The Power Characteristics of the Reversible Radial Crowns with Disk Tools for Roadheaders of Selective Action

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***Abstract* — The areas of improvement in the design of the crowns of roadheaders of selective action and other mining machines. Suggested was the usage of biconical, conical disk tools and their attachment assemblies to the triangular prisms on the crowns of roadheaders and shearers-bladed screws for the destruction of structurally inhomogeneous working faces. The solution to the problem of combining the processes of rock destruction, crushing and loading by boom-type cutting bodies in driving headings by roadheaders of selective action is presented. The recommendations are given on agreed reverse modes of two radial crowns with the disc tool mounted on triangular prisms for the extension of loading area in the near-sidewalls spaces of mine workings. The process of formation of loads on the disc tool during destruction of rock was studied. The calculated dependences are presented of the transverse efforts on the cutting body with two kinematiccally connected radial reversible crowns for eight standard fixed stages of rotation of the crowns with the disc tools in the destruction.**

Keywords* — roadheader, effector, crown, triangular prism, disc tool, reverse, displacement, rock face, contact strength, effort, moment.

I. INTRODUCTION

Currently the fleet of roadheading machines at coal mines in Kuzbass basically consists of boom-type roadheaders of domestic and import production with the capacity of 1.7 to 2.8 m3/min (at σ_{compr} up to 30–40 MPa) and up to 0.15–0.35 m^3/min (at σ_{compr} up to 80–120 MPa), and weight from 23 to 135 t. They are used for breaking and loading of rock mass with the index of abrasion (a) up to 15–18 mg when driving horizontal and inclined (up to 12–18°) mine workings of arched, trapezoidal and rectangular shapes with the cross-sectional area (S) 7 to 38 m^2. The fleet of roadheaders by country of production includes the following types: KP21, KP21-150, KP-200; KP220, KP200T, KPYU-50, SM130K (Russia); П110, П220, KSP-22, KSP-32(33), KSP-35, KSP-42, KPL, KPD, KPA, KPU (Ukraine); M200, LH1500, MK2BP, MK5 (UK); MC 350, MR 520, MT 720, MB 600, MB 670 (Sweden); EBZ135, EBZ160, EBZ200, EBZ340 (China); T1.14, T1.24, T2.21, T2.24, T3.20, T4.31 (Germany). The analysis of the parameters of the cutting bodies of the roadheaders which have a significant effect on the processes of formation of the loads during destruction of rocks shows that they are in the following range: the engine power of the roadheader cutting bodies (N) from 75 to 400 kW, crown rotation speed (n) from 23 to 65 min^{-1}, diameter of crowns ($D_к$) from 0.85 to 1.2 m, the telescopic boom extension (lt) from 0.5 to 0.8 m.

II. SUBJECT OF RESEARCH

The research conducted by the scientists of the department of mining machines and complexes of the Mining institute of the T.F. Gorbachev KuzSTU together with the employees of the company of “SUEK-Kuzbass” was focused on the development and identification of parameters of loading of two kinematically connected reverse radial crowns equipped with a disk tool [1–3]. Various processes and roadheading equipment were reviewed in publications [4–27] and can be useful in addressing several issues in designing of cutting bodies for roadheaders.

In the previous studies we studied the mechanisms of destruction of coals and rocks by the disk tools on screw-type cutting bodies of coal miners and on crowns of roadheaders with two-point attachment assemblies.

The present study is aimed at determining the stress-strain state and the total loads on double-crown cutting bodies with a disk tool on multi-faceted prisms in the presence of supporting brackets as attachment assemblies.

III. RESULTS AND DISCUSSIONS

In the process of driving a heading, two radial crowns 1 and 2 equipped with disc tools on triangular prisms (Fig. 1) can operate in the following modes: reverse rotation (n) of crowns; joint motion (V) of crowns from the bottom upwards (Fig. 1, a) and vice versa (Fig. 1, b). The formation of the external load was investigated for all the above-mentioned modes in a wide range of rocks from mudstone to hard sandstone with the contact strength of (P_c) 150, 230, 350, 490, 700, 860, 1000, 1250 MPa.

