UDC 621.9 **doi: 10.20998/2078-7405.2025.103.09**

IMPROVING THE EFFICIENCY OF TOOLS FOR TURNING HIGH-STRENGTH MATERIALS

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Received: 19 November 2025/ Revised: 25 November 2025/ Accepted: 29 November 2025 / Published: 15 December 2025

Abstract. *The article presents the results of a comprehensive study of heavy turning of high-strength steels used in structural components of defense and energy engineering, particularly in the tyres and rims of railway wheelsets. The aim of the work is to improve the efficiency of cutting tools by optimizing their geometry and cutting parameters based on the analysis of thermomechanical loading, the stress–strain state of the cutting wedge, and the regularities of tool wear development. The study includes modeling of temperature fields and contact stresses, analysis of the action of elementary force components on the rake and flank surfaces of the tool, as well as experimental determination of cutting forces, wear, and surface roughness during turning of steels with hardness of 2850–3600 MPa. The obtained results show that the geometry of the cutting part is a critical factor in ensuring tool stability: the use of a shortened rake face, strengthening chamfers, and a rational nose radius reduces contact stresses and local overheating in the tool-nose zone. Optimal cutting conditions (V = 45–55 m/min, s = 1.4–2.0 mm/rev, t = 6–8 mm) were established, ensuring minimal wear intensity and a stable chip-formation process. The practical significance of the work lies in the possibility of increasing tool life, machining accuracy, and technological reliability in the production of high-responsibility components from high-strength steels.*
Keywords: *heavy turning; high-strength steels; wheelsets; cutting tool; tool geometry; thermomechanical stresses; cutting temperature; wear; tool life.*

1. Introduction

Machining steel workpieces under heavy cutting conditions is one of the most complex and resource-intensive operations in mechanical engineering, particularly during the processing of large components such as railway wheelsets or rolling mill rolls. The combination of large depths of cut, high feed rates, and increased hardness of the surface layer leads to intensive tool wear, an increase in cutting forces, and significant thermomechanical loading on the cutting edge. Under such conditions, traditional approaches to improving tool life—use of cutting fluids, wear-resistant coatings, or preheating of the workpiece—lose their effectiveness due to the sharp rise in temperature on the rake and flank surfaces. This causes plastic deformation of the carbide layer, reduces its shape stability, and decreases tool life by a factor of 2–3 compared to standard cutting conditions.

The need to reduce wear intensity and maintain geometric stability of the cutting edge has made the optimization of tool geometry a highly relevant task. It has been established that the formation of the temperature-stress state is largely determined by the rake and clearance angles, the nose radius, the configuration of micro-chamfers, and the parameters of chip–tool contact. Optimizing these elements makes it possible to reduce the temperature in the cutting zone, stabilize the chip-formation process, and minimize plastic deformation even under conditions of large undeformed chip thickness.

The aim of this work is to increase the efficiency of heavy turning of alloy steels by determining rational cutting regimes and optimizing tool geometry under conditions of intensive thermomechanical loading. This involves experimental investigation of the influence of cutting speed, feed, depth of cut, rake and clearance angles, and nose radius on tool wear, chip-formation stability, and surface quality, followed by justification of geometric parameters that ensure minimal wear at high productivity.

2. Analysis of Research and Problem Statement

Increasing requirements for the strength and service life of wheelset components in modern transport and energy engineering have intensified research aimed at improving the efficiency of heavy turning of high-strength and hardened steels. A significant body of work focuses on the analysis of temperature fields, cutting forces, and tool wear mechanisms, as elevated temperatures and intensive thermomechanical processes determine both chip formation and the degradation rate of the cutting edge [1–3]. The studies by Duc et al. [1] and Mane et al. [2] present experimental and FEM-based temperature models for machining high-strength steels, showing the influence of cutting speed, tool geometry, and cooling conditions. Work [3] highlights temperature and residual stress characteristics during machining of hardened AISI 52100 steel, confirming the complex thermal loading relevant to railway wheelset bandages as well. Studies by Zheng et al. [4] and Zhang et al. [5] emphasize the critical role of high temperatures in wear mechanisms of coated inserts under heavy mechanical loads.

