Modeling and calculation of load on cutting inserts of disk milling cutters in software environment of Autodesk Inventor

E G Zlotnikov, A D Khalimonenko, D Yu Kazakov

Saint-Petersburg Mining University, 21st Line 2, 199106 St. Petersburg, Russia

E-mail: Zlotnikov_EG@pers.spmi.ru

Abstract. The article deals with the issues related to the definition of the construction of roll crusher's disk mills for processing metal chips. The constructional parameters of the cutters are selected according to the calculation of loads on the cutter inserts at work and selection of their optimal geometry using the finite element method of Autodesk Inventor software environment. Recommendations on the choice of constructional parameters of cutter inserts are given according to the results of calculations.

1. Introduction

The actual task for machine-building enterprises and other industries, in the technological processes of which the machiningis carried out by cutting, is processing of metal chips. This type of waste as a valuable secondary raw material can be effectively used for melting in metallurgical furnaces in the form of briquettes, which significantly reduces the loss of metal in heat of melting. The processing is implemented on production lines, including metal chips removal and collecting devices, devices for crushing chips into small pieces to loose state, for separation of metalworking fluids and subsequent cold or hot briquetting [1].

To cut drainage chips which are an indicator of cutting stability, especially for high-speed machining of cutting ceramics [1, 2, 3, 4, 5], a knife, a rotor, a hammer and other types of crushing plants are used. Roller chipbreakers were widely used for grinding metal chips. They can be single-stage and multi-step: two-, three- and four-cylinder depending on the required capacity [1].There are fixed and movable knives, which are performed in the form of disc cutters mounted on the rotating rolls and are used in the construction of roller crushers (Fig. 1).

a b

Figure 1. Construction of roller crushers: a – single-roller crusher; b – multi-roller crusher.

2. Materials and methods

During the construction development of mills for roller crushing plants, there are problems of choosing the material for their production and determining the optimal geometry of the cutting teeth appear. The material must have high wear resistance and hardness, which allows processing chips from the basic structural materials (cast iron, carbon and alloy steels, non-ferrous metals) with sufficient resources.

The problem of material selection is complicated by the high physical and mechanical properties of the chip, as its hardness with a slope of the surface layer of the contact side of the chip can be 2.5...4 times greater than the original hardness of the work piece material [1, 3, 7, 17, 19].

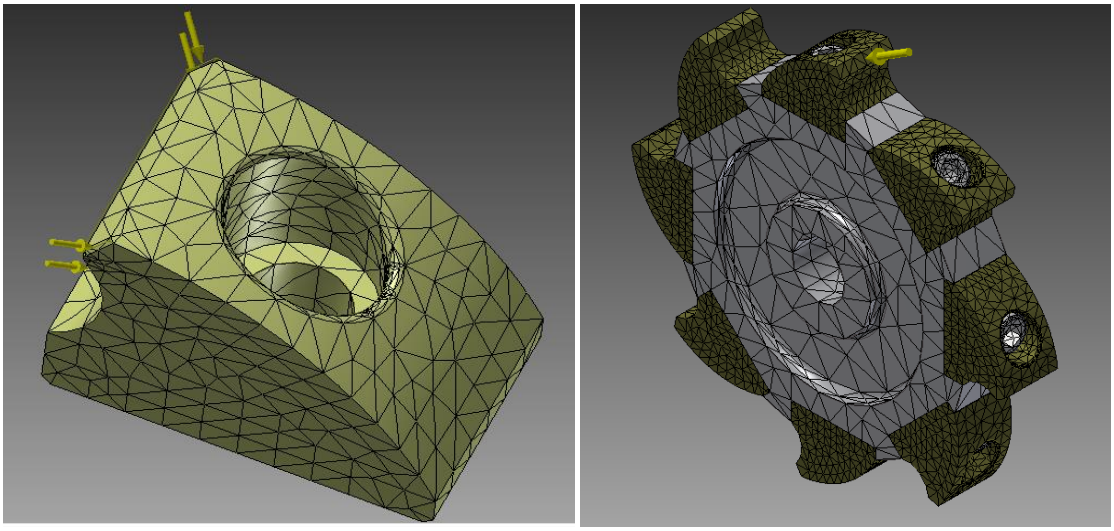
In addition, the chips may have embedded particles of the growth, the hardness of which according to the steel processing is HRC 60...65 that corresponds to the hardness of high-speed tool steels [1, 7]. Therefore, chip material and growth particles have an intense abrasive effect on the crushing working tool, significantly reducing its service life [1, 8].