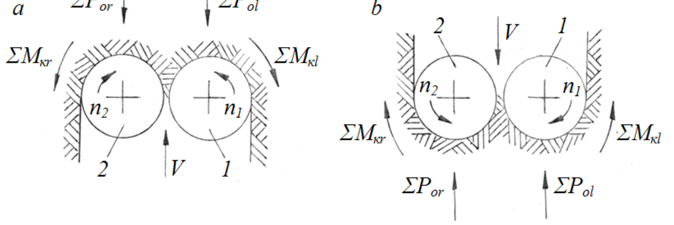

Fig. 1. Schematic of forces ΣP_o and torques $\Sigma M_к$ in the plane of rotation of a two-crown cutting body: a – at boom lifting; b – at boom lowering

The conference was funded by RFBR according to the research project №16-05-20506

The schemes of the set of tools on each crown form a double-threaded helix with two disc tools in the line of rolling and a pitch t between them of 75 mm. The disc tools are installed on the crowns with a certain radius R: disc 1 – 0.340 m; disc 2 – 0.360 m; disc 3 – 0.385 m; disc 4– 0.41 m; disc 5 – 0.43 m; disc 6 – 0.45 m; disc 7 – 0.475 m; disk 8 – 0.49 m. During the calculations, the turning of the left crown was fixed at a certain angle in stages: stage 1 – 22.5°; stage 2 – 67.5°; stage 3 – 122.5°; stage 4 – 157.5°; stage 5– 202.5°; stage 6 – 247.5°; stage 7 – 292.5°; stage 8 – 337.5°. The turning of the right crown was also fixed in stages: stage 1 – 45°; stage 2 – 90°; stage 3 – 135°; stage 4 – 180°; stage 5 – 225°; stage 6– 270°; stage 7 – 315°; stage 8 – 360°.

In the interaction of the crown with the rock it experiences the external load as the total efforts ΣP_{or}, ΣP_{ol} and total torques $\Sigma M_{кr}$, ΣM_{kl} (Fig. 1).

It is suggested on the basis of research conducted by the authors to focus on the efforts as the most important component of external loads on the disk tool.

Effort ΣP_o was determined from the expression:

$$\sum P_o = P_{o1} + P_{o2} + P_{o3} + P_{o4} + P_{o5} + P_{o6} + P_{o7} + P_{o8} \text{ , kN} \quad (1)$$

where P_{o1}–P_{o8} projection of efforts on Y-axis (Fig. 2, 3, 4, 5) acting from the side of rock on disc tools nos. 1, 2, 3, 4, 5, 6, 7, and 8.

In Fig. 2, as an example, diagrams of the efforts on the disk tools no. 6, 2, 7, 3, 8, 4, 5, 1 of the first spiral of the left crown during its upward motion, and in Fig. 3 – on discs no. 5, 1, 8, 4, 7, 3, 6, 2 of the second spiral of the left crown during its downward motion. Fig. 4 shows a diagram of the efforts on the disk tools no. 5, 1, 8, 4, 7, 3, 6, 2 of the first spiral of the right crown during its upward motion, and in Fig. 5 – on discs no. 5, 1, 8, 4, 7, 3, 6, 2 of the second spiral of the right crown during its downward motion. Disc tools are mounted two on one beam: № 6 and № 2; № 7 and № 3; № 8 and № 4; № 5 and № 1 with different radius of rolling R. In the diagrams of Fig. 2–5 for the purpose of simplification the efforts are shown acting only on the outer disk tools. On the internal disk tools the layout is shown similarly using the coordinates of application of effort of rolling Pz and impressing effort Py, whose direction coincides with the direction of the radius-vector of the triangular prism with a specific disk.

Components of the efforts of rolling P_z and the effort of impressing P_y in the coordinates of the points of application of resultant efforts in the contact area of disk tools 5, 8, 7 and 6 with the rock of the face were determined by the known methods described in the standard OST 12.44.258-84. Mining combines. Selection of parameters and calculation of cutting and feeding forces on the cutting bodies.

As an example, Fig. 6 shows the dependences of the total axial effort ΣP_o acting on all disk tools of the double-threaded left-hand crown of the cutting body during its one full clockwise turn with the upward motion.