Further research focuses on modelling thermal and mechanical processes within the cutting tool. Work [6] demonstrates the effectiveness of protective coatings in reducing local overheating, while Twardowski et al. [7] highlight the potential of predicting tool wear based on temperature and force parameters. The findings of Krbata et al. [8] provide insight into tribological interactions between tool materials and hard workpiece materials, which is relevant for machining hardened wheelset bandages. In parallel, intelligent wear-prediction methods are actively developing: neural-network-based models presented in the works of Guan et al. [9] and Cheng et al. [10] show high accuracy in predicting tool degradation during high-speed machining of high-strength steels.

Considerable attention is also devoted to optimizing cutting parameters. Bhemuni et al. [11] investigated the relationship between cutting conditions and temperature in the cutting zone, while work [12] offers optimal machining parameters for AISI 52100 steel considering surface roughness and cutting forces. Review articles by Shihab et al. [13] and Sivaram et al. [14] summarize recent trends in hard turning technologies, and study [15] examines the influence of cooling-lubrication conditions on the surface quality of AISI 52100 steel.

A synthesis of the literature shows that despite substantial progress in hard-turning research, significant gaps remain for the machining of steel bandages and wheelset rims. Notably, there is a lack of models capable of correctly accounting for plastic deformation of the tool tip under large stock allowances and elevated thermo-mechanical loads characteristic of heavy turning. Moreover, available data on the stress–strain state of the cutting wedge under real industrial loading conditions remain limited.

3. Object, Subject, and Research Methodology

The object of the study is the turning process of high-strength structural steels under heavy thermomechanical loading of the cutting tool. The subject of the research includes the tool materials of carbide inserts, the geometry of cutting tools, the temperature–force loads in the contact zone, the shear stresses on the rake and flank surfaces of the tool, and the wear mechanisms of the cutting wedge during machining of large stock allowances.

The research methodology is based on the combination of theoretical modelling and experimental verification. To determine the temperature on the rake and flank surfaces of the tool, a thermomechanical model was applied, accounting for heat generation due to plastic deformation in the cutting zone and friction on the contact surfaces. The average temperature was calculated considering the main technological parameters according to the generalized dependence:

$$T=f(V,s,t,\gamma,\alpha,r_{\varepsilon}),$$

where V — cutting speed, S — feed, t — depth of cut, γ — rake and clearance angles, $r_{\varepsilon r}$ — tool nose radius.

This approach makes it possible to determine heat distribution in the cutting zone and assess the conditions of local overheating, which significantly influence tool wear resistance.

To evaluate the stress state of the cutting wedge, a modified Mitchell method was used, allowing calculation of the maximum shear stresses on the rake surface through the frictional component of cutting force:

$$\tau_{\text{мах}} = \frac{F_c}{A_F}$$

F_c — component of the cutting force associated with friction, A_f— actual contact area between the chip and the rake surface.

The obtained relationships reflect the influence of chip thickness and wear-land width on the growth of shear stresses, which determines the intensity of plastic deformation of the cutting wedge.

Tool wear was analyzed by determining the wear intensity, introduced as the derivative of the wear-land width with respect to the cutting path:

$$I = \frac{dh}{dL},$$

where h — wear-land width, L — cutting path.

Using wear intensity makes it possible to characterize tool degradation not only in the steady-state stage but also at initial and transitional phases, which is particularly important when machining high-strength steels with non-uniform heat generation in the cutting zone.

Experimental investigations were performed to determine the evolution of cutting forces, thermomechanical loading, and wear intensity of the cutting tool during heavy turning of hardened and high-carbon steels. The tests were carried out on a heavy lathe model KZh1832, which provides the required stiffness of the technological system, stable feed, and the capability to machine large stock allowances under elevated loads (Fig. 1).

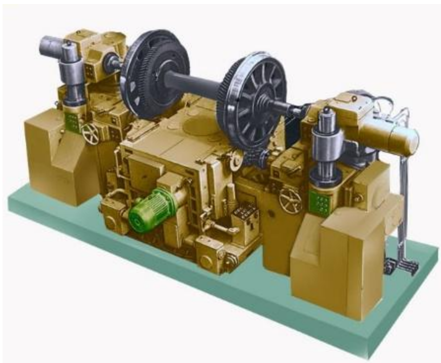

Figure 1 - Heavy-duty lathe model KZh1832 (manufactured by the Kramatorsk Heavy Machine Tool Plant)

For the experimental investigations, heat-treated specimens of steel grade 60—typical for railway wheel-set tyres—were used. The tool geometry was varied by adjusting the rake angle γ, clearance angle α, and nose radius rε, while ensuring identical microgeometry of the cutting edge. Cutting parameters were changed within the range typical for heavy turning according to a factorial experimental design, which made it possible to evaluate both the individual influence of each factor and their interactions.

