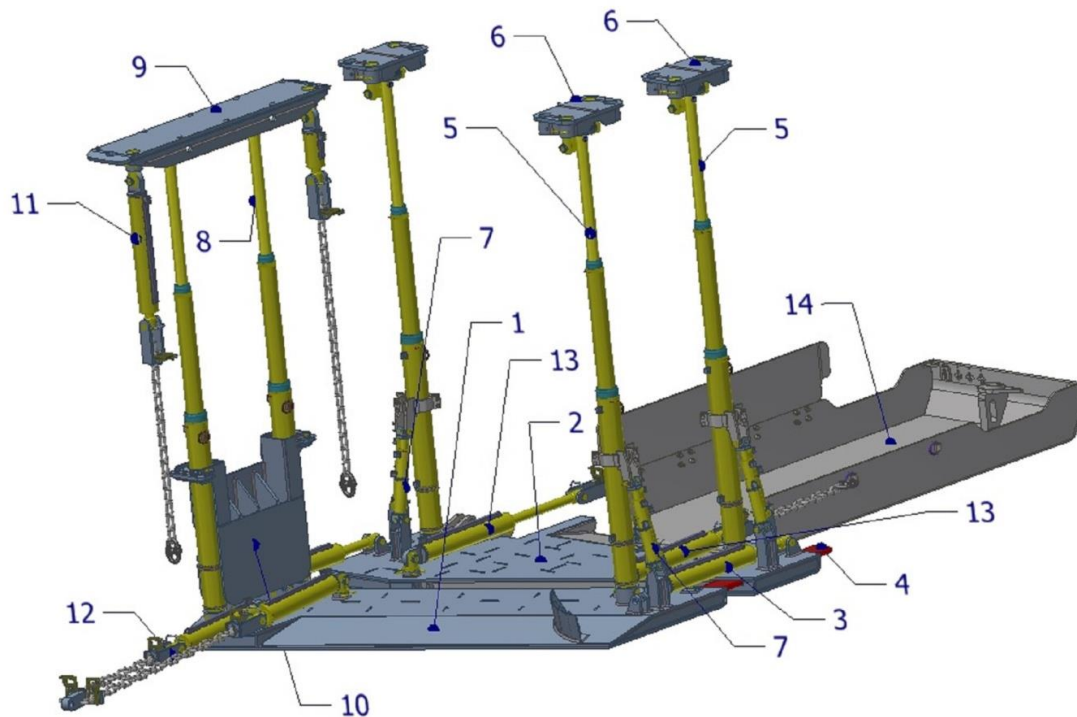

Fig. 1. Visualization of the device for withdrawal of the UWZ-1 roof support during liquidation of a mining longwall panel along with a transportation platform

The UWZ-1 device is made of two moving segments inrun (item 1) and descending (item 2) connected by an advancing system.

The advancing system consists of two hydraulic cylinders (item 3) and two guiding boards (item 4). The advancing cylinders are attached to the eyes of each advancing segment. The guiding boards are fixed in the inrun segment, while in the descending segment, the guiding tunnels are installed allowing the guiding boards to slide. The advancing cylinders have 800 mm range of movement. The inrun segment consists of a platform equipped with a descending wedge and a guiding buffer. The wedge and buffer are used to guide the withdrawn roof support into the device's transportation tunnel.

A single hydraulic leg (item 5) is installed on the side of the buffer and the wedge. A small bolting canopy (item 6) is installed on the hydraulic leg. The leg is stabilized with a stabilization unit (item 7) consisting of a pair of hydraulic cylinders and a stabilizing clamp. The stabilization unit stabilizes the leg vertically with possibility of its correction in two planes by ±10˚. On the other side of the inrun segment, there are two interlocked hydraulic legs (item 8).

A large bolting canopy (item 9) is installed on the legs. The legs are stabilized with a stabilization unit (item 10), consisting of a platform and a hydraulic cylinder. The stabilization unit stabilizes the leg vertically with possibility of its correction in one plane by ±10˚.

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The large canopy is equipped with two auxiliary hydraulic cylinders (item 11), fixed with two pairs of hinged joints with mutually perpendicular axes of rotation. The cylinders are used as auxiliary components in the operation of pulling the withdrawn roof support into the transportation tunnel of the device and correcting its position in the tunnel. On the side of the interlocked hydraulic legs, there is a roof support withdrawing unit (item 12). It consists of a pair of hydraulic cylinders connected to the inrun segment platform using the same method of fixing as the item 11 cylinders.