It is advisable to use the tool material only for the cutter inserts, which are mechanically mounted on the cutter disc, made of cheaper structural steel. It allows reducing the tool material consumption. The increased service life of the cutting blades of the inserts and the possibility of using the mills for processing chips of different alloys are achieved by selecting the optimal geometry of the instrument [1, 8, 9].

3. Results and Discussion

In order to calculate the stresses during the work of cutting inserts of disk mills and to choose the optimal geometry, an integrated CAD/CAE system Autodesk Inventor was used.

To calculate the load using the finite element method, the parametric 3D-model of the cutting insert and assembled disk cutter were projected (Fig. 2).



a b

Figure 2. Solid-state 3D-models created in the software environment: a – 3D-model of the cutter insert; b – 3D-model of the assembled roller crusher disk mill.

Tool alloy steel was considered as a material for cutting inserts [1, 10, 11]. In the software environment, Autodesk Inventor carried out the calculation and analysis of stresses on the cutting insert of the disk cutter. Stresses under the action of cutting force on the front and rear surfaces of the tool are determined [1, 12, 13, 14, 18], as well as deformation (displacement) of surfaces and safety factor (Fig. 3).

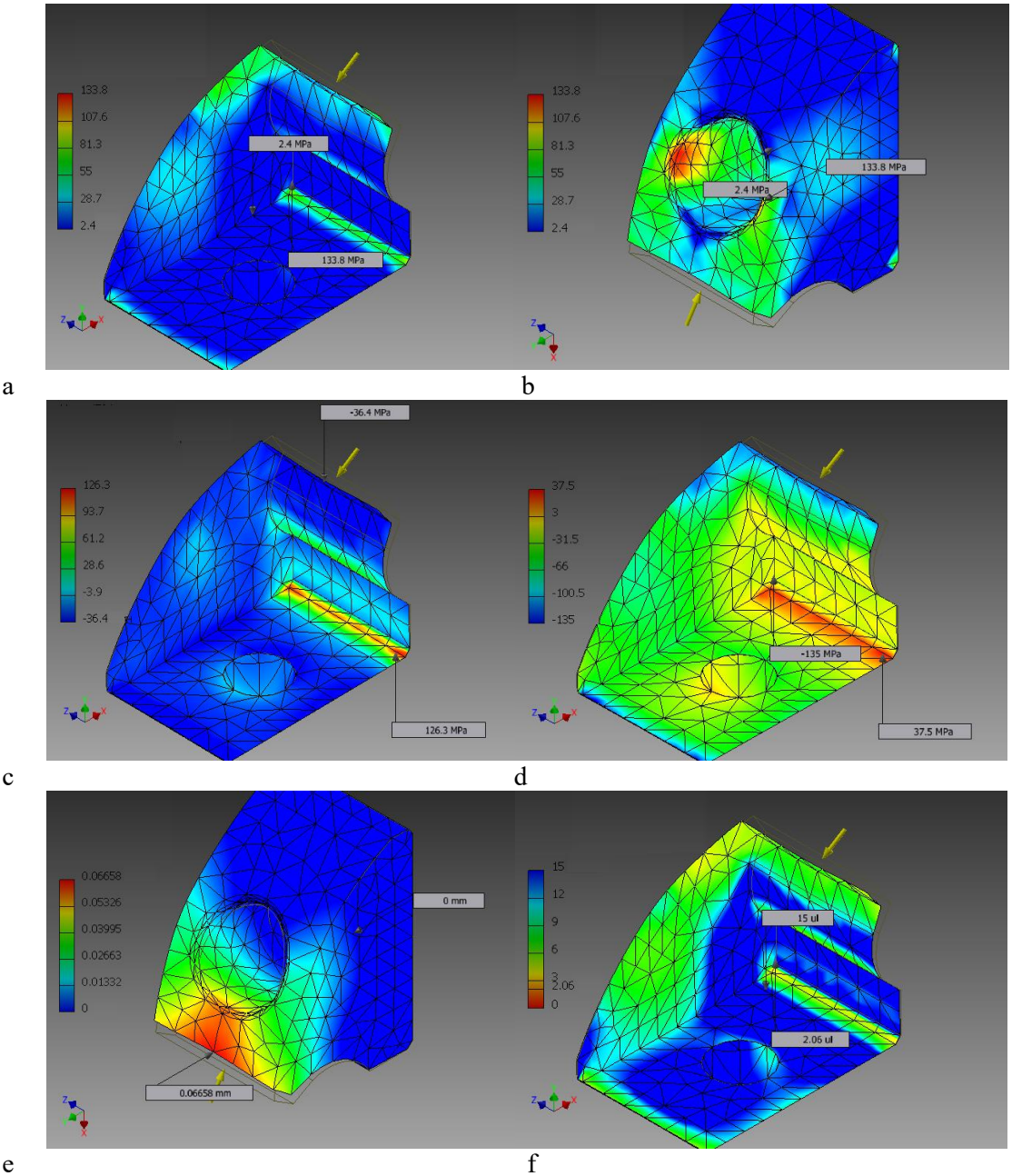


Figure 3. Results of stress analysis of cutter inserts by the finite element method in Autodesk Inventor software environment: a, b – stresses by Mises; c – the first main stress, d – the second main stress; e – displacement on the front surface; f – factor of safety.