Cutting forces were measured using a strain-gauge system equipped with a dynamometer, allowing the registration of tangential, radial, and axial components. The temperature in the cutting zone was monitored using a thermoelectric method. Tool wear was assessed optically by measuring the width of the flank wear land and identifying signs of edge degradation or loss of shape stability.

The obtained data were subjected to statistical processing. Based on variations in cutting forces, temperature, and wear intensity, rational cutting regimes and optimal geometric parameters of the cutting insert were determined for operating under elevated thermomechanical loading conditions.

4. Theoretical Principles of Tool Geometry Optimization for Machining High-Strength Steels

4.1. Modelling of Temperature in the Cutting Zone

Accurate prediction of temperature in the cutting zone is fundamental for the optimization of cutting tool geometry when machining high-strength steels, where the thermal load often approaches the heat-resistance limits of carbide materials. The thermal processes are described by the equations of non-stationary heat conduction, which consider the heat generated by plastic deformation of the removed layer as well as friction on the contact surfaces.

An important criterion characterizing the ratio between heat conducted into the chip and into the tool is the Péclet number:

$$\mathrm{Pe} = \frac{Vt}{a},$$

where

V — cutting speed, t — characteristic chip thickness, a — thermal diffusivity of the workpiece material.

At low Pe values, most of the heat flows into the tool, while at high Pe the primary heat flow is carried away by the chip, fundamentally influencing the temperature fields on the contact surfaces.

The general thermal balance is expressed as:

$$q=q_p+q_{fr},$$

where

q_p — heat generated by plastic deformation of the material, q_{fr} — heat generated by friction between the chip and the tool rake face.

The subsequent distribution of heat is determined by its partition into the chip (η_c), tool (η_t) and workpiece (η_w):

$$\eta_c+\eta_t+\eta_w=1.$$

The maximum temperature on the rake face is estimated as:

$$T_{max} = T_o \frac{ql}{kA},$$

where

T_0 — initial temperature of the tool, l — chip–tool contact length, k — thermal conductivity of the tool material, A — contact area.

The geometry of the cutting part significantly affects the resulting temperature fields. Increasing the rake angle γ reduces the real contact area and lowers peak temperatures, although excessive γ decreases wedge strength. Chamfers on the rake face help stabilize chip deformation and redistribute the thermal load. The nose radius $r_{\varepsilon r}$ affects heating on the flank face and the overall mechanical stability of the cutting edge: a larger radius increases strength but also enlarges the contact zone, raising frictional heating.

4.2. Stress State and Deformation of the Cutting Edge

Evaluation of the stress–strain state of the cutting edge is a key stage in the analysis of heavy turning of high-strength steels, since the distribution of normal and tangential stresses directly determines tool durability, wear intensity, and the accuracy of surface formation. Under large feeds and depths of cut, the cutting wedge experiences significant thermo-mechanical loading, which leads to local stress concentrations on the rake-land facet and the flank surface, particularly in the tool-tip zone where the maximum wear land width is formed and peak heating occurs (fig 2).

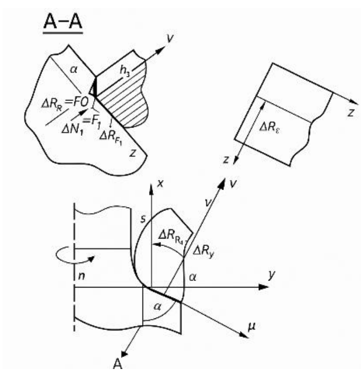

Figure 2 - Scheme of the stress state of the cutting wedge during machining of high-strength steel

In the stress–strain model of the cutting tool, individual sections of the working surfaces are considered as being subjected to elemental force components. On the rake face, within the chip–tool contact zone, an elemental tangential component ΔF_1, a normal component ΔN_1, and the resultant force component ΔR_ξ directed along the chip flow line act simultaneously. For the clearance face, where a stagnation zone is formed, a uniformly distributed normal pressure q_N is introduced, representing the contact load on the wear land.

