Analysis of effort of lifting eye fixation in the tilt cylinder in the powered roof support's gob shield

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Abstract:

Cases of damage to the lifting eye fixation in the tilt cylinder of a gob shield during operation of powered roof support is discussed. Using the FEM model of the gob shield, the lifting eyestrain was assessed, both in conditions of the discussed longwall panel as well as in the most adverse load. The probable cause of the damage has been determined as well as a suggestion to modify the design of lifting eye fixation in the tilt cylinder is analysed.

Streszczenie:

Omówiono przypadki uszkodzenia mocowania ucha podpory stropnicy w osłonie odzawałowej, powstałe w trakcie użytkowania sekcji. Korzystając z modelu MES osłony oceniono wytężenie ucha, zarówno w warunkach rozpatrywanego wyrobiska ścianowego, jak również przy najbardziej niekorzystnym przypadku obciążenia. Określono przypuszczalną przyczynę powstałych uszkodzeń oraz przeanalizowano propozycję modyfikacji postaci konstrukcyjnej mocowania ucha podpory stropnicy.

1. Introduction

Powered roof support are assumed to be the machines having a significant impact on safety of workplaces and technological processes in the mine longwall panel [3]. That is why their use in a longwall panel is conditioned by meeting the safety requirements provided in the harmonized standard [8]. Powered roof support designing processes and its proper selection to local mining and geological conditions require determination of static and dynamic loads acting on the roof support[1, 4, 9, 10]). In the case of already used roof supports, the operational parameters and technical conditions are assessed [7]. Before another use of powered roof supports in the longwall panel, their technical condition is inspected and assessed [2, 11]. However, despite the above-mentioned procedures there are some incidents of damages to the roof support components.

Analysis of effort of the lifting eye fixation in the tilt cylinder of a gob shield in the aspect of reported accidents of its damage as well as suggested changes to design of its fixation in a gob shield within the range of installation height from 1.4 m to 3.2 m, is the paper subject. Positive results of testing the powered roof supports means that they meet all standard requirements. The reported incidents of damages to welds connecting the tilt cylinder'slifting eye with the gob shield sheeting forced both roof supports users and manufacturers to undertake actions aiming at determination the damages reasons and elimination of future damages to the lifting eye fixation in the tilt cylinder of a gob shield.

2. Analysis of damages to the lifting eye fixation unit in the tilt cylinder of a gob shield

The discussed damages to welds connecting the tilt cylinder's lifting eye with the gob shield sheeting were reported at the beginning of the longwall panel of symbol B. A set of 156 line roof supports and 6 end supports made a longwall supporting system.

Longwall of length 250 m was located at depth 1035 ÷ 1065 m. Seam thickness, depending on number and thickness of interlayers and degree of seam erosion and change in the range from 1.7 m to 2.9m, while at the longwall panel beginning it was 2.5 m. Due to natural hazards, the seam in "B" longwall panel was classified to:

- I degree of water hazard,
- class B of coal dust explosion hazard,
- IV category of methane hazard,
- Partly to the category of coal and rocks burst hazard.

Already at the second week of longwall mining, damage to the gob shields in two roof supports were reported. After a month damages to the welds connecting the eye system of the tilt cylinder with a gob shield sheathing sheet were found in the next four roof supports. The damaged welds were marked. Based on a visual inspections it was found that length of damaged welds did not change. Sample weld damages are presented in Fig. 1 and 2.

Fig. 1. Damages to the welds connecting the lifting eye system of the tilt cylinder with a gob shield sheathing sheet [12]
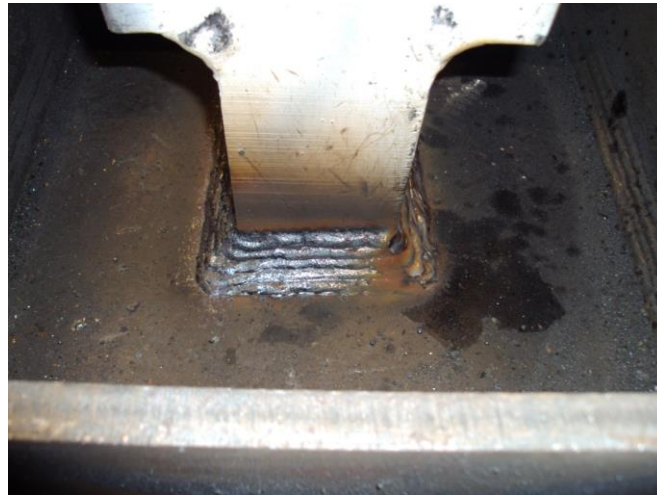