To optimize the geometrical parameters of the cutting inserts [1, 15, 16] depending on the processed material (carbon structural, alloyed, stainless steel and cast iron), simulation was carried out in the Autodesk Inventor software environment with varying of the following parameters (Fig. 4):

- radius on the front surface (r),
- the size of the edge (h),
- the rear corner of the cutting insert (α).

The optimal values of the parameters within the limits are:

r = 20…22 mm; h = 5…9,5 mm; α = 25…45º for specified materials (Table 1).

Modeling of chip grinding process by milling cutters with optimized geometry of cutting inserts

showed that the service life of roller crushers can be increased 1.5...2 times [1].

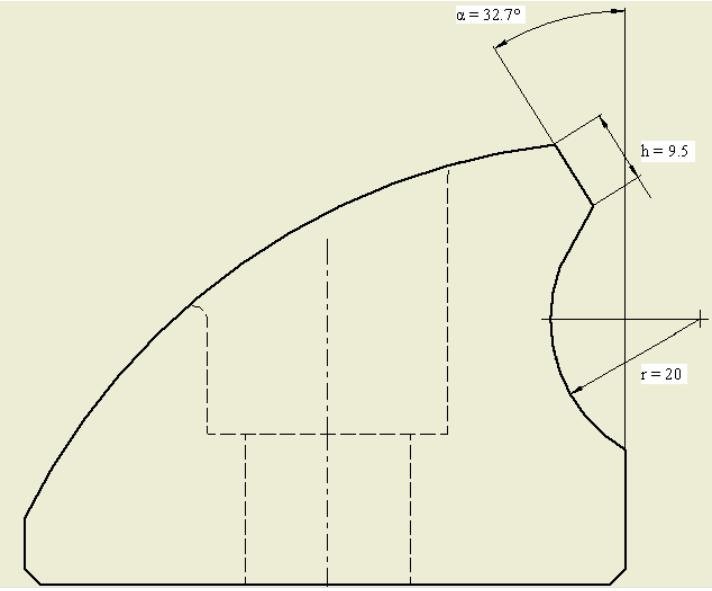


Figure 4. Determination of the geometric elements of the contruction of roller chipbreaker disk mills cutting inserts.

Table 1. Optimal parameters of constructional geometric elements of the cutting inserts depending on the grounded material

Type of chips	Rear angle α, (°)	Size of the edge h, mm	Radius on the front surface r, mm
Cast iron shavings	32.7	9.5	20
Structural steel shavings	25	9.5	20
Stainless steel shavings	45	5	22

4. Conclusion

After the study, it can be concluded that during the construction of mills for the roller crushing machine, there are problems not only with the choice of material for their manufacture, but also to determine the optimal geometry of the cutting inserts. Such problems can be solved by modeling the loads on the cutter inserts at work and the selection of their optimal geometry.

