SIMULATION MODELLING OF THE DISCHARGE PLATE OF A JAW CRUSHER

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ABSTRACT. At present, the application of jaw crushers in the first stage of crushing is most widespread, especially for the purposes of the enrichment industry. During the process, crushing on the jaw crusher elements causes very large mechanical stresses. Determining the magnitude and distribution of deformations and strains in structural elements of mechanical systems is a particularly important engineering task. The application of computer technology has an ever increasing impact in a variety of areas of human knowledge development. This fact is particularly relevant for the heavy machinery industries, one of the main players of which is the enrichment machinery. The main task of this article is to demonstrate the possibilities of modelling, research and analysis (finite element method) of jaw crushers through specialised software products. The object of the study is a real high-performance machine, part of the crushing compartment of a mine situated underground. A simulation computer study of 3D CAD model and CAE analysis was made to obtain the values and the distribution of the deformations and stresses on the model. In this way, it is possible to predict the mechanical damages, the operating time and constructive and other changes in order to optimise the mechanical load and increase safety at work. This article looks at a 3D CAD model of the cut plate. By examining the model of the cut plate the necessary constraints were imposed and it was loaded with the analytically determined forces. From the results of the study, it is clear that the splintered plate is oversized, which is why some suggestions for constructive changes are made.

Keywords: simulation study, movable jaw, jaw crusher

СИМУЛАЦИОННО МОДЕЛИРАНЕ И ИЗСЛЕДВАНЕ НА РАЗПОРНАТА ПЛОЧА НА ЧЕЛЮСТНА ТРОШАЧКА

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РЕЗЮМЕ. В настоящия момент прилагането на челюстните трошачки в първи стадий на трошене е най широко разпространено, особено за целите на обогатителната промишленост. По време на процеса трошене върху елементите на челюстните трошачки въздействат много големи механични натоварвания. Определянето на големината и разпределението на деформациите и напреженията в конструкционните елементи от механични системи е особено важна инженерна задача. Основната задача на настоящата статия е чрез специализирани софтуерни продукти да се демонстрират възможностите за моделиране, изследване и анализ (по метода на крайните елементи) на челюстни трошачки. Обект на изследването е реална високопроизводителна машина, част от трошачното отделение на рудник разположен под земята. Направено е симулационно компютърно изследване на 3D-CAD модел и CAE - анализ за да се получат стойностите и разпределението на деформациите и напреженията върху модела. По този начин могат да се прогнозират механичните повреди, експлоатационният срок и извършват конструктивни и др. промени с цел оптимизиране на механичното натоварване и повишаване на сигурността при работа. Тази статия разглежда 3D CAD модел на разпорната плоча. При изследването на модела на разпорната плоча съм наложил необходимите ограничения и съм я натоварил със силите определени по аналитичен път. От резултатите на изследването става ясно, че разпорната плоча е преоразмерена, поради което съм направил предложения за конструктивни промени.

Ключови думи: симулационно изследване, разпорна плоча, челюстна трошачка

Creation of a CAD model of jaw crusher

When creating the model, all dimensions are compiled according to the working drawings of the jaw crusher. This model will be needed in the simulation study of the machine. For this purpose, a CAD model of the jaw crusher was created, according to the original working documentation. For the creation of the current model, a specialised software product for CAD modelling, namely Solid Works, was used. A general view of the 3D model is shown in Figure 1, and Figure 2 presents a sectional view of the model showing the main machine nodes. The simulation analysis was performed on the basis of the three-dimensional model of the crusher with the specialised Solid Works software.