On the side of a single hydraulic leg there is a hydraulic cylinder of the transportation platform (item 13), which also uses the same method of fixing as the item 11cylinders. It is used to pull and stabilize transportation platform in relation to the device for withdrawal of roof support. In addition to the guiding buffer, there are additional eyes for installation of the cylinder, and which can be used to correct position of the withdrawn roof support in the transportation tunnel. The descending segment consists of a platform (item 2) equipped with a descending wedge and a set of eyes for installation of the chain puller's return end. The descending wedge is used to facilitate moving the withdrawn roof support from the device's transportation tunnel onto the transportation platform (item 14). Double eyes and fastening pins are used to connect the roof support withdrawing device with the return end of the chain puller. Single hydraulic legs are installed on both ends of the segment (item 5).

Small bolting canopies (item 6) are installed on the hydraulic legs. The legs are stabilized with stabilization units (item 7) similarly to the stabilization of a single leg of the inrun segment. The hydraulic cylinder of the transportation platform (item 13) is located on the side of the chain puller's return end, connected to the descending segment platform by a set of two mutually perpendicular articulated pairs. It pulls and stabilizes the transportation platform in relation to the roof support withdrawing device.

A removable handle for mounting the chain is placed in the area of the descending wedge. The chain connects the handle with the beam of the sliding system of the withdrawn roof support moved into the device's transportation tunnel. The canopies of the moving segments form a transportation tunnel into which the withdrawn roof support is pulled.

Fig. 1 also shows a transportation platform onto which the withdrawn roof support is pulled.

The principle of operation of the UWZ-1 device

The UWZ-1 device is installed at the height of the powered roof support neighboring to the roof support to be withdrawn (Fig. 2). It is set to load using the canopies and hydraulic legs. The empty transportation platform is pulled to the unit and anchored with an additional individual hydraulic leg (not shown in figure).
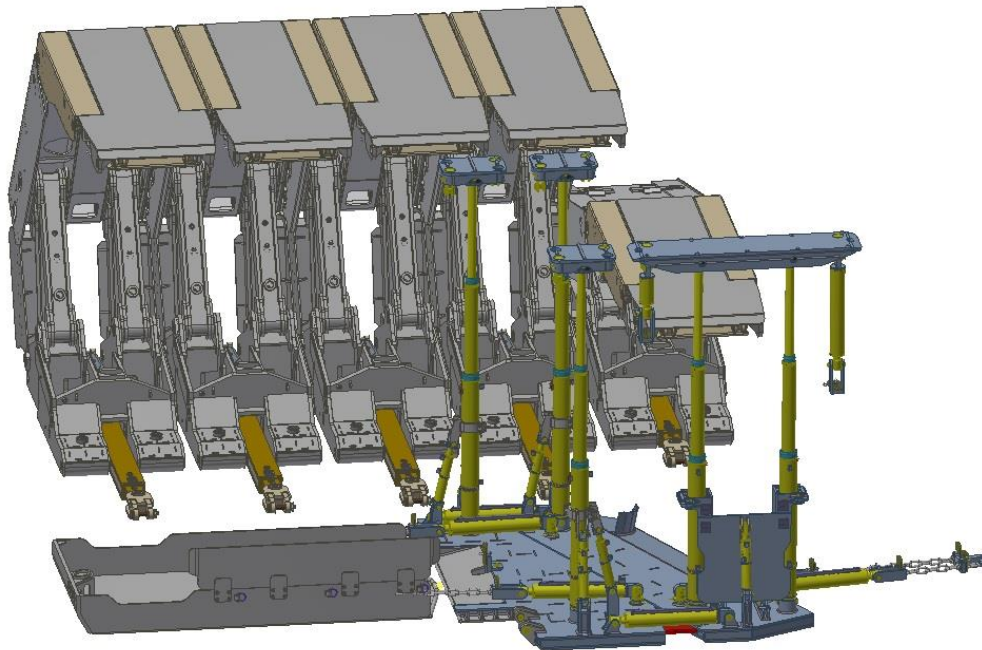

Fig. 2. Visualization of the UWZ-1 device prepared for withdrawal of the roof support from a row.

The roof support to be withdrawn from the row is pulled out using a set of pulling cylinders, correcting its position using the auxiliary cylinder installed on the large canopy of the device. The withdrawn roof support is pulled into the transportation tunnel of the securing support using the roof support's advancing system while auxiliary cylinders are correcting its position., The roof support withdrawn from the transportation tunnel is pulled onto the transportation platform using its advancing system.