Fig. 2. Damaged welds in the gob shield of roof support No. 135[12]

Damaged gob shields were successively replaced and inspected to check condition of welds connecting the lifting eye attachment of the tilt cylinder with top plate (Fig. 3). It was found that all welds were made in accordance with the documentation.

Analysing the nature of the sheathing sheet and tilt cylinder's lifting eye's welds deformation, it can be concluded that they were caused by the force of pressure in the under-piston area of the tilt cylinder. In this case the tilt cylinder is compressed.

For a longwall height of 2.50 m, the roof support convergence results in an increase in the length of the tilt cylinder. For example, reducing the height of the roof support from 2.50 m to 2.46 m results in an extension of the tilt cylinder from 1140 mm to 1147 mm. In this case, the cylinder is stretched. It means that the observed damages did not happen during the realization of the roof support basic function related to taking over the load caused by the pressure of floor rocks. During typical manoeuvring of the roof support, the piston area of the tilt cylinder may be an active space, but then the pressure in this area is equal to the supply pressure.

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Fig. 3. Weld connecting the base of tilt cylinder's lifting eye fixation system with a gob shield top plate [12]

Theoretically, during the implementation of non-standard auxiliary functions of roof supports, it is possible to create operating pressure in the under-piston area of the tilt cylinder. Therefore, it is necessary to check the effort of fixation of the tilt cylinder's lifting eye in the case when this cylinder is stretched by a force of 703.7 kN, resulting from the working pressure in the under-piston area.

3. Determination of the effort of the tilt cylinder's lifting eye system at the load as in the real operational conditions

In cooperation with KOPEX Group factories, effort and deformation of lifting eye system in the tilt cylinder of the powered roof support were calculated using the FEM method.

The geometric model of the gob shield, for which numerical simulations were performed, is presented in Fig. 4. The assumed finite elements mesh, consisting of 237224 knots and 53 539 elements, was densified in the area covering the tilt cylinder's lifting eyes as well as in the metal sheets for attaching this lifting eye to the other components of the gob shield.
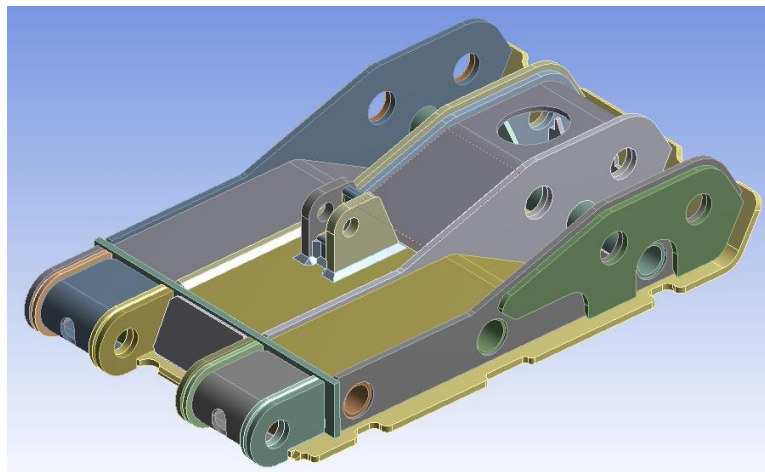
Fig. 4. Geometric model used in numerical simulations[6].

Elastic-plastic material characteristics with linear strengthening was assumed in numerical calculations (Fig. 5). The following material properties were applied in the model:
- Young modulus - $2 \cdot 10^5$ MPa
- Poisson number – 0.3
- flow stress Re = 400 MPa
- strengthening module - $2 \cdot 10^3$ MPa.

