*Applied Mechanics and Materials Vol 770 (2015) pp 429-433*
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*doi:10.4028/www.scientific.net/AMM.770.429*

*Submitted: 2015-03-13*
*Accepted: 2015-03-18*

# Finite Element Models of Disk Tools With Attachment Points on Triangular Prisms

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**Keywords:** Roadheader, working body, radial bit, triangular prism, attachment point, disk tool, coal cutting, crushing, loading, stress state, Finite Element Method.

**Abstract.** The paper presents simulation of the stress-strain state of various designs of disk tool attachment points on triangular prisms of radial bits of the roadheaders working body when cutting of coal and rock face.

## Introduction

In leading mining countries, the main means of mechanization for mining are roadheaders. Improvement of the boom-type roadheader cutting heads by a rational combination and arrangement of cutting and disk tools to implement destruction of coal and hard rocks by lumps is an important task.

It is well known that quantitative indicators of mechanical coal cutting are determined by physical and mechanical properties of a coalface and cutting conditions, including type and geometrical parameters of the instrument; by parameters of cutting, type of rock cutting machine, its specific power and a scheme of placement and travelling in the face space. It is clear that designers of rock-cutting mining machines primarily seek to achieve the minimum specific energy consumption and energy intensity in cutting of various rocks [1, 2]. Rock cutting power consumption equally affects both the mining machine operation, and the power consumption costs; in recent years the cost of the latter is increasing, that increases the cost of unit of production. This reinforces the need for development and improvement of the design of multipurpose shearing and cutting tools with high competitiveness of energy consumption when cutting both viscous carbons and brittle rocks.

Modern excavating mining machines extract minerals by mechanical cutting of coal and rock masses using a wide range of mining cutting tools of various designs. Mechanical methods are attractive because they are feasible, well adapted to geological conditions, provide the possibility of localization of energy, transferred to rock masses, and continuous monitoring of operations. The authors of [3] claim that cutting of rocks is an energetically favorable process. However, in abrasive rocks of average and medium strength, this method is not acceptable because of intensive tool working wear, and because of inability to transfer large unit capacity required for destruction of the rock mass. Therefore, the area of effective use of the rock cutting is limited by low-abrasive rocks (at least 15 mg) with a strength of up to 60 MPa.

Studies [4, 5], held in T.F. Gorbachev KuzSTU proved the feasibility and perspective of using disk tools on cutting heads of shearers and roadheaders.

The variety of cutting tools on the working bodies of the roadheaders dictates the need for researches, aimed at defining the functional capabilities and effective use of disk tools in the form of radial and axial bits [4-16].

Requirements for designs of bit working bodies of multipurpose boom roadheaders are based on the relation of kinematic, power and design parameters of the disk tool attachment points with physical-mechanical properties and parameters of rock mass cutting and possibility of mounting and dismantling operations at the face space.

In the first stage of research [4], the staff of Department of Mining Machines and Complexes, T.F. Gorbachev KuzSTU, designed a radial bit with two-point disk tool (Fig. 1). The bit consists of the following structural elements: 1 - housing: 2 - disk tool; 3 - cutter; 4 - starting borer; 5 - cutting disc.

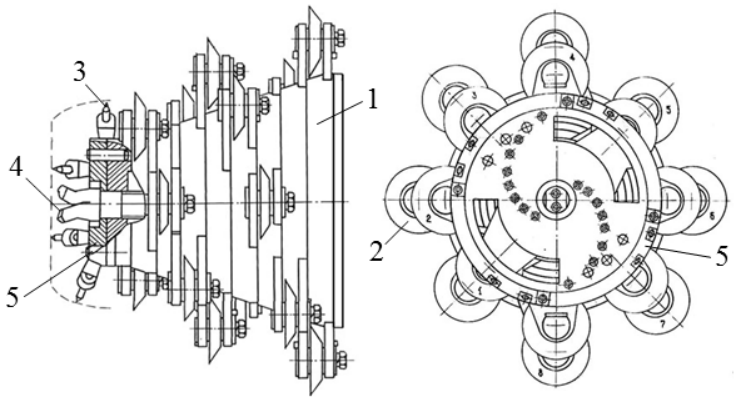


Fig. 1. The basic design of the roadheader bit with the disk tool

This basic design of the roadheader radial bit with disk tools was tested during excavations in ore and coal seams with solid inclusions and layers with compressive strength ($\sigma_{compress}$ from 87 to 112 MPa) [4].