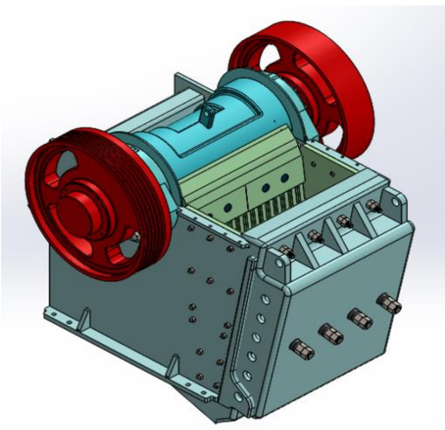

Fig. 1. Jaw crusher type CJ615:01

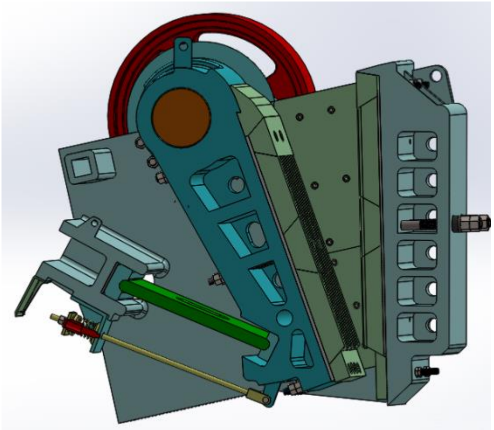

Fig. 2. Jaw crusher type CJ615: 01

The simulation analysis was performed on the basis of the three-dimensional model of the crusher with the specialised Solid Works software. It was chosen to explore the main details - eccentric shaft and moving jaw by neglecting the details that are unrelated to the bearing ability of the structure. The Finite Element method is used with the COSMOS Works software.

Selection of a border condition criterion

The estimation of the stress-strain state of the studied model is a task that has no universal solution for all the cases encountered in practice and is mostly dependent on the material used. On the other hand, the materials can behave as fragile or plastic depending on the temperature, the degree of loading or the way the article is made. All these peculiarities predetermine the choice of one of the following strong theories (Damyanov T., 2009):

- Theory of maximum normal voltages. Valid for fragile materials. It is based on the condition that the boundary of destruction of the material is the same under tension and pressure. This assumption does not correspond to the truth in all cases. For example, most stress concentrators reduce the resistance of the material to tensile loads much more than with a load of stress. According to this theory, the state of frontier occurs when the maximum main voltage reaches the permissible:

$$\sigma_1 \geq [\sigma] \quad (1)$$

- Theory of maximum tangential voltages. Valid for wavy and malleable material. When applied to materials with different mechanical characteristics of tensile and compressive forces, as well as in tensile stress conditions, the obtained results may substantially materially differ from reality. According to the theory, the boundary state criterion is the maximum tangential strain:

$$\tau_{\max} \geq [\sigma] \quad (2)$$

where:

$$\tau_{\max} = \frac{\sigma_1 - \sigma_3}{2} \quad (3)$$

- Energy theory (Von Mises). The theory is based on the appearance of plastic deformations in the masonry materials when equalised with the maximum allowable stress. In most cases the yield limit of the material is given. The results for materials with different mechanical characteristics of tensile and compressive stress are also unsatisfactory. From the point of view of the main stresses, the boundary condition criterion is:

$$\sigma_{VonMises} \geq [\sigma] \quad (4)$$

where:

$$\sigma_{VonMises} = \sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_1 - \sigma_3)^2}{2}} \quad (5)$$

- Mor - Columbus Theory. Applicable to brittle materials with different tensile and compressive properties. According to this theory, a border condition occurs when one of the following conditions is met:

$$\sigma_1 \geq [\sigma_{on}] \text{ for } \sigma_1 > 0, \quad \sigma_3 > 0; \quad (6)$$

$$\sigma_3 \geq [-\sigma_{Ham}] \text{ for } \sigma_1 < 0, \quad \sigma_3 < 0; \quad (7)$$

$$\frac{\sigma_1}{[\sigma_{on}]} + \frac{\sigma_3}{[\sigma_{Ham}]} < 1 \text{ for } \sigma_1 \geq 0, \quad \sigma_3 \leq 0 \quad (8)$$

According to the application areas of the studied theories of strength, the theory of maximum tangential strains and energy theory is obviously closest to the conditions typical of the material and the load of the studied structure. It can be summed up that the discharge plate of jaw crusher depends on the type of crushing material and the installed power of the drive motor (Hristova et al., 2012, Christov, Minin, Hristova, 2012).The crushed slag plate 3 is a basic element and serves to close the cementitious crusher chain. At the same time, it acts as a protective element in the extreme load caused by falling into the crushing space of a neutral object. The forces that arise at this point exceed the crushing power 10 times (Minin, 2015), the broken plate is made with special holes thanks to it, which breaks and protects the other crusher elements. It is made of ductile cast iron, bearing its spherical ends in the specially made wedges and frame.