The purpose of the numerical simulations was to assess the impact of force in the tilt cylinder on lifting eyeeffort. Therefore, the strain on the sheathing caused by the forces in the rotational pairs connecting it with other roof support components was treated as a "zero" reference level when assessing the impact of force in the tilt cylinder on the change in strain of the system for fixation of lifting eye to the gob shield.
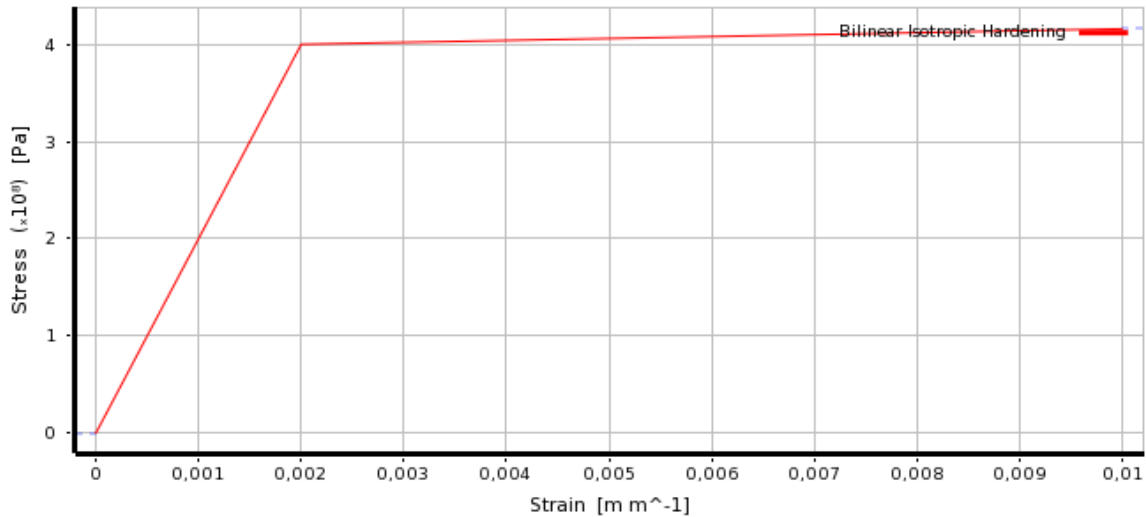

Fig. 5. Elastic-plastic characteristic of the material [6]

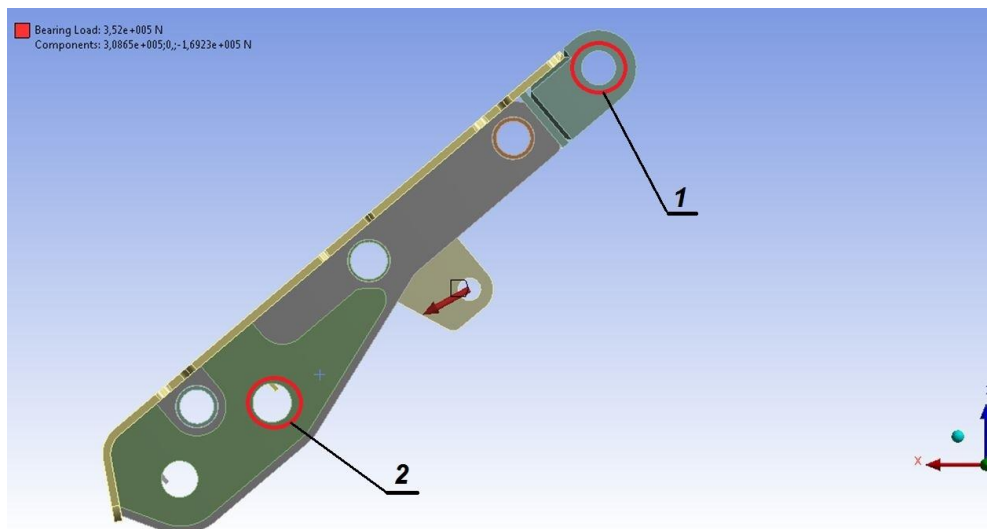Supporting method and load to the gob shield is presented in Fig. 6.

Fig. 6. Supporting method and load to the gob shield [6].

Cylindrical support was applied in eyes of the hinges connecting the gob shield with the canopy (point 1 Fig. 6) to enable rotation of the gob shield around hinges axles and in the eyes of hinges connecting the gob shield with the front links (point 2 Fig. 6), the cylindrical support with a possibility of gob shield rotation around the hinges and moving along the hinges was used.