Fig. 2 shows a finite element model of two-point attachment of the disk tool for the basic bit design of the roadheader; the model is developed for calculating parameters of the stress state if the compressive strength rock masses $\sigma_{compress}$ = 50÷140 MPa [6]. For the model four variants of disk tool designs with diameter D = 160 mm (three biconical with taper angles: $\varphi = \varphi_1 + \varphi_2$ = 25 ° + 5 ° = 30 °;

20 ° + 10 ° = 30 °; 15 ° + 15 ° = 30 and one conical φ = 30 °) were used.

The calculation was made in SolidWorks Simulation. When constructing the grid, parabolic finite elements in the form of triangular pyramids were used. The size of finite elements was selected such that further increase of the grid density would not affect results of calculation significantly. Material for details was 35 ХГСА steel. Forces of cutting $P_z$, sump $P_y$ and lateral $P_x$ were determined considering design of disk tools, mode parameters and characteristics of rock mass $\sigma_{compress}$. Rated forces $P_z$, $P_y$, $P_x$ were applied (Fig. 2) to two-point attachments of the disc instruments to obtain models of stress-strain states of biconical and conical disk tools (Fig. 3) [6, 7].

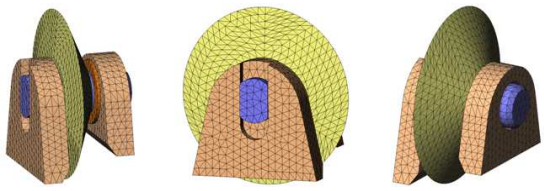

Fig. 2. Finite element model of the disk tool two-point attachment

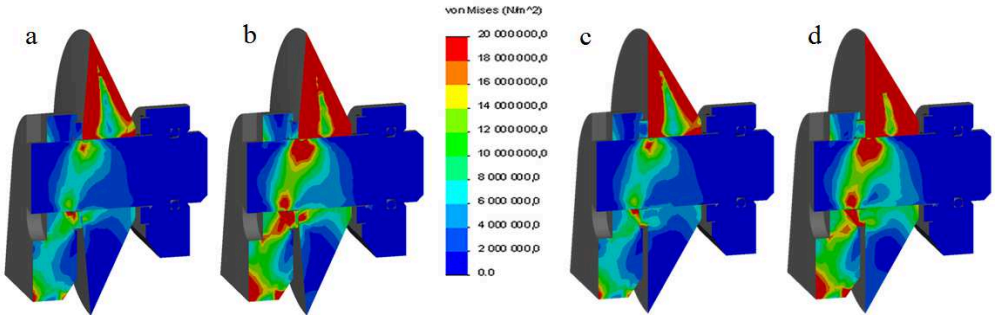


Fig. 3. Distribution of equivalent stresses according to Mises criterion in two point attachments:

- biconical disk tool (φ= 25°+5° = 30°) if: a – $\sigma_{compression}$ = 70 MPa; b – $\sigma_{compression}$ = 120 MPa;
- conical disk tool (φ = 30°) if: c – $\sigma_{compression}$ = 70 MPa; d – $\sigma_{compression}$ = 120 MPa

Operating tests revealed that the main drawback of the roadheader bit basic design is clogging of inter-support spaces of disk tool attachment and work surfaces of the bit housing by cuttings which reduce the efficiency of rock mass destruction and loading on the pulley feeder desk of the road header.

It is recommended to use disk tools on triangular prisms in the design of reversible radial longitudinal axis bits for working bodies of multi-purpose roadheaders (Fig. 4) [8-14].