An important element of the model is the description of the cutting edge shape in local coordinates (ξ, z), which reflects the real geometry of the edge radius and the rake chamfer. According to the geometric relations for the radius portion of the cutting edge, the coordinates of an arc element are defined as:

$$x^2+y^2=r_\varepsilon^2,\ dl = \frac{r_\varepsilon}{\sqrt{r_\varepsilon^2 - x^2}}dx.$$

The elemental increment of the tangential cutting-force component is expressed as:

$$dP_y = K_V S b \frac{x}{\sqrt{r_\varepsilon^2 - x^2}} dx q_N f_y sin\gamma dx + \sigma_r b h_3 dx,$$

where: K_V — coefficient accounting for the workpiece material properties, S — feed, b — contact width, q_N — normal stresses on the wear land, $h_з$ — wear-land thickness, f_y — friction coefficients, γ — rake angle.

Similarly, for the axial and radial force components:

$$dP_x = K_V S b \frac{x}{\sqrt{r_\varepsilon^2 - x^2}} dx q_N f_x sin\gamma dx + \sigma_r b h_3 dx, dP_z = K_V S b \frac{x}{\sqrt{r_\varepsilon^2 - x^2}} dx q_N f_z sin\gamma dx,$$

The integration limits are determined by the cutting-edge contact length:

$$x \in \left[0, \sqrt{2r_\varepsilon t - t^2}\right]$$

where t is the chip thickness.

Thus, the total components of the cutting force are obtained by integrating the corresponding differential expressions:

$$P_x = \int dP_x,\ P_y = \int dP_y,\ P_z = \int dP_z.$$

These components are then transformed into the global coordinate system (Fig. 2), enabling determination of the resultant load acting on the cutting wedge:

$$\vec{R} = P_x, P_y, P_z,$$

Additionally, using Mitchell's solution for a wedge, the shear stresses in the tool cross-section are defined as:

$$\tau_m = \frac{P_x}{be}\frac{tan\frac{\beta}{2}}{cos\frac{\beta}{2}},$$

where β is the wedge angle, e is the cross-sectional thickness, b is the contact width.

An increase in the wedge angle β reduces τm, confirming a lower tendency toward plastic deformation as the wedge strength increases — a typical effect for tools with a shortened rake face.

The generalized analysis shows that maximum stresses are concentrated in the edge-radius zone, where peak thermal and mechanical loads occur simultaneously. This region becomes the initiation point of intensive wear and formation of the wear land $h_з$, which is confirmed by experimental results and agrees with the modelling outcomes.

4.3. Wear Intensity Model

The functional efficiency of a cutting tool during the machining of high-strength steels is determined by the regularities of wear development on the cutting wedge and its ability to maintain geometric parameters under increased thermomechanical loading. To quantify this process, a wear-intensity model is used, which assumes division of the contact zone into local regions, each characterized by its own rate of cutting-edge degradation.

The local wear intensity at a point with coordinate x along the cutting edge is expressed as:

$$I(\mathrm{x}) = \frac{dh(\mathrm{x})}{dL},$$

where *h(x)* is the local wear value (micro-chipping depth or flank-wear width), *L* is the cutting path.

The highest values of *I(x)* are observed in the tool-nose region, where maximum shear stresses, workpiece-induced pressure, and localized temperature peaks coincide (Fig. 3).

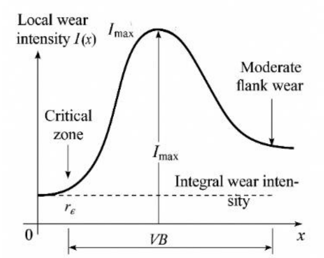

Figure 3 - Diagram of the local and integral wear intensity of the cutting edge

The boundary conditions for edge shape stability are defined as:

$$T_{max} < T_f,\ \sigma_{eq} < \sigma_p,$$

where T_f is the temperature at which the hard alloy begins to soften, σ_p is the strength limit or the conventional yield strength of the tool material.

Exceeding these parameters leads to a loss of geometric stability of the cutting wedge, accelerated wear, and the onset of plastic deformation in the tool tip.

The integral wear intensity is defined as the average degradation rate of the cutting edge:

$$I_{int} = \frac{1}{L}\int_0^L I(x)dx,$$

which makes it possible to evaluate the tool life and determine the cutting length at which the critical wear value VB_{crit} is reached.