Using the computer program OStO v.4.0 for analysis of static load to the powered roof support [5], the angle between the tilt cylinder axis and surface of the gob shield top sheet, at height 2.5 m, equal to $11.5^{0}$was determined, so it was possible to settle the resultant force components during feeding the under-piston area of the tilt cylinder. In the global coordinates system given in Fig. 6, at the resultant force in the tilt cylinder equal to 703,7 kN, the force acting on each eye of the tilt cylinder has the following components:

$$F_x = 308.649 \text{ kN} \qquad F_y = 0 \qquad F_z = -169.233 \text{ kN}$$

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In Fig. 7 distribution of the equivalent stress on the deformed model the eye and base is presented. The scale of the equivalent stresses was set in such a way that places in which the equivalent stress is higher than the yield point are marked in red.
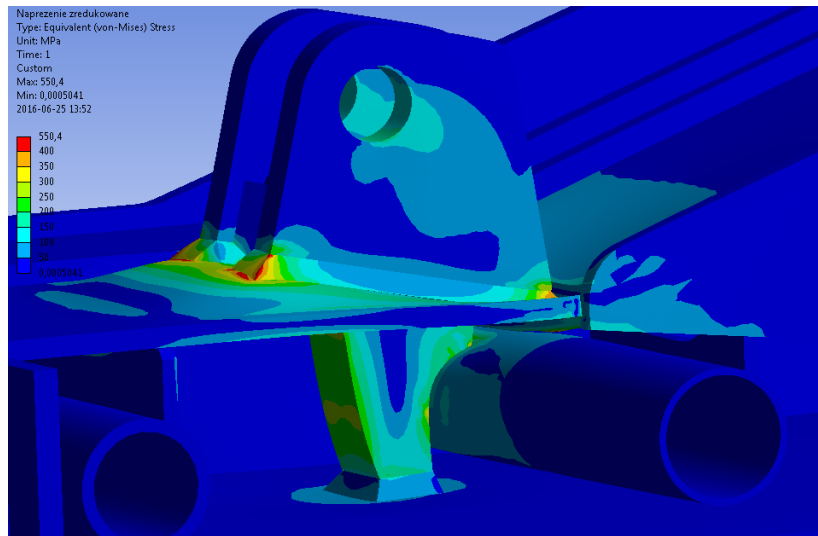

Fig. 7. Distribution of equivalent stress of the deformed model [6]

The analysis of the obtained results showed that there are local concentrations of equivalent stress, especially in the elements that model the welds as well as at the point between the welds and the sheathing sheets. To some extent, the local build-up of stress above the yield point results from the specificity of the calculation method used. Simplification of the geometric form of welds (no rounding radius when passing from one plane of the weld to another) resulted in creation of edges that are not present in the real object, which generates additional stress build-up in the vicinity of the edges.

The maximum equivalent stress in the base is lower than the stress at the yield point. It was also found that the equivalent stress is lower than the yield point, except for the weld edges and the edge of the weld transitions into the material of joined sheets.

Local equivalent stress above the yield point, and the associated permanent deformation, can cause cracks in the case of periodically variable loads and a high number of load cycles. Hence, Fig. 8 presents a distribution map of the highest main stress. The fatigue process is initiated in areas where the value of such stress is the highest.

To summarise the discussion concerning the analysis of stress and deformation in the eye of the tilt cylinder fixation system, it was found that under the conditions of roof support operation in Longwall B, local permanent deformation may appear. Due to the fact that they can occur in a small area, they should not lead to a deterioration of the roof support's functionality as a result of collision of the tilt cylinder against the lifting eye. It should be noted that the stress and deformation analysis in the area under consideration took into account the load resulting from the forces occurring in the tilt cylinder, neglecting the stress in the gob shield, caused by internal forces in the turning pairs of the roof support.

The most unfavourable load to the eye will occur when the bending moment acting on the lifting eye being a support is the highest. Assuming that the force in the tilt cylinder is nominal, it will take place when the angle between the tilt cylinder and the surface of the top plate of the gob shield is the smallest.