The software environment of the integrated CAD/CAE system Autodesk Inventor allowed creating parametric 3D models of the cutting insert and assembling the disk cutter for load calculation using the finite element method. The software environment made it possible to calculate and analyze the stresses on the cutting insert of the disk cutter, to determine the stresses under the action of the cutting force on the front and rear surfaces of the tool, as well as the deformation (displacement) of the surfaces and the factor of safety.

The variation of the geometrical parameters of the cutting inserts allowed one to determine their optimal geometry according to the grounded material, which led to an increase in the service life of the roll crushing machine.

References

[1] Maksarov V V, Zlotnikov E G 2014 Modern technologies for processing and briquetting of metal shavings in automated factories *Journal of mining institute* **209** 37-41
[2] Maksarov V V, Olt J 2015 Improving the precision of manufacturing power hydraulic cylinders of powered roof supports based on a vibration-damping tooling system *Journal of mining institute* **214** 71-84
[3] Maksarov V V, Olt J 2017 Dynamic stabilization of machining process based on local metastability in controlled robotic systems of cnc machines *Journal of mining institute* **226** 446-451
[4] Maksarov V V, Khalimonenko A D, Matrenichev K G 2017 Stability analysis of multipoint tool equipped with metal cutting ceramics *IOP Conference Series: Earth and Environmental Science* **87** 082030
[5] Timofeev D Yu, Kosheleva E V 2017 Improving the quality of manufacturing parts from titanium alloys using the method of preliminary local plastic deformation *IOP Conference Series: Earth and Environmental Science* **87** 082048
[6] Khalimonenko A D, Viushin R V 2014 Accuracy of the machining turning process of the workpieces when cutting tool equipped with removable ceramic inserts *Journal of mining institute* **209** 99-103
[7] Ershov D Y, Zlotnikov E G, Koboyankwe L E 2017 Dynamic processes in technological systems of machining and the nature of their origin *IOP Conference Series: Earth and Environmental Science* **87** 082016
[8] Olt J, Liyvapuu A, Madissoo M, Maksarov V 2016 Dynamic simulation of chip formation in the process of cutting *International Journal of Materials and Product Technology* **53(1)** 1-14
[9] Olt J, Liivapuu O, Maksarov V, Liyvapuu A, Tärgla T 2016 Mathematical modelling of cutting process system *Springer Proceedings in Mathematics and Statistics* **178** 173-186
[10] Olt J, Maksarov V V 2016 Cutting process simulation on the basis of rheological properties of metals *26th DAAAM International Symposiumon intelligent Manufacturing and Automation* 229-237
[11] Olt J, Maksarov V V 2016 Development of chatter-resistant system of cutting tool *26th DAAAM International Symposiumon intelligent Manufacturing and Automation* 223-226
[12] Matsuura K, Watanabe Y, Hirashima Y 2004 Use of recycled steel machining chips and aluminum can shreds for synthesizing iron aluminide intermetallic alloys *ISIJ International* **44(7)** 1258-1262
[13] Understanding the differences between grinding, shredding and chipping *BioCycle* **44(4)** 14
[14] Mikhailova L Ya, Reznyakov A A 1991 Stockpiling and processing alloy steel chips *Metallurgist* **34(9-10)** 194-195
[15] Maksarov V, Khalimonenko A 2017 Forecasting performance of ceramic cutting tool *Key Engineering Materials* **736** 86-90
[16] Maksarov V V, Krasnyy V A, Viushin R V 2018 Simulation of dynamic processes when machining transition surfaces of stepped shafts *IOP Conference Series: Materials Science and Engineering* **327(2)** 022047
[17] Ivancivsky V V, Skeeba V Y, Bataev I A, Lobanov D V, Martyushev N V, Sakha O V, Khlebova I V 2016 The features of steel surface hardening with high energy heating by high frequency currents and shower cooling. *IOP Conference Series: Materials Science and Engineering* **156(1)** 012025
[18] Gabov V V, Zadkov D A 2017 Peculiarities of stress field formation during cutting isotropic material by mining machine cutters. *IOP Conference Series: Materials Science and Engineering* **87(1)** 022007
[19] Martyushev N V, Egorov Y P 2003 Determination of the signal strength with the computer analysis of the material structure. *Proceedings of the 9th International Scientific and Practical Conference of Students, Post-graduates and Young Scientists - Modern Techniques and*

Technologies **1438190** 192-194