5. Optimization of Tool Geometry for Machining High-Strength Materials on Heavy Turning Machines

Studies of thermomechanical loading during turning of steel wheel-set tyres and rims have shown that the geometry of the cutting part has a decisive influence on cutting forces, stress localization in the edge zone, and tool wear rate. For steels with hardness HB 2850–3600 MPa, the maximum loads are concentrated at the tool nose, where peak temperatures and the largest wear-land width are formed. For standard prismatic inserts, the vertical cutting-force component ***Pz*** reaches 40–45 k_N, which leads to accelerated tool degradation.

Comparison of different geometries demonstrated the advantages of inserts with a shortened rake surface: a reduced rake angle on the chamfer increases wedge strength, while a larger inclination of the main rake surface stabilizes chip formation.

Such tools promote a more uniform distribution of normal stresses and reduce peak shear stresses in the nose region. Radius inserts with ***r*** = 4–14 mm also effectively decrease local loads in the transition zone, provided that the clearance angle is corrected to prevent backside overheating.

Analysis of cutting forces showed that at ***t*** = 8 mm and feed 1.2–1.6 mm/rev, the Pz component increases by 20–25 %, accelerating wear-land development. This confirms the need to limit feed in rough turning of wheel-set tyres.

The optimal tool parameters were found to be: rake angle 12–14°**,** clearance angle 4–6°, nose radius 1.2–1.6 mm for tyres and 4–6 mm for rims. This geometry reduces shear stresses τ_m by 15–20 % and stabilizes the stress state of the cutting wedge. Combined with rational cutting regimes (*V* = 45–55 m/min, *S* = 1.4–2.0 mm/rev, *t* = 6–8 mm), tool life increases by 25–30 %**.**

A rationalized tool geometry includes the use of strengthening chamfers, adaptive selection of nose radius depending on operation type, adjustment of rake angle according to tyre hardness, and minimization of the real chip-contact zone to reduce thermal loading. This approach ensures improved tool life and stable profile formation under heavy-duty machining of high-strength steels.

6. Experimental investigations

Experimental studies were carried out to verify the adequacy of the analytical models and to determine the influence of cutting tool geometry on tool life and machining quality when turning high-strength steels under heavy-duty conditions. Cutting force measurements showed that the tangential component of the cutting force Fc increases almost linearly with feed rate, which corresponds to the regularities of chip thickness formation in heavy turning. The characteristic form of this dependence is shown in Fig. 3.

As the feed increased from 1.2 to 2.5 mm/rev, the cutting force rose by approximately 25–30 %, confirming the dominance of mechanical loading over thermal effects within the tested cutting-speed range. An increased nose radius contributed to a reduction of peak stresses in the tool-tip zone, which is consistent with the analytical stress model.

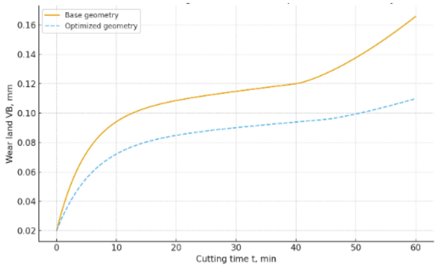

Figure 4 - Comparison of wear intensity for the baseline and optimized tool geometry

The wear of the cutting tool during heavy turning followed a three-stage pattern: rapid initial break-in, steady uniform wear, and a sharp acceleration before the catastrophic stage (Fig. 4). At the beginning, wear intensity was maximal due to micro-geometric adaptation; this was followed by an almost linear increase in flank wear VB under stable thermal conditions, and after 40–45 minutes a rapid rise in wear occurred as a result of local plastic deformation of the cutting edge and increasing temperature on the flank surface.

A comparison of the baseline and optimized geometries showed that modifying the rake angle, clearance angle, and nose radius significantly influences the degradation of the cutting edge. The optimized geometry provided a 20–35% reduction in wear intensity, delayed the onset of the catastrophic stage, and resulted in lower temperatures in the tool-tip region, which agrees with the modelling results.