3. Estimation of strength properties of UWZ-1 device

The description of the design and operating principle of the device for withdrawal of the roof support presented above shows that the device technical parameters and dimensions must be adapted to the local conditions in the longwall (roadway height, load-bearing capacity of the roof and floor) and the weight and dimensions of the roof support to be transported. In such a situation, designing a series of types of devices is not rational and therefore each withdrawing device should be designed for a specific application.

Therefore, at the current stage of development of the device, the strength calculations were limited to a preliminary determination of the stress of each component. For this purpose, the Finite Element Method module available in the Autodesk Inventor Professional 2019 engineering program was used. Due to the large number of assemblies included in the UWZ-1, the complex interactions of each of them and the limitations of Autodesk Inventor, it was decided to narrow the scope of the simulations to a few basic assemblies most exposed to loads resulting from cooperation with the surrounding components of the device working environment.

The simulation covered the inrun and descending segments cooperating with the floor, as well as small canopy and large canopy cooperating with the roof lining of the cross-cut entry.

The following assumptions were made for the simulation purposes:
- the device can be used for the withdrawal of a roof support of a pitch 1.5 m and a weight of ~23,000 kg,
- the height range of the device is 2400 ÷ 4400 m,
- the width of the transportation tunnel for the withdrawn roof support should be ~2400 mm,
- hydraulic legs will be two-telescopic with a diameters Ø160/Ø140/Ø100, operating at a working pressure of 34 MPa,
- the device will be self-advancing with 800 mm advance,
- when estimating the strength properties of the device, cylinders for withdrawing the roof supports were neglected due to insufficient force compared to the force of the hydraulic legs.

Estimation of the strength properties of a small canopy

The method of supporting the canopy, shown in Fig. 3, was adopted for the simulation. Two beams with a cross-section 100x100 mm, located at the ends of the canopy, were used to simulate the supporting method.
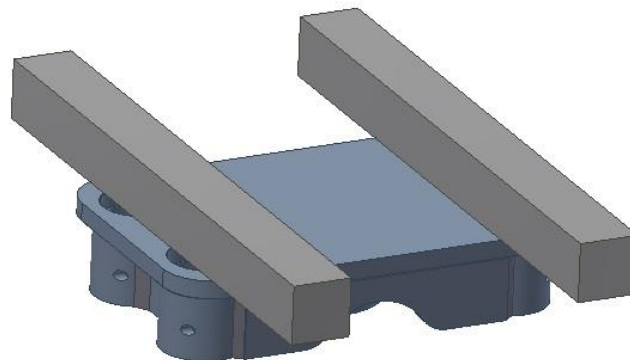

Fig. 3. The method of supporting a small canopy

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The canopy was loaded with the force from the hydraulic leg applied at the leg fixation. The simulation results are shown in Fig. 4.
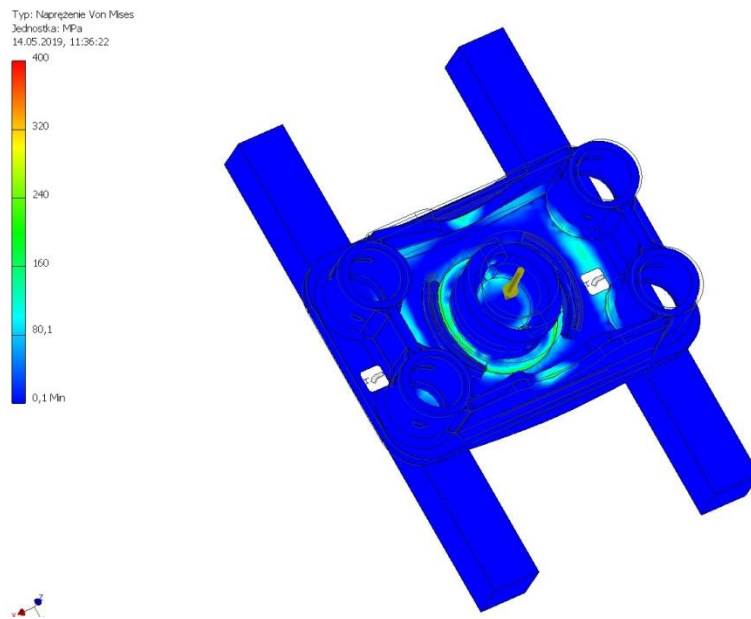

Fig. 4. Map of reduced stresses in a small canopy

The stress map in Fig. 4 shows that the local reduced stress is lower than 400 MPa. Therefore, the small canopy can be made of typical available construction materials (e.g. S460N steel).