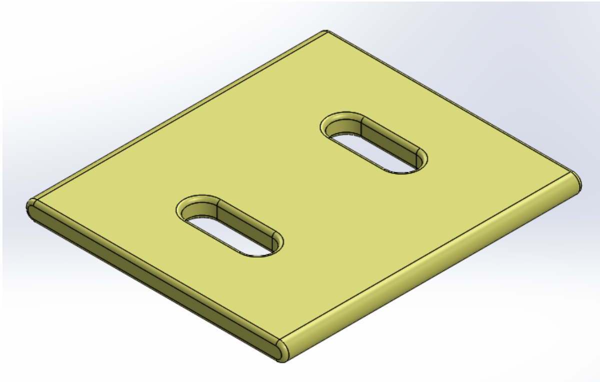

Fig. 3a. Ripped plate

The laser scanner is placed inside the drum on a tripod (Fig. 3).

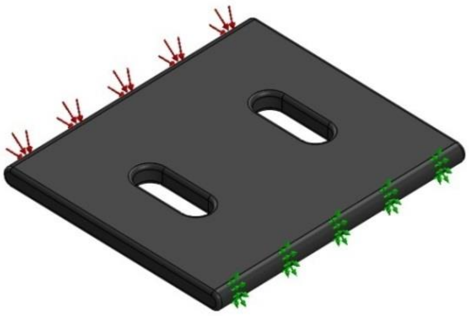

Fig. 3b. Forces and backlash responses

Setting up the sampling tools

The Finite Element Method (FEA) (Nedyalkov 2010) is a numerical method for assessing engineering solutions. For this purpose, the three-dimensional model is divided into small parts of simple-to-form elements, interconnected with common points (nodes). The method determines the behaviour of the model by combining the information obtained from all the forming elements.

Model splicing (discretisation) is one of the most important steps in the study. The large number of elements implies a higher accuracy of the results but also increases the length of the computation process. Conversely, with a small number of endpoints, the calculation time decreases, but this is a prerequisite for network failures and inaccurate results.

Optimal settings for model discretisation are obtained after several dithering attempts.

It is necessary to monitor the time to perform the operations, the size and the number of the final elements obtained, as well as the details in which errors have occurred in their discretion. In some cases, when examining large assembled units containing details of complex shape or relatively small dimensions, the overall reduction in the size of the end elements would lead to an unacceptable increase in their number. In this case, only the problem details are reduced to the size of the end elements, and the overall size is retained at the optimal for the whole model.

In Fig. 4 shows the pattern of the cut plate after sampling in Fig. 5 and 6 show the tensions and security ratios in the jaw crusher plate.

