Modeling of mine workings intersections in KOMPAS 3D program

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Abstract. The article deals with the design engineering of mine workings intersections using KOMPAS 3D program. As known, mine workings intersections are the most dangerous and difficult parts of mine workings, therefore, increased requirements for fixations are imposed on these constructions. Use of Boolean operation allowed us to determine the type of intersection line of workings of various cross-sectional shapes that allowed choosing the type of intersections with the minimal length of the dangerous areas. To obtain numerical values, the standard functions of the KOMPAS 3D program were used such as «Measure». According to the modeling results, the statistical dependencies were built. All completed procedures will allow choosing a rational construction of mine workings intersection from the point of least load on the lining construction and thereby increasing the safety of mining operations.

1. Introduction
The mine workings intersection is understood as the part of the mountain mass where mutual influence of two or more intersectings of technogenic outcrops (workings) appears.

The especially important ones are intersections of shaft bottoms, as their service life is equal to the service life of the mining enterprise or its specific level. Moreover, the workings adjoining to the shaft have larger areas of the section. All these circumstances determine the special requirements for the quality and reliability of the intersections fixings.

2. Classification of mine workings intersections
The mine workings intersections may be divided into three groups differing in laying conditions and peculiarities of the technological operations [1].

The first group includes the intersections situated within the limits of the shaft inset, which workings lay as a rule in the solid resistant rocks.

The second group includes the intersections situated at the long horizontal workings.

The third group includes the intersections situated at the slope workings. For the intersections the diversity of the lining materials is characteristic. Their service life is ranged from the service life of the mine, of the block up to the service life of the inclined district or dip-working panel.

The mine workings intersections are classified by the shape onto the rectangular and acute-angled crossings, the rectangular and acute-angled sidings, the angular and curved branches, intersections of «triangular node» type, and obtuse angled and rectangular abutments.

The cross-sectional shape of the intersection is generally defined by mining-and-geological
conditions. The most common form is arched with a semicircular vault, with straight walls unclosed. In unstable rocks the closed arched linings with inverted arc, the elliptic or circular linings are used. In unstable rocks the trapezoidal shape of lining may be used [2-5].

3. Selection problems of mine workings intersections
When choosing a shape of intersections, it is necessary to consider the type of transport and radii of curvature, as well as the main parameters of the intersections: an estimated span, the corner between the openings, outcropping area and length of the parts of the intersected workings experiencing cross-impact.

Fixation of the intersections is connected with great difficulty of technological nature and according to the strength analysis of the intersection construction.

From the geomechanical point of view, after performance of the mine working around it the zone of plastic stress (ZPS) or the breaking zone is formed if this working is not situated in the rocks which are hard enough [6, 7]. To create an equilibrium of ZPS and rock massif, various types of minings fastening are used. Along with this, the shape and size of this ZPS are formed around the working for a certain time depending on many factors such as the strength of rocks, rheological properties, the level of stresses acting in the mass, etc. [8, 9].

During performing other working(s) near the already existing one (creating of workings intersections), this balance is disturbed with a sharp increase of the size and shape of the ZPS, which in turn requires use of special technological methods and solutions, as well as use of special lining structures and its individual elements [10].

Particular attention should be paid directly to the line of intersection of two workings as the line having a quite complicated spatial configuration [11].

4. Modeling of mine workings intersections
In this case, the construction of the intersection line of two workings can be simplified by use of modern graphic packages of application programs [12, 13].

In particular, for the considered intersection variants, the KOMPAS program created by Russian company ASCON was used [14].

Several variants of mine workings intersections were modelled. Horizontal and vertical mine workings were taken as basic ones.

The vertical mine workings were represented by two models – a shaft with a 6 m diameter and 0.5 m lining thickness and a shaft with a 3 m diameter and 0.2 m lining thickness.

The vertical mine workings were also represented by two variants – arched with a semicircular vault and trapezoidal with an inner heading width of 5.2 m.

To build the intersection line in KOMPAS program, the «Boolean operation» was used [15].

The Boolean operation is intended for creation of a new body based on two or more already existing bodies. In the result of the operation, a new body is created, being a combination of the original bodies.

There are three types of Boolean operations:
- Addition. The result of the operation performance is the body uniting all the parts of the bodies involved in the operation (see Figures 1 a).
- Subtraction. The result of the operation performance is the body obtained by subtraction of one body from another one (see Figures 1 b).
- Intersection. The result of the operation performance is the body obtained by intersection of the bodies involved in the operation and consisting of the common parts of these bodies. (see Figures 1 c).
In this case, the Boolean operation was used as a «subtraction» and «intersection» for various combinations of horizontal and vertical mine workings. The modeling results were presented as subtracting of one working from another one and building of the intersection line of two workings.

In addition, the function «Measure – Edge Length (Area)» was used to calculate the numerical parameters.

The calculations results are presented as drawings made by Kompas program (see Figures 2 and 3).

The intersection area decreased by 18 %, and the length of the intersection line decreased by 12 %.

In the presented drawings of the mine workings intersection, this parameter depends very much on the shape of the section, on the inclination angle and on the angle of the mine workings intersection. For the presented options, the mathematical modelling of intersection of the mine workings of trapezoidal shape with intersection angles of 30, 40, 45, 60, 75 and 90 degrees was carried out. The results of the sizes of the intersection area and the length of the intersection line for these options are obtained.
According to the results, the statistical dependencies were built (see Figure 4). All the results were processed using EXCEL program, and the correlation coefficient close to 1 was obtained, which indicated a close relationship between the modeling results and the obtained mathematical models of this process [16].

Figure 4. Results of statistical processing of the modelling results: a – area; b – edge length.

5. Conclusion
Decrease of the intersection area and decrease of the intersection line length greatly reduce the value of building of the intersection, increase its stability and thereby reduce the cost of finished products and even more important – increase the safety of technological processes of the underground mining enterprise.

However, availability of rail haulage, scraper and belt conveyors [17, 18] in mine workings imposes severe restrictions on the use of large (close to 90°) junction corners of the mine workings. In this case, by changing some intersections parameters within the allowable limits, it is possible to achieve the minimal line of mine workings, thereby significantly reducing the load on the intersection lining and increasing the stability of this structure.

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