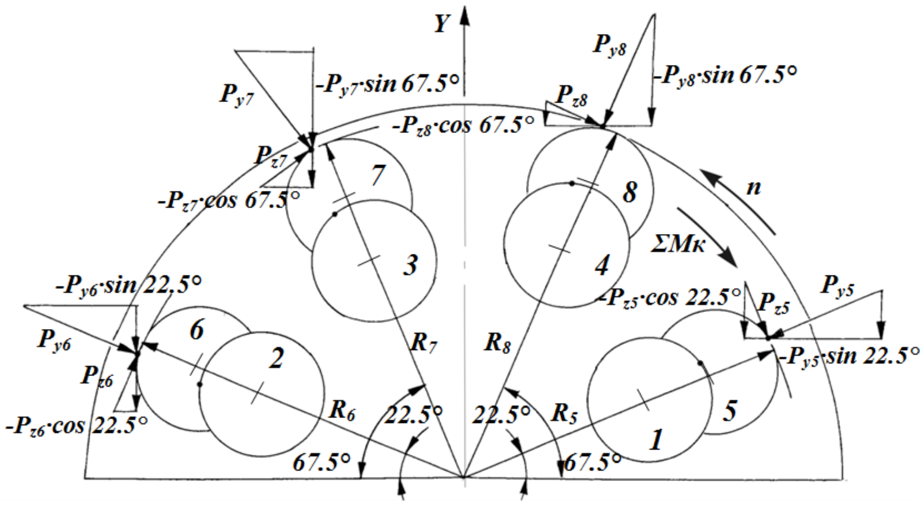

Fig. 2. The scheme of components of the rolling efforts P_z and the effort of impressing P_y in the destruction of rock in the face by disk tools (№ 6, 2, 7, 8, 5) of the left crown at its upward motion

The method was implemented with reference to the design scheme in Fig. 2 in the form of the following expressions included in the structure of formula (1):

$$P_{o6} = -P_{y6}\sin 22.5° - P_{z6}\cos 22.5° ; \quad P_{o7} = -P_{y7}\sin 67.5° - P_{z7}\cos 67.5° ;$$

$$P_{o8} = -P_{y8}\sin 67.5° - P_{z8}\cos 67.5° ; \quad P_{o5} = -P_{y5}\sin 22.5° - P_{z5}\cos 22.5° ;$$

$$P_{o2} = -P_{y2}\sin 22.5° - P_{z2}\cos 22.5° ; \quad P_{o3} = -P_{y3}\sin 67.5° - P_{z3}\cos 67.5° ;$$

$$P_{o4} = -P_{y4}\sin 67.5° - P_{z4}\cos 67.5° ; \quad P_{o1} = -P_{y1}\sin 22.5° - P_{z1}\cos 22.5° .$$

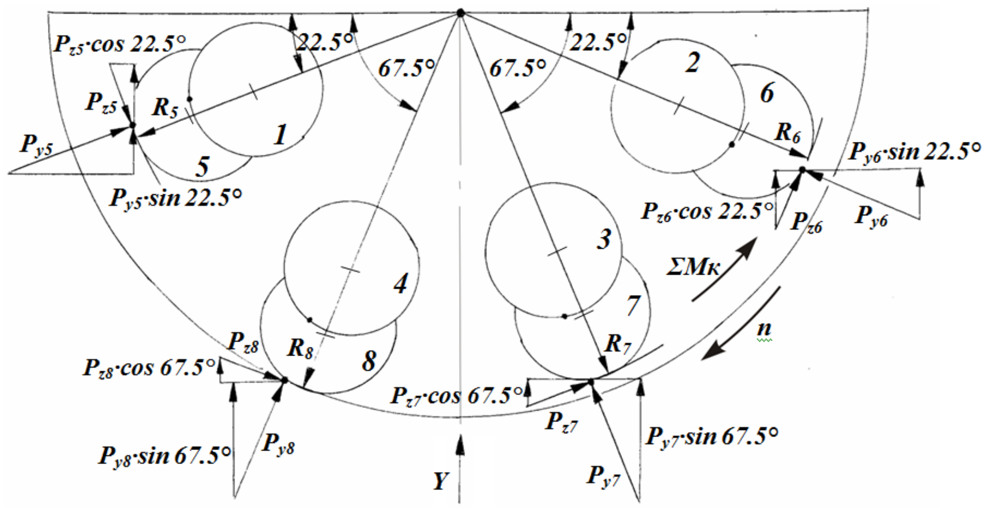

Fig. 3. The scheme of components of the efforts of rolling P_z and the effort of impressing P_y in the destruction of rock by disk tools (№ 5, 1, 8, 4, 7, 3, 6, 2) of the left crown at its downward motion