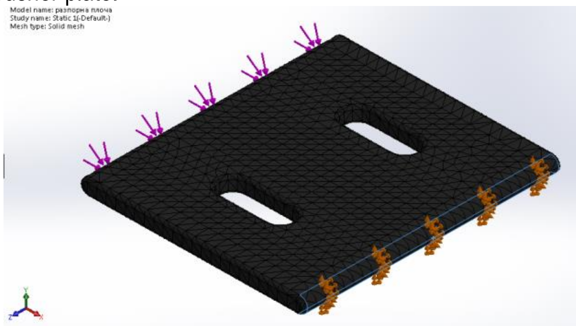

Fig. 4. Discretisation of the plate

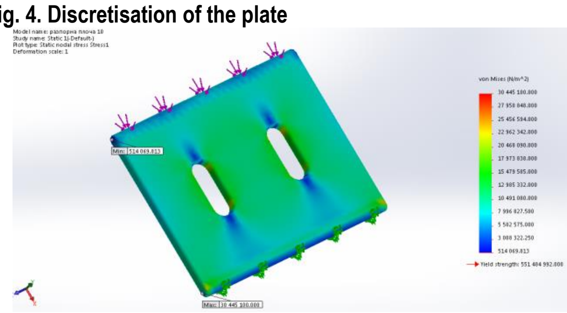

Fig. 5. Distribution of equivalent stresses in the gap plate

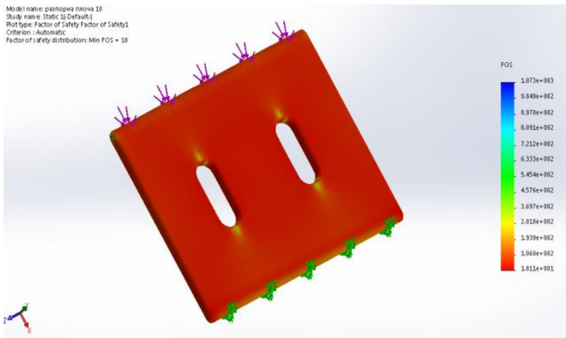

Fig. 6. Distribution of the security factor in the gap plate at normal load

A study of the splintered slab have been done when a neutral object comes in and the crushing power is increased 10 times.

In Fig. 7 and 8 show the stress diagrams and the safety factor for extreme loading of the split plate.

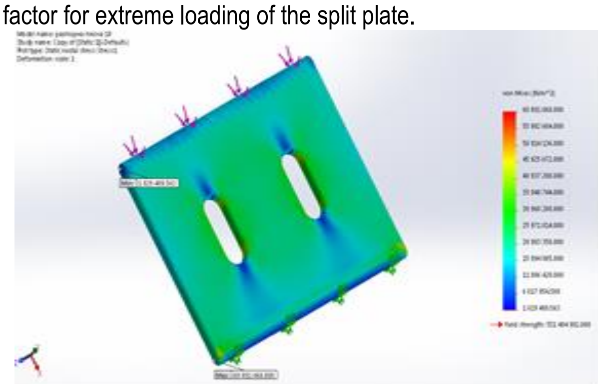

Fig. 7. Distribution of equivalent stresses at extreme load

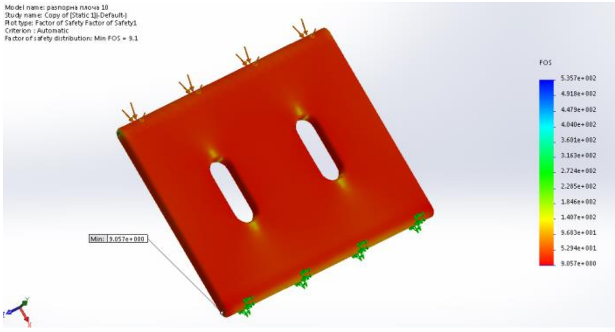

Fig. 8. Distribution of the security factor in the gap plate at extreme crushing strength

During the operation of the crusher, the hydraulic hammer falls and falls into the crushing space, whereby the saw blade does not break and the studs are cut off from the foundation. Due to the resizing of the cut plate constructive changes in its construction have been made.

Two new models on the plate have been made:

- larger openings (Fig. 9).
- with larger openings and two-sided channels (Fig. 10).

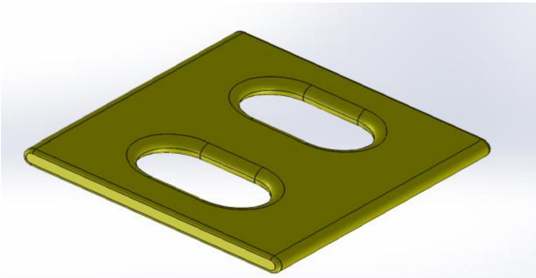

Fig. 9. The laid out a plate with larger openings

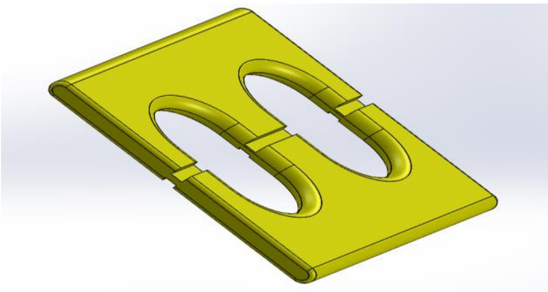

Fig. 10. A slave plate with larger openings and two-sided channels

Fig. 11, 12, 13 and 14 show the voltage and safety ratios in the two jaws of the jaw crusher at extreme stress.