Estimation of strength properties of a large canopy

Due to the possible different methods of cooperation of the large canopy with the roof lining of the cross-cut entry, it was decided to limit the computer simulation to the two most unfavorable and, at the same time, the most common methods of supporting the canopy.

I support method.

The cooperation of the canopy with the lagging is modelled by a 100x100 mm beam located in the middle of the canopy (Fig. 5).
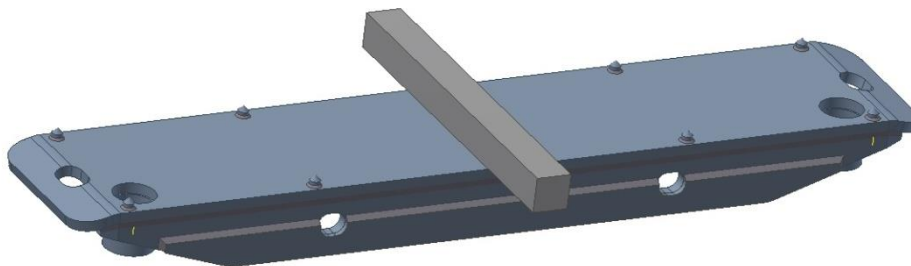

Fig. 5. First method of supporting a large canopy

The canopy was loaded with forces from two hydraulic legs applied at the legs fixation points. The results of the simulation in the form of a map of reduced stresses on the deformed model of the canopy are shown in Fig. 6.
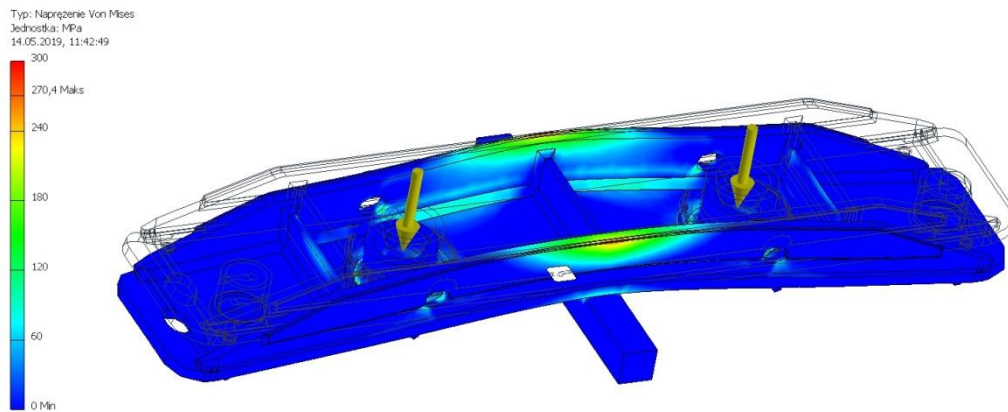
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Fig. 6. Map of reduced stresses in a large canopy - I supporting method

With this method of loading, the reduced stress in the canopy is lower than 300 MPa.

II support method.

The impact of the roof lining on the canopy is modelled by two 100x100 mm beams, moved away by 100 mm from the canopy ends. The canopy was loaded with forces from two hydraulic legs applied at the legs fixation points. The results of the simulation are presented in Fig. 7.
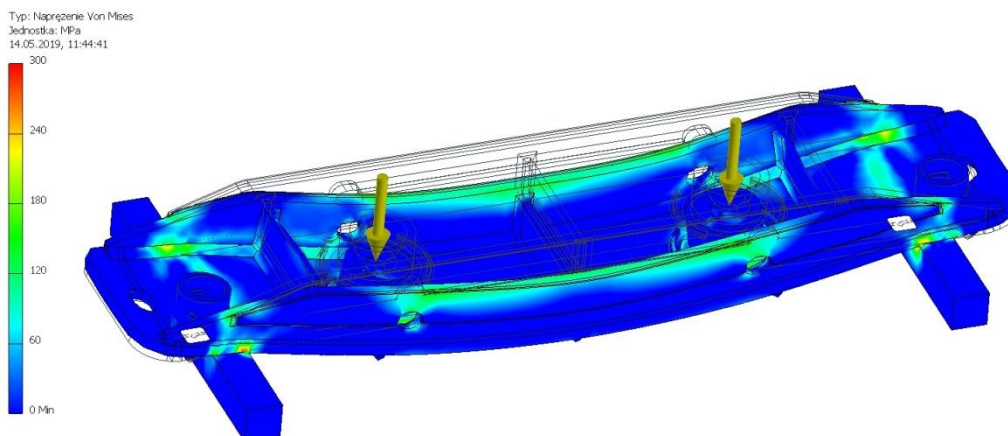

Fig. 7. Map of reduced stresses in a large canopy - II support method

Fig. 7 shows that the stresses in the canopy are lower than 300 MPa. The results of both simulations allow concluding that the typical available construction materials (e.g. steel S420N) can be used for its manufacturing.