For the scheme shown in Fig. 3 the following calculated expressions were received:

$$P_{o5} = P_{y5} \sin 22.5° + P_{z5} \cos 22.5° ; \quad P_{o8} = P_{y8} \sin 67.5° + P_{z8} \cos 67.5° ;$$

$$P_{o7} = P_{y7} \sin 67.5° + P_{z7} \cos 67.5° ; \quad P_{o6} = P_{y6} \sin 22.5° + P_{z6} \cos 22.5° ;$$

$$P_{o1} = P_{y1} \sin 22.5° + P_{z1} \cos 22.5° ; \quad P_{o4} = P_{y4} \sin 67.5° + P_{z4} \cos 67.5° ;$$

$$P_{o3} = P_{y3} \sin 67.5° + P_{z3} \cos 67.5° ; \quad P_{o2} = P_{y2} \sin 22.5° + P_{z2} \cos 22.5° .$$

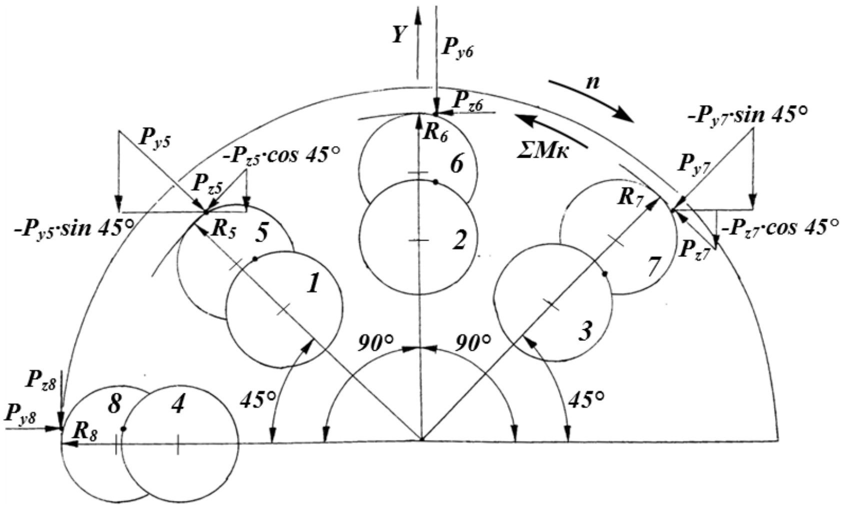

Fig. 4. The scheme of components of the efforts of rolling Pz and the effort of impressing Py in the destruction of rock by disk tools (№ 7, 3, 6, 2, 5, 1, 8, 4) of the right crown at its upward motion

For the option of the upward motion of the right crown presented in Fig. 4, the calculated expressions are as follows:

$$P_{o7} = -P_{y7} \sin 45° - P_{z7} \cos 45° ; \quad P_{o6} = -P_{y6} ; \quad P_{o5} = -P_{y5} \sin 45° - P_{z5} \cos 45° ; \quad P_{o8} = -P_{z8} ;$$

$$P_{o3} = -P_{y3} \sin 45° - P_{z3} \cos 45° ; \quad P_{o2} = -P_{y2} ; \quad P_{o1} = -P_{y1} \sin 45° - P_{z1} \cos 45° ; \quad P_{o4} = -P_{z4} .$$

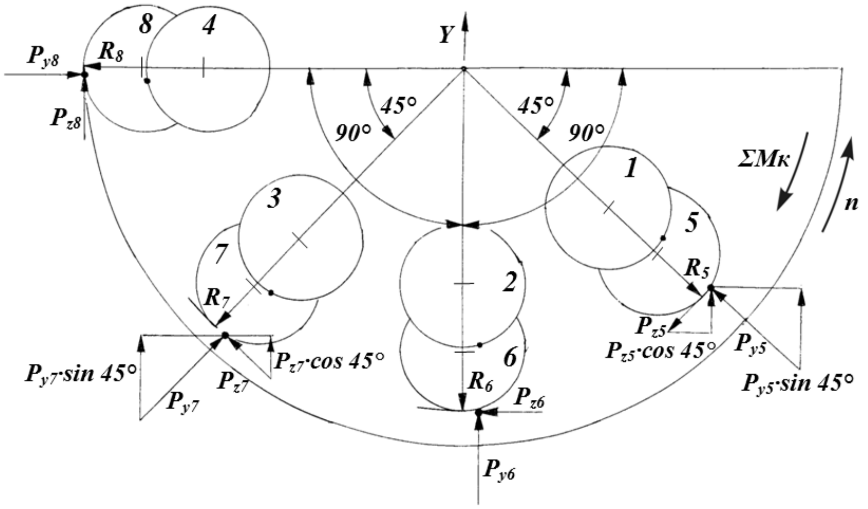

Fig. 5. The scheme of components of the efforts of rolling P_z and the effort of impressing P_y in the destruction of rock by disk tools (№ 5, 1, 6, 2, 7, 3, 8, 4) of the right crown at itsdownward motion