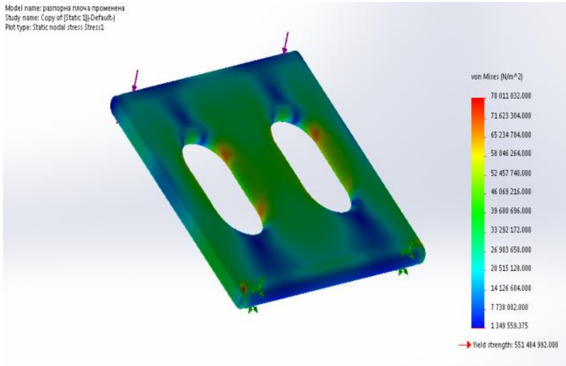

Fig. 11. Distribution of equivalent stresses in the gap with larger openings

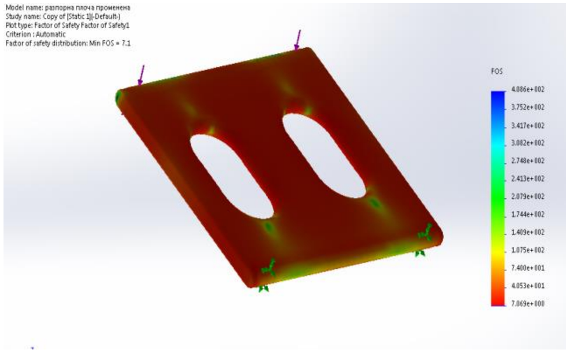

Fig. 12. Distribution of the security factor in the gap with larger openings at extreme load

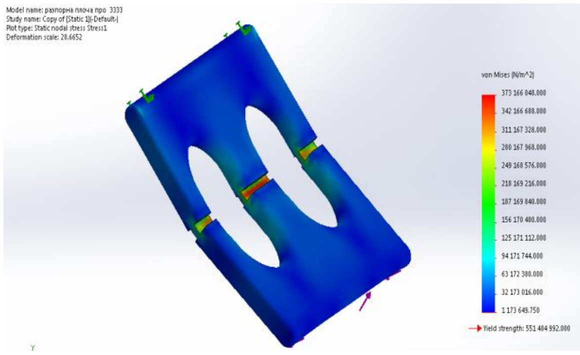

Fig. 13. Distribution of equivalent stresses in the split plate with larger openings and two-sided channels at extreme load

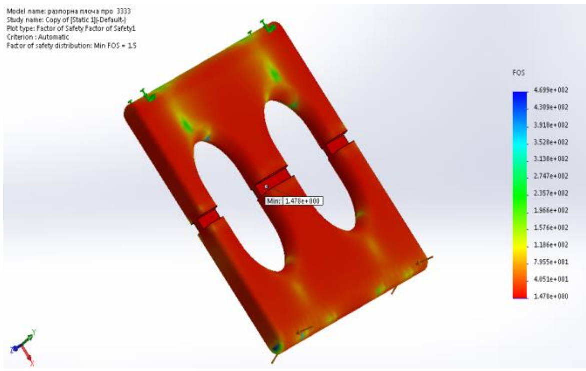

Fig. 14. Distribution of the security factor in the gap with larger openings and two-sided channels at extreme load

Conclusion

1. From the figures and stress diagrams it is clear that the maximum value of 3MPa is located at the end of the edge of the cut plate Fig. 5, where the minimum security factor FOS = 18 Fig. 6 is at normal load, and at extreme load the minimum security factor is FOS = 9.1 (Fig. 8), which is why two more slab plates with a lower security factor have been constructed.

2. A slave plate with enlarged holes in the figures and voltage diagrams makes it clear that the maximum value of 3.9MPa is located at the end of the edge of the cut plate (Fig. 11), where the minimum security factor FOS = 7.1 (Fig. 12) is at normal load.

3. A plate with enlarged holes and two-sided transverse grooves - it is clear from the figures and stress diagrams that the maximum value of 18MPa is located at the end of the edge of the slotted plate (Fig. 13), where the minimum security factor FOS = 1.5 (Fig. 14) is at extreme load, which means that the cavity plate will break at extreme load.

The analysis of the results of the linear static analysis shows that the highest values of strains and deformations do not exceed the permissible ones for the specific case.

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