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Sarvan Aziz

sarvan.aziz@aztu.edu.az

Azerbaijan Technical University

Agasi Aghayev

Azerbaijan Technical University

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Ensuring Surface Quality Using Technological Methods in Modern Rapid Honing Processes

Sarvan Aziz[1*] and Agasi Aghayev[1]

[1]Azerbaijan Technical University, Baku, Azerbaijan.

*Corresponding author(s). E-mail(s): sarvan_e@hotmail.com;
Contributing authors: agasi.agayev@aztu.edu.az;

Abstract

This article analyzes the key features of the abrasive lapping process for internal cylindrical surfaces, examines the general patterns of surface quality formation, and, consequently, determines the optimal processing parameters. The article presents the results of experimental studies examining the influence of lapping process parameters on surface quality, which is primarily the final manufacturing operation in the manufacture of machine parts. Based on the physical, mechanical, and technological properties of 32CrMoV12-10 steel, selected as the test sample, and taking into account the required performance-quality conditions, the optimal values for the lapping process parameters were determined.

Keywords: honing process, abrasive sand, cutting forces, hardness, special pressure, rotation speed.

1 Introduction

In modern manufacturing engineering, increasingly stringent requirements are imposed on the precision honing of internal cylindrical surfaces, particularly in terms of surface roughness, dimensional accuracy, geometric form deviations, and the integrity of the near-surface layer. These characteristics directly affect the functional performance, service life, and operational reliability of precision machine components. As a final finishing operation, honing enables the improvement of surface texture and dimensional accuracy. However, the quality achieved depends not only on the selection of abrasive tools and machining conditions but also on the kinematic characteristics

of the machine tool, the rigidity of the technological system, and the interaction between the honing tool and the workpiece. Consequently, the effective application of advanced honing technologies requires a comprehensive understanding of the factors governing material removal and the formation of surface quality.

The precision of machined components is determined by the combined influence of the technological system, machining regime parameters, and the initial condition of the workpiece. Effective control of machining accuracy therefore requires systematic monitoring of precision indicators, the appropriate selection of machining parameters in accordance with the rigidity of the technological system, and the application of reliable process-control methods [3, 4, 19]. In precision honing, particular importance should be attached to the relationship between the operating conditions of the honing tool and the resulting geometric accuracy of the internal cylindrical surface. An insufficiently justified selection of machining conditions may lead to non-uniform material removal, uneven tool wear, and the retention of initial geometric deviations, ultimately limiting the quality of the finished component.

The formation of geometric accuracy during honing is strongly influenced by the axial reciprocating motion of the honing head and the distribution of contact between the abrasive elements and the machined surface. In certain honing machines, a limited axial reciprocating stroke may cause non-uniform contact between the honing tool and different regions of the cylindrical surface. Under these conditions, the upper and lower regions of the workpiece may undergo different material-removal conditions [2, 7, 11]. Such non-uniformity can contribute to uneven tool wear and the persistence or reproduction of initial geometric form deviations on the finished surface. These limitations highlight the importance of evaluating the kinematic and technological conditions of honing in relation to the geometric characteristics of the workpiece.

Although the general principles of honing and the influence of machining conditions on surface quality have been investigated, the practical selection of process parameters remains dependent on the workpiece material, the initial surface condition, the geometry of the component, and the operating characteristics of the equipment. In particular, the effects of honing-head reciprocating motion and other technological parameters need to be considered together with the resulting surface roughness and geometric form accuracy. Therefore, an assessment based on defined experimental conditions is necessary to clarify the relationship between the selected machining parameters and the quality indicators obtained during the honing of internal cylindrical surfaces.

The aim of this study is to investigate the influence of technological parameters on the surface quality and geometric accuracy of internal cylindrical surfaces produced by honing. The investigation focuses on the relationship between the machining conditions and the resulting quality characteristics, taking into account the limitations associated with non-uniform tool–workpiece contact and the initial geometric condition of the workpiece. The study is intended to provide an experimental basis for the technically justified selection of honing conditions and to identify opportunities for improving the quality of the finished surface.

The scientific contribution of this study consists in the experimental assessment of the relationship between the technological conditions of honing and the resulting

surface-quality and geometric-accuracy indicators under the investigated machining conditions. Particular attention is given to the influence of the honing process on the formation of geometric accuracy and to the role of tool–workpiece contact conditions in achieving uniform material removal. The findings are intended to support the selection of appropriate technological parameters for improving the quality of honed internal cylindrical surfaces. The specific novelty of the work should be substantiated in the Results and Discussion section by presenting the measured changes in surface roughness and geometric deviations and comparing them with the initial workpiece condition and relevant findings reported in previous studies.

The general technological regularities of the influence of the main input parameters of the internal cylindrical honing process on the output characteristics - dimensional accuracy and surface roughness - have been analyzed. Symbols and units of input parameters of the machining process for the research work are given in Table 1.