Surface roughness analysis confirmed an improvement to Ra = 2.4–3.8 μm (20–30% better than the baseline tool), which is associated with reduced plastic deformation of the tool tip and lower equivalent stresses. Based on the overall results, the optimal heavy-turning cutting conditions were identified as: cutting speed 45–55 m/min, feed rate 1.4–2.0 mm/rev, depth of cut 6–8 mm, with rake angle 12–16°, clearance angle 4–6°, and nose radius 8–10 mm. These parameters ensure minimal wear intensity, stable mechanical and thermal loads, and high tool life when machining high-strength steels on heavy lathes.

7. Conclusions

The study presents a comprehensive investigation of heavy turning processes applied to high-strength and hardened steels, combining thermomechanical modelling, analysis of the stress–strain state of the cutting wedge, construction of a wear-intensity model, and experimental verification on a heavy lathe. It is shown that an accurate assessment of tool shape stability is possible only when temperature, force, and contact phenomena are considered simultaneously, as these factors govern the behaviour of the cutting edge under large depths of cut, increased feed rates, and variable hardness of the surface layer.

Thermomechanical modelling established the critical influence of the rake and clearance angles, nose radius, and the configuration of strengthening chamfers on the distribution of heat fluxes and the location of maximum temperatures. It was demonstrated that optimization of these parameters reduces local overheating at the tool nose and delays the onset of intensive wear. Analysis of the stress state using a modified Mitchell approach confirmed that tools with a shortened rake face and a properly selected nose radius reduce peak shear stresses and ensure a more uniform distribution of normal stresses on contact surfaces, thereby lowering the risk of plastic deformation and edge chipping.

The wear-intensity model made it possible to quantitatively describe the development of edge degradation and confirmed the critical role of the nose region in the formation of the wear land. Experimental studies during the turning of steels used for wheel-set tyres and rims demonstrated reductions in cutting forces, slower wear progression, and improved machining accuracy when optimized tool geometry was applied.

The generalised results enabled the formulation of recommendations: the use of strengthening chamfers, adaptation of the nose radius to the type of operation, correlation of the rake angle with material hardness, and minimisation of the real chip–tool contact zone. The optimized solutions enhance tool life, stabilise the cutting process, and improve surface quality when machining large, high-strength steel components.

References: **1.** *Pham Minh Duc P., Giang L.H., Nguyen V.T.* Analyzing Cutting Temperature in Hard-Turning Technique with Standard Inserts Through Both Simulation and Experimental Investigations. Applied Sciences, 2025, 15(2), 983. DOI: 10.3390/app15020983 **2**. *Mane S., Patil R.B., Kolhe M.L., Siddiqui M.I.H., Chan C.K., Xu Y.* Analysis of Thermal Aspect in Hard Turning of AISI 52100 Alloy Steel Under Minimal Cutting Fluid Environment Using FEM. Applied Mechanics, 2025, 6(2), 26. DOI: 10.3390/applmech6020026 **3**. *Mane S., Patil R.B., Siddiqui M.I.H., et al*. Effect of Cutting Parameters and Tool Coating on Residual Stress and Cutting Temperature in Dry Hard Turning of AISI 52100 Steel Using Finite Element Method. Frontiers in Materials, 2025. DOI: 10.3389/fmats.2025.1613630 **4**. *Zheng G., Li L., Li Z., Gao J., Niu Z.* Wear Mechanisms of Coated Tools in High-Speed Hard Turning of High Strength Steel. International Journal of Advanced Manufacturing Technology, 2018. DOI: 10.1007/s00170-017-1132-1 **5**. *Zhang H.P., Sutanto B., To S.* Tool Wear in High-Speed Turning Ultra-High Strength Steel Under Dry and CMQL Conditions. Materials and Manufacturing Processes, 2020. DOI: 10.1080/10584587.2020.1728633 **6**. *Hao G., Tang A., Zhang Z., et al*. Finite Element Simulation of Orthogonal Cutting of H13-Hardened Steel to Evaluate the Influence of Coatings on Cutting Temperature. Coatings, 2024, 14(3), 293. DOI: 10.3390/coatings14030293 **7**. *Twardowski P., Wiciak-Pikuła M*. Prediction of Tool Wear Using Artificial Neural Networks During Turning of Hardened Steel. Materials, 2019, 12(19), 3091. DOI: 10.3390/ma12193091 **8**. *Krbata M., Eckert M., Majerik J., Barenyi I.* Wear Behaviour of High Strength Tool Steel 90MnCrV8 in Contact with Si_3N_4. Metals, 2020, 10(6), 756. DOI: 10.3390/met10060756 **9**. *Guan R., Cheng Y., Jin Y., et al*. Tool Wear Prediction for Milling High Strength Steel Based on DenseNet-ResNet-GRU. Journal of Mechanical Science and Technology, 2024, 38, 3585–3596. DOI: 10.1007/s12206-024-0632-9 **10**. *Cheng M., Kim S., Zhao Y., et al*. Intelligent Prediction Model of the Tool Wear Based on Machine Learning Technique in Turning of High-Strength Steel. Proceedings of the IMechE Part B: Journal of Engineering Manufacture, 2020. DOI: 10.1177/0954405420935787 **11**. *Bhemuni V., Chelamalasetti S., Kondapalli S.* Effect of Machining Parameters on Tool Wear and Nodal Temperature in Hard Turning of AISI D3 Steel. Open Access Library Journal, 2014. DOI: 10.4236/oalib.1100627 **12.** *Umamaheswarrao P., Venkata Rao P., Srinivasa Rao M.* Achieving Optimal Process Parameters During Hard Turning of AISI 52100 Steel. Key Engineering Materials, 2019, Vol. 818, pp. 87–95. DOI: 10.4028/www.scientific.net/KEM.818.87 **13**. *Shihab S.K., Khan Z.A., Mohammad A., Siddiquee A.N.* A Review of Turning of Hard Steels Used in Bearing and Automotive Applications. Production & Manufacturing Research, 2014, 2(1), 24–49. DOI: 10.1080/21693277.2014.881728 **14**. *Sivaram N.S., Prakash S.* Recent Developments in Turning Hardened Steels – A Review. IOP Conference Series: Materials Science and Engineering, 2017, 197, 012009. DOI: 10.1088/1757-899X/197/1/012009 **15**. *Rao R., Alluru V., Kumar J.* Surface Integrity of