Estimation of strength properties of the descending moving segment

The segment is supported by a beam located halfway between hydraulic legs. Such a supporting method results from the principle of kinematically variable system striving to take the balanced position. The adopted model of supporting the descending segment as a 100x100 mm beam is shown in Fig. 8.
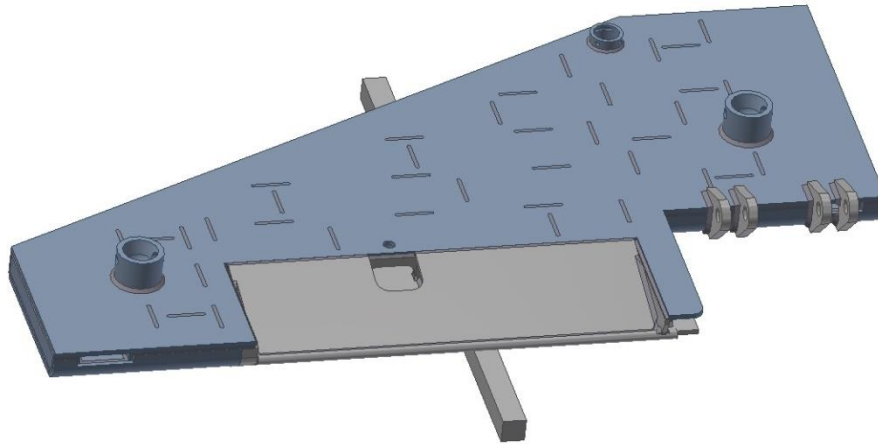
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Fig. 8. The method of supporting the descending moving segment

The segment was loaded with forces from two hydraulic legs applied in the place of legs fixation. Results of the simulation are shown in Fig. 9.
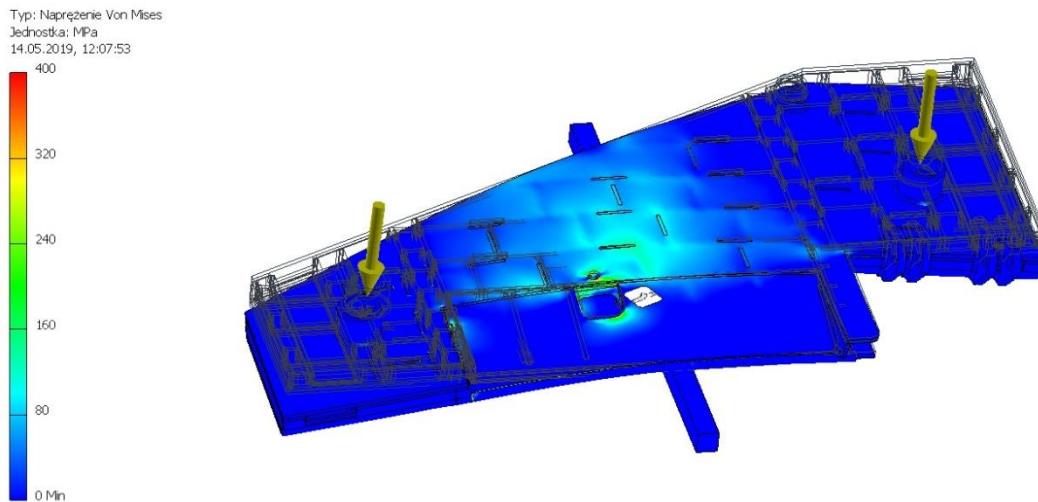

Fig. 9. Map of reduced stresses in the descending moving segment

The stress map shown in Fig. 9 shows that the local reduced stress is lower than 400 MPa. The descending moving segment can therefore be made of construction materials available on the market (e.g. S460N steel).