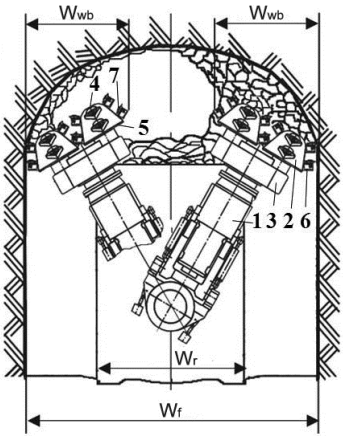


Fig. 4. Twin-bit working body with disk tools on triangular prisms

The working body of the road header (Fig. 4) consists of the boom 1, on which two destructive-loading bits 2 are installed; the bits are interlocked via distributing reducer 3. Each bit 2 consists of two truncated cones or prisms with a small base 4 and a large base 5, the hub of which is fixed to the reducer output shaft 3. Triangular prisms 6 with disc tools 7 are attached to the outer surfaces of the bits. Kinematic geared connection allows triangular prisms 6 of the bits 2 during rotation to combine operations of cutting, crushing and loading within a design width of the face $W_f$; considering a working area of the working body $W_{wb}$ and width of the pulley feeder desk of the roadheader $W_r$.

Currently in the Department of Mining Machines and Complexes of T.F. Gorbachev KuzSTU together with the Department of Mining Equipment of YTI (affiliate) TPU stress-strain state of console attachment points of the disk tools are being tested by the Finite Element Method. The results are shown in Figure 5 and 6 [7, 15].

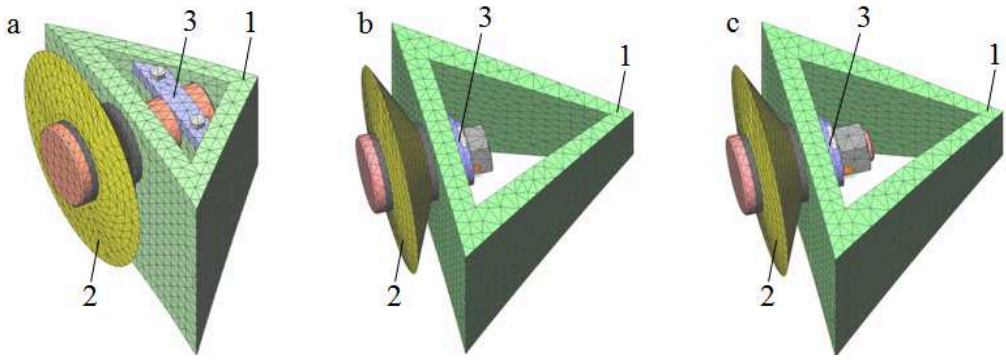


Fig. 5. Finite element models of three variants of attachment points: a – bar-lock; b – fastening screw; c – nut; 1 – triangular prism; 2 – disc tool; 3 – attachment point

Biconical and conical disk tools are used in all structural variants of attachment points. The procedures for constructing finite element models and calculation of loading efforts $P_z$, $P_y$, $P_x$ are similar to those two-point attachments of the disk tool described above. As an example, Fig. 6 shows distribution of equivalent stresses according to Mises criterion for three variants of disk tool attachment points with D = 160 mm on triangular prisms.

The presented designs of the disk tool console attachment points on the triangular prisms, considering results of simulation of stress-strain behavior of cutting tools while rock face destruction, are promising for equipping of working bodies of tunneling machines, shearers and drilling mining machines.