For the option of the downward motion of the right crown presented in Fig. 5, the calculated expressions are as follows:

$$P_{o5} = P_{y5}\sin 45° + P_{z5}\cos 45°; \quad P_{o6} = P_{y6}; \quad P_{o7} = P_{y7}\sin 45° + P_{z7}\cos 45°; \quad P_{o8} = P_{z8};$$

$$P_{o1} = P_{y1}\sin 45° + P_{z1}\cos 45°; \quad P_{o2} = P_{y2}; \quad P_{o3} = P_{y3}\sin 45° + P_{z3}\cos 45°; \quad P_{o4} = P_{z4}$$

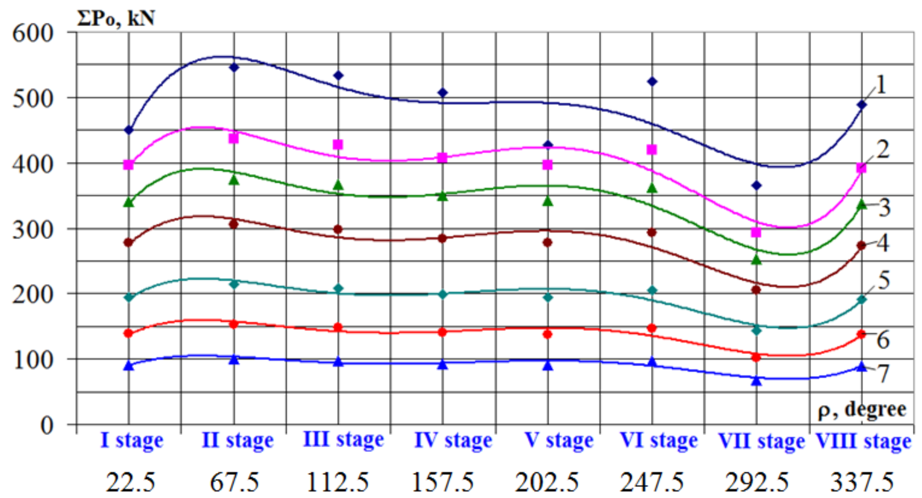

Fig. 6. Dependences of efforts ΣPo from the angle of rotation ρ of the left crown: 1 – Pc (1250 MPa); 2 – Pc (1000 MPa); 3 – Pc (860 MPa); 4 – Pc (700 MPa); 5 – Pc (490 MPa); 6 – Pc (350 MPa); 7 – Pc (230 MPa)

The graphs presented in Fig. 6 are described by the following polynomial dependences:

$$1 - \sum P_o = 0.9799\rho^5 - 22.082\rho^4 + 187.25\rho^3 - 739.62\rho^2 + 1323.6\rho - 303.88; \qquad R^2 = 0.6158;$$

$$2 - \sum P_o = 0.9662\rho^5 - 21.061\rho^4 + 170.08\rho^3 - 628.13\rho^2 + 1034.6\rho - 163.17; \qquad R^2 = 0.8185;$$

$$3 - \sum P_o = 0.8281\rho^5 - 18.042\rho^4 + 145.62\rho^3 - 537.59\rho^2 + 885.67\rho - 138.25; \qquad R^2 = 0.816;$$

$$4 - \sum P_o = 0.6787\rho^5 - 14.802\rho^4 + 119.6\rho^3 - 441.86\rho^2 + 727.68\rho - 115.95; \qquad R^2 = 0.8211;$$

$$5 - \sum P_o = 0.4751\rho^5 - 10.361\rho^4 + 83.72\rho^3 - 309.31\rho^2 + 509.39\rho - 81.169; \qquad R^2 = 0.8211;$$

$$6 - \sum P_o = 0.3488\rho^5 - 7.6188\rho^4 + 61.64\rho^3 - 227.84\rho^2 + 374.69\rho - 63.548; \qquad R^2 = 0.816;$$

$$7 - \sum P_o = 0.2279\rho^5 - 4.9733\rho^4 + 40.2\rho^3 - 148.49\rho^2 + 244.27\rho - 40.78; \qquad R^2 = 0.8113$$

The calculations are made for boom-type cutting bodies of roadheaders, which use two-threaded schemes of a set of disk tools on two kinematically connected reverse radial crowns. The crowns contain the bodies of a truncated conical shape with the triangular prisms of the same length with the disk tool attachment assemblies forming the radial beams of various radii equal to radii of rolling of disks on a face with angular shift relative each other. This excludes contacting of disk tools of the left and right crowns between themselves in the central part of the face.