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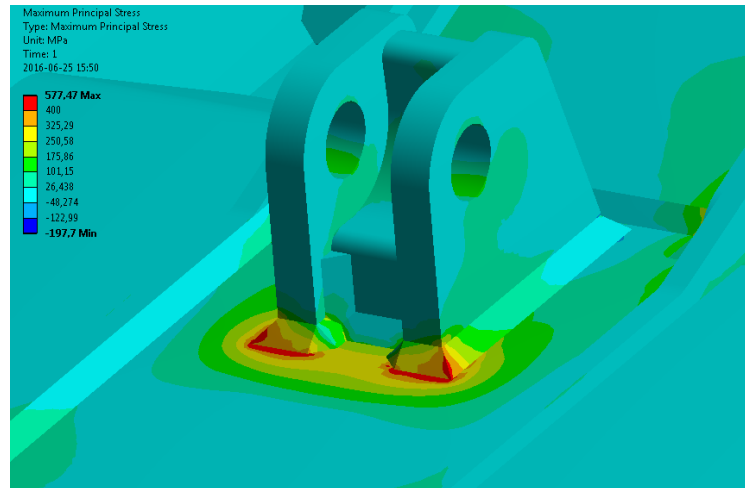
Fig. 8. Distribution of maximum main stress [6]

Using the OStO v.4.0 [5] software for analysis of static load to the tilt cylinder, a change of the angle between the axis of the tilt cylinder and the surface of the top plate of the gob shield was analysed as a function of a roof support height. This angle was found to be the lowest at the roof support height 1.6 m and was 2.95o. With a resultant force in the tilt cylinder equal to 703.7 kN, the force consisting of the following components acts on each lifting eye of the tilt cylinder:

$$Fx = 280.058 \text{ kN} \qquad Fy = 0 \qquad Fz = -213239 \text{ kN}$$

The eye support and load model for a section height of 1.6 m is shown in Fig. 9.
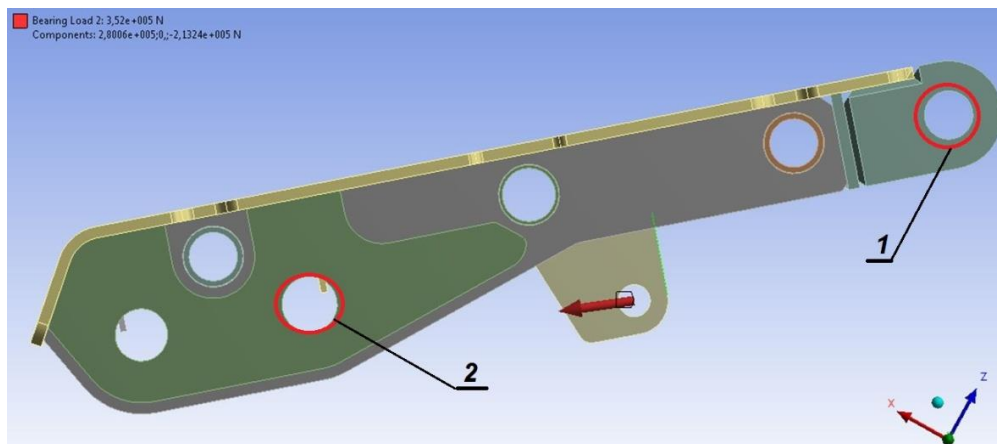
**Fig. 9.** Eye support and load model for a roof support height of 1.6 m [6].

As a result of the analysis of the gob shield's FEM model, it was found that in the analysed case of load, the level of stress in the tilt cylinder unit components is slightly higher compared to the load variant corresponding to a roof support of height 2.5 m. The displacements and maximum main stress are also slightly higher [6].

4. Analysis of fixation of tilt cylinder's eye of modernized design

The manufacturer modified a design of tilt cylinder's eye fixation to the gob shield to avoid its damage.