AISI 52100 Steel During Hard Turning Under Various Cooling/Lubrication Strategies. Advances in Materials Science and Engineering, 2020, Article ID 4256308. DOI: 10.1155/2020/4256308

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ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ІНСТРУМЕНТІВ ДЛЯ ТОКАРНОЇ ОБРОБКИ ВИРОБІВ З ВИСОКОМІЦНИХ МАТЕРІАЛІВ

Анотація *У статті представлено результати дослідження процесів важкого точіння високоміцних та загартованих сталей, що застосовуються у конструктивних елементах відповідального призначення в транспортному, оборонному й енергетичному машинобудуванні. Робота спрямована на підвищення ефективності різального інструмента шляхом оптимізації його геометрії та режимів різання з урахуванням дії інтенсивних термомеханічних навантажень, характерних для обробки великих припусків і матеріалів з підвищеною твердістю. У межах дослідження виконано моделювання температурних полів, розподілу контактних напружень, силових взаємодій у зоні різання, а також формування локальних пікових температур, що визначають розвиток пластичної деформації різального клина та зростання інтенсивності зношування. Експериментальні випробування, проведені при точінні сталей твердістю 2850–3600 МПа, підтвердили домінуючий вплив геометрії ріжучої частини інструмента на концентрацію напружень у зоні вершини та на стабільність стружкоутворення. Показано, що застосування укороченої передньої поверхні, зміцнювальних фасок та оптимального радіуса вершини сприяє зниженню локального перегріву, рівномірнішому розподілу сил різання і сповільненню розвитку зношування. Встановлені раціональні режими різання забезпечують підвищення стійкості інструмента на 25–30 %, покращення точності формоутворення та зменшення шорсткості поверхні оброблюваної деталі. Отримані результати можуть бути використані для оптимізації технологічних процесів обробки високоміцних сталей у важких режимах, підвищення ресурсу інструмента та покращення технологічної надійності виробництва. Запропонований підхід також створює основу для подальшого удосконалення моделей прогнозування зношування в умовах змінних навантажень. Отримані напрацювання можуть бути інтегровані в системи цифрового виробництва для підвищення керованості процесів металорізання.*

Ключові слова*: надійність; знос інструменту; втома; важке машинобудування; обробка різанням; адгезійний знос; термомеханічне навантаження; пластична деформація; різальна крайка.*