Estimation of strength properties of the inrun moving segment

The most unfavorable variant of loading the segment consists in supporting it with one beam. Its position on the surface of bottom plate of the segment was determined using the equilibrium state of the discussed system. Assuming such a supporting method also results from the principle of kinematically variable system striving to take the balanced position. The adopted model of supporting the inrun segment as a 100x100 mm beam is shown in Fig. 10.
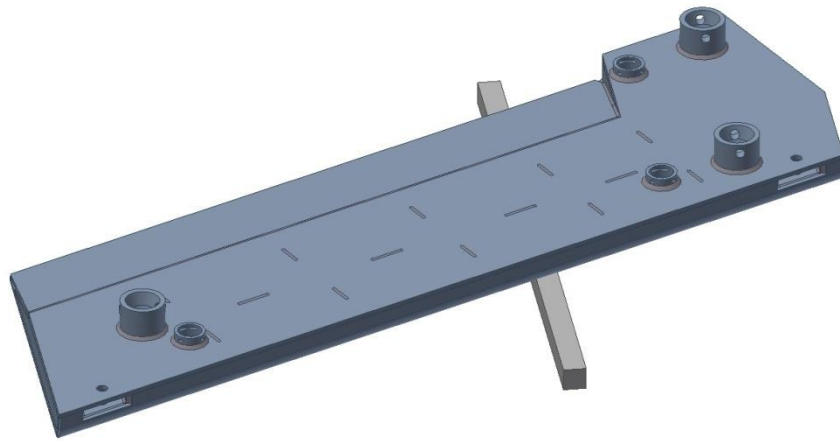
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Fig. 10. The method of supporting the inrun moving segment

The segment was loaded with the forces coming from two hydraulic legs applied at the legs fixation point. Results of the simulation are shown in Fig. 11.
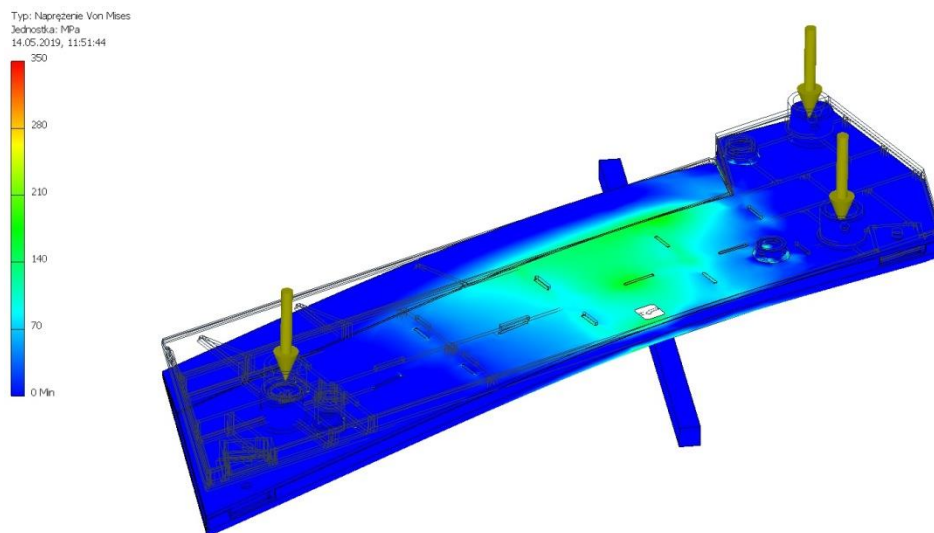

Fig. 11. Stress map of the inrun moving segment

The stress map shown in Fig. 11 shows that the local reduced stress is lower than 350 MPa. The inrun moving segment can therefore be made of construction materials available on the market (e.g. S420N steel).

4. Conclusions

The method of estimating strength properties of the presented UWZ-1 device for withdrawal of powered roof support, illustrates the complexity of problems faced by designers of such devices. It is not enough to create 3D models of the device components of such a device, but each phase of its operation, method of cooperation with the components of the cross-cut entry, the shape of the floor and the specificity of the withdrawn roof support design needs to be known. The knowledge of the problems allowed to adopt proper supporting methods allowing to estimate strength properties of the UWZ-1 device for withdrawal of roof support.

The basic advantages of UWZ-1 roof support are as follows:

 − possibility of securing and supporting the roof of cross-cut entry in the area of the roof support withdrawal,
 − mechanization of withdrawal process of the roof support starting from its removal from the row to the loading it onto the transportation platform, under the permanently protected roof,

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– the device is self-advancing, what means that its mobility does not require any additional equipment for moving.

All these advantages significantly improve the efficiency of the entire process as well as the comfort and safety of the personnel during withdrawal of the powered roof support from the liquidated longwall panel.

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