Geometric model of the gob shield with the modernized tilt cylinder's eye unit is presented in Fig. 10. Additional covers for the sheathing sheets as well as the supporting sheets between the eye and cover were used around the eye to strengthen the analysed fixation system. The finite elements mesh, made of 325447 nods and 79315 elements, was concentrated in the area covering the tilt cylinder's

eye and in the sheets fixing the eye to other components of the gob shield including the sheathing sheets of the gob shield.
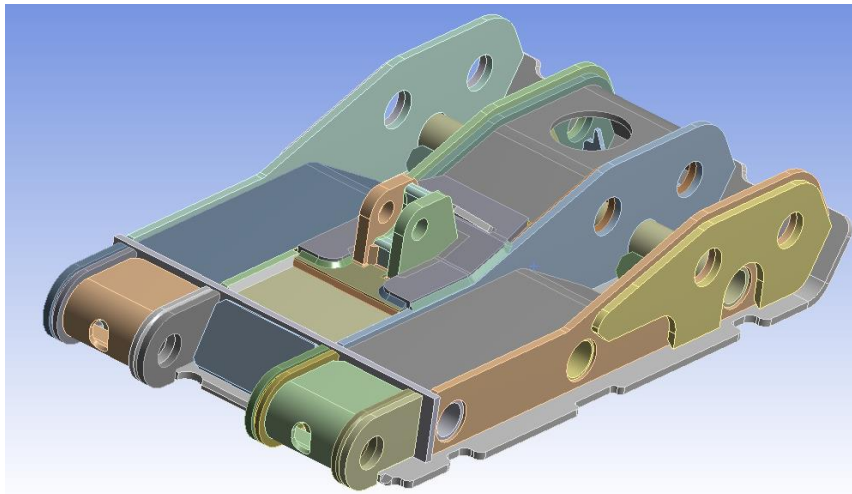
Fig. 10. Geometric model of the gob shield with modernized design of tilt cylinder's eye fixation system [6]

Numerical simulations and analysis of effort of tilt cylinder's eye fixation system in the gob shield were made for the most adverse case of load to the eye, that is for the loads in the case of loads existing at roof support height 1.6 m. Supporting and load conditions to the gob shield are presented in Fig. 9.

Distribution of equivalent stresses for the modernized design of the gob shield is presented in Fig. 11.The scale of the equivalent stress was set in such a way that places of the gob shield in which the equivalent stress is higher than the yield point are marked in red.
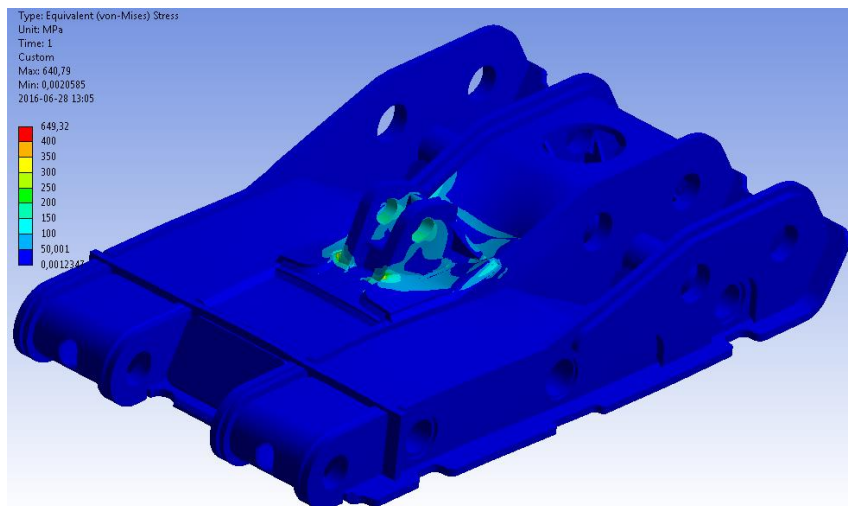
Fig. 11. Distribution of equivalent stress in the eye unit after modernization

The level of effort of the gob shield's eye unit after design changes significantly decreased. Although the maximum equivalent stress is still high but it occurs locally at the place of connecting the eye with the covering sheet. In this area, welds were modelled in a simplified way. The end of the solid modelling the V-type weld with a vertical plane and the lack of rounding radii at the transition of one weld plane to the other caused that in this area there were geometric notches that do not appear in the real object. The simplification of the geometrical form of welds meant that additional stress

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concentration was obtained in these areas, which would not occur in the real object. This fact should be taken into account when further interpreting the simulation results.