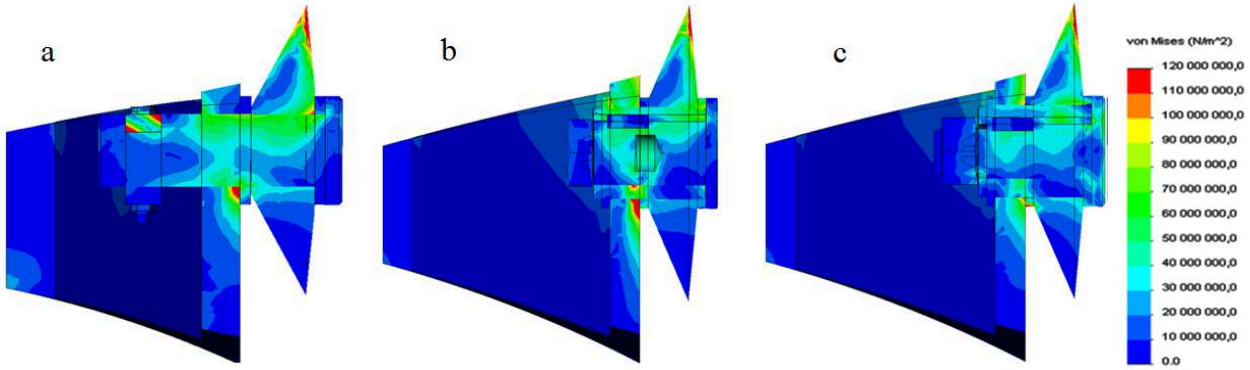


Fig. 6. Distribution of equivalent stresses according to Mises criterion for three variants of disk tool attachment points with angle of taper φ = 25°+5° = 30° in triangular prisms considering characteristics of cutting mass $\sigma_{compression}$ = 70 MPa: a – bar-lock; b – fastening screw; c – nut

Technical solutions and test results were obtained within the base part of Ministry of Education and Science of Russia state order, project №632 "Investigation of technologies and techniques parameters for selecting and developing innovative designs to improve operating efficiency of multipurpose mining machines in Kuzbass".

## Conclusion

It has been found that the equivalent stress, according to Mises criterion, in all designs of disk tool bit attachment points in the working bodies of tunneling machines are significantly lower than yield strength of steel 35HGSA ($\sigma_T$ = 490 MPa). With transition from asymmetric to symmetric biconical disk tools, reduction of parameters of equivalent stress areas in the attachment points is observed, wherein maximum stresses increase totally in a wide range of $\sigma_{compress}$ = 50-120 MPa if rock strength increases.

It has been revealed that disk tools of conical (φ =30°) and biconical form (φ = 25°+ 5°=30°) cut rocks with larger areas of maximum equivalent stress and travelling compared with tools of

biconical form (φ =20°+10° = 30° and φ =15°+15° = 30°); and a biconical form (φ = 15°+15° = 30°) performs minimum areas of equivalent stress and travelling.
It has been observed that sizes of maximum equivalent stress and travelling areas on the triangular prism face plane in the third version of the disk tool attachment point are reduced in comparison to the second version; this proves a higher rigidity of the nut attachment.
Specifications for design of working bodies with two reversible radial axial bits have been developed; which will be produced both on the basis of technical solutions for the disk tool attachment points on the triangular prisms, and on the results of stress-strain state simulation; that in the future will expand the scope of use of multipurpose tunneling machines.

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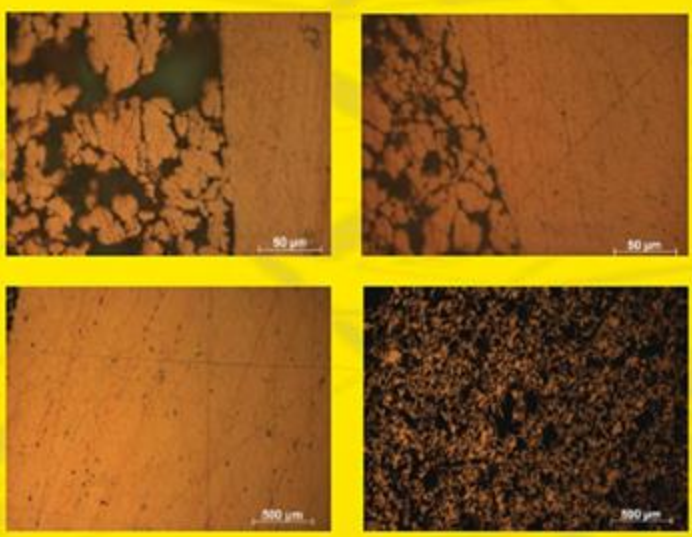

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| BISAC: | TEC000000 |
| Keywords: | Automation, Control, Designing, Environmental Research, Industrial Engineering, Materials Science, Mechanisms, Mechatronics, Metal Processing, Modelling of Machines |
| Details: | Selected, peer reviewed papers from the International Conference "Urgent Problems of Up-to-Date Mechanical Engineering", UTI TPU, December 11-12, 2014, Yurga, Russia |
| Pages: | 776 |
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ISBN-13 (softcover): 9783038354833

ISBN-13 (CD): 9783038592648

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