IV. CONCLUSION

It is shown that the external efforts P_o acting on the disk tools from the face depend on the following parameters: crown angle of rotation ρ, radius of a trajectory of rolling of disks R, efforts of rolling P_z, effort of impressing P_y.

It is defined that external efforts P_o on single disk tools have the areas of increments from $P_{o\ min}$ 0.7–0.8 kN to $P_{o\ min}$ 70.9–92.7 kN and then the areas of falling from $P_{o\ min}$ 70.9–92.7 kN to $P_{o\ min}$ 0.6–7.9 kN.

Recommended were the parameters of two-spiral schemes of disk tools arrangement on crowns (a rolling pitch, angular distance between the next disks, number of disks in the rolling line) which provide the change in the external loading ΣP_o for one full turn of crowns not exceeding 26–37%.

It was identified that with an increase in contact strength of rock P_c from 230 MPa to 1250 MPa, total effort ΣPo increases pro rata.

It is noted that during the upward operation of the crowns, ΣP_o is less than during their downward operation by 10–15% which is explained by weakening of the rock mass (k = 0.85–0.9).

It is established that the total external loading ΣP_o on the right crown is 16–38% less than on the left crown as at ρ = 0° or 360 ° due to mutual influence of disk tools on each other the rock in the face is broken in the zone between the crowns by the disks of the left crown, and the disks of the right crown don't engage with them. At the same time, on dependences $\Sigma P_o = f(\rho)$ its concavity is observed (ρ = 270–360 °), and these dependences represent the family of polynoms of the fifth degree.

ACKNOWLEDGEMENT

The authors express their thanks and gratitude to the first deputy chief mechanical engineer on mining equipment in the company "SUEK-Kuzbass" Mukhortikov S.G., head of laboratory of underground robotics of the Federal research center of coal and coal chemistry, Siberian branch of the Russian Academy of Sciences, Ph. D., Aksenov V.V., head of department of metal cutting machines and instruments, professor, Ph. D. Korotkov A.N., professor of department of technology of machine-building, Ph. D., Blumenstein V.Yu., head of center of informatization, candidate of technical sciences, associate professor of department of mining equipment of Yurga technological institute (branch) of the Federal state autonomous educational establishment of higher education "National research Tomsk Polytechnic University" Vorobyov A.V. for their active, creative cooperation and support.

The research results are obtained within the framework of the state order of the Ministry of Education and Science of Russia, project 632 "Investigation of technologies and techniques parameters for selecting and developing innovative designs to improve operating efficiency of multipurpose mining machines in Kuzbass".

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The 8th Russian-Chinese Symposium Coal in the 21st Century: Mining, Processing and Safety

10-12 October, 2016
Kemerovo, Russia

The conference was funded by RFBR according to the research project nº 16-05-20506

Edited by:

Oleg V. Tailakov
Vice-Rector on Research and Strategic Development, KuzSTU
e-mail: tov@kuzstu.ru

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AMSTERDAM – PARIS – BEIJING

ISBN: 978-94-6252-232-9

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Foreword

The 8th Russian-Chinese Symposium "Coal in the 21st Century: Mining, Processing and Safety" was organized jointly by T.F. Gorbachev Kuzbass State Technical University (Russia) and Shandong University of Science and Technology (China), which have had a long-term partnership of 25 years. The event was designed to promote the development of the Russian-Chinese scientific and technical cooperation in the field of mining including high-technology coal mining and deep coal processing, reduction of anthropogenic impact on the environment, production and operation of modern equipment, means and methods of industrial safety in the coal industry, as well as modern technologies of construction and modernization of the coal industry operations.

The symposium brought together the leading Russian and Chinese scientists working in the field of coal, heads of coal-mining companies, industrial safety professionals, managers and specialists of the government. The Symposium participants expanded their scientific and business contacts in the field of mining and defined new promising areas of research and engineering research aimed at the development of the coal industry.

We are confident that the 8th Russian-Chinese Symposium "Coal in the 21st century: Mining, Processing, Safety" will contribute to a new quality of relations between the scientists of Russia and China in the field of the mining science for the benefit of the two countries. We sincerely thank the local and foreign scholars who provided their support to the Symposium and all the authors who submitted their papers for publication.

Vladimir A. Kovalev

Rector, KuzSTU

Oleg V. Tailakov

Vice-Rector on Research and Strategic Development, KuzSTU

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