Excluding the areas, where the notches appear in the result of simplified modelling, it can be concluded that the equivalent stress is significantly below the yielding point (Fig.12).
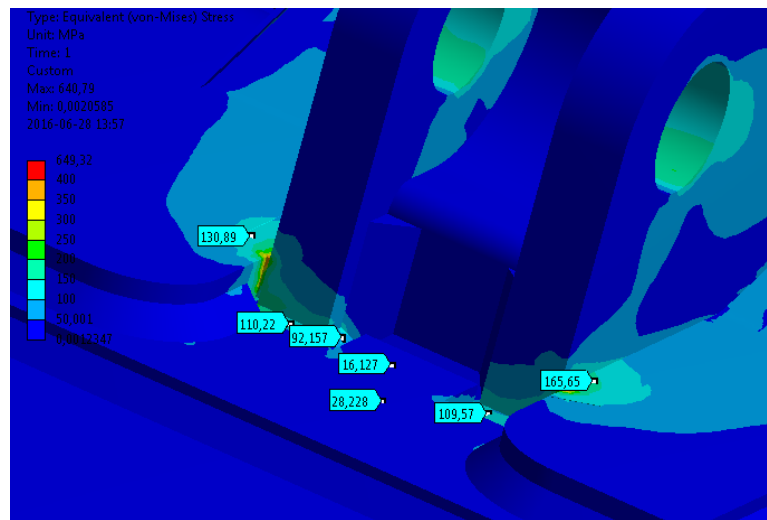

Fig. 12. Equivalent stress in the selected model elements [6]

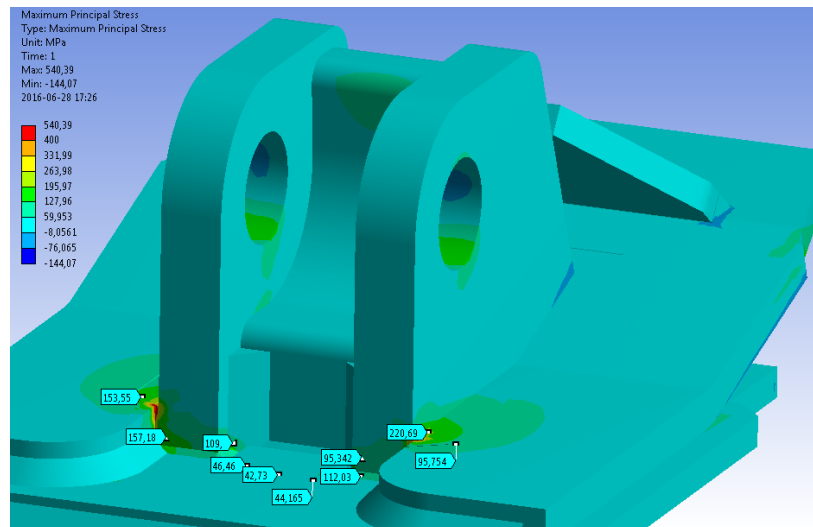Distribution of the highest stress in the tilt cylinder's eye unit is presented in Fig.13.

Fig. 13. Distribution of maximum main stress [6]

When analysing the effort of tilt cylinder's eye unit for the gob shield, it can be concluded that change in the design of this unit caused significant reduction in the effort level. Concentration of stress in geometric notches are mainly caused by simplifications associated with modelling of welds. Maximum displacement of the eye was reduced by almost three times. Also, maximum main stress was significantly reduced.

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5. Conclusions

Numerical simulation of the effort of tilt cylinder's eye in the gob shield was carried out for three variants: a load corresponding to the conditions of the roof support operation, the most unfavourable load case of this unit before modernization, and for the modernized design in the most adverse load case.

It was found that under the conditions of using the roof support in the "B" longwall, local concentrations of equivalent stress with values above the stress at the yield point may occur in the eye area. This could lead to slight permanent deformations. Due to the small area in which these deformations may occur, they should not cause deterioration of the roof support functionality as a result of collision movement of the tilt cylinder relative to the eye. In the aspect of damages observed in this longwall, it can be assumed that they arose as a result of adverse circumstances such as random ear overload or/and manufacture errors.

After design changes consisting in implementation of additional covers, the effort of gob shield's lifting eye unit significantly reduced. Excluding the areas, where the notches appear in the result of simplified modelling, it can be concluded that the equivalent stress is significantly below the yielding point. Thus, it can be concluded that the analysed change to the design of tilt cylinder's eye of a gob shield is reasonable.

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