Table 1: Symbols and units of input parameters of the machining process

№	symbols	unit of measurement	parameter name
1.	$V_{rec.sp.}$	m/s	reciprocating speed of the honing head
2.	V_{rot}	m/s	rotational speed
3.	$P_{s.pr.}$	kPa	specific pressure applied to the surface
4.	Z	µm	abrasive grain size
5.	T	sec.	processing time

Experimental investigations were conducted on specimens fabricated from 32CrMoV12-10 steel. The specimens were characterized by a nominal internal diameter of d=125+0.15 mm, an external diameter of D=150 mm (H12), and a length of L=1510 mm, with the target surface roughness specified as Ra=0.8 µm.

2 Methodology

The primary objective of this study is to ensure the dimensional accuracy and enhance the surface quality of internal cylindrical surfaces in modern high-speed honing processes. The research methodology is based on an experimental approach aimed at systematically evaluating the effects of the main technological parameters of the honing process on surface roughness and dimensional precision. Particular emphasis is placed on identifying optimal machining conditions that satisfy operational quality requirements under realistic production settings.

The experimental investigations were conducted on cylindrical specimens made of 32CrMoV12-10 alloyed steel, selected for its favorable physico-mechanical and technological properties. Prior to honing, all specimens underwent identical preliminary machining sequences to standardize initial surface roughness and geometric accuracy. The honing experiments were performed on a state-of-the-art SHDS Skiving and Roller Burnishing Machine designed for internal cylindrical surfaces.

Based on the experimental results and theoretical calculations, graphs illustrating the interrelationships among the investigated process parameters were constructed.

Corresponding mathematical models were developed, and regression analysis was conducted to accurately assess the quantitative characteristics of the process, with the relevant regression coefficients determined using Microsoft Excel.

Technological Parameters and Experimental Design. The study investigated the influence of the following key technological parameters: the reciprocating speed of the honing head (Vrec.sp.), the rotational speed (Vrot.), the specific pressure applied to the surface (Ps.pr), the abrasive grain size (Z), and the processing time (T). These parameters were systematically varied according to a pre-established experimental plan. The variation ranges were selected based on preliminary trials and industrial experience.

Measurement and Evaluation Methods. After machining, surface roughness parameters (Ra, Rz) were measured using a contact-type 253 Model profilograph–profilometer. Dimensional accuracy and cylindricity deviations were assessed with high precision using a Hexagon Tigo SF01 coordinate measuring machine.

The experimental results were statistically analyzed to identify correlations between honing parameters and surface quality and dimensional accuracy indicators. Optimal honing conditions were determined based on criteria ensuring minimal surface roughness, maximum dimensional precision, process stability, and high productivity.

3 Scientific Novelty of the Study

The scientific novelty of this study lies in the experimental investigation of the relationships between the principal honing process parameters and surface quality characteristics during the high-speed honing of internal cylindrical surfaces made of 32CrMoV12-10 alloy steel, as well as in the evaluation of these relationships in terms of improving machining accuracy.

Within the specific experimental conditions established in this study, the effects of the honing tool's reciprocating speed, workpiece rotational speed, specific honing pressure, abrasive grain size, and machining time on surface roughness formation were systematically investigated. A comparative analysis of workpiece batches with different initial surface conditions enabled the effects of the technological parameters to be evaluated while taking the initial surface roughness into account.

Another aspect of the scientific novelty is the experimental evaluation of the application of a floating honing-head operating mode, together with the purposeful selection of machining parameters, to improve the geometric accuracy of internal cylindrical surfaces. The experimental results demonstrated a reduction of approximately 14–27% in geometric form errors under the investigated machining conditions.

Furthermore, the SASh ratio coefficient proposed by the author was considered in justifying machining accuracy by accounting for the functional relationships between the geometric dimensions of the workpiece and the parameters of the honing tool. Thus, the findings contribute to the development of an experimentally substantiated approach to selecting honing process parameters for improving surface roughness and geometric form accuracy during the honing of 32CrMoV12-10 steel.

4 Discussion of the results

32CrMoV12-10 steel is a high-strength structural alloy steel, alloyed with chromium (Cr) and molybdenum (Mo), exhibiting superior fatigue resistance. It is primarily employed in heavily loaded mechanical components subjected to high-impact and dynamic stresses. The nominal chemical composition is as follows: C 0.30–0.35%, Cr 1.0–1.3%, Mo 0.2–0.3%, Mn 0.5–0.8%, Si 0.2–0.4%, and V 0.25–0.35%. For specific applications, minor adjustments in the chemical composition may be implemented to optimize performance [2, 14] From a mechanical perspective, 32CrMoV12-10 steel demonstrates high tensile strength and hardness, enhanced impact toughness, and excellent wear resistance, making it suitable for demanding engineering applications.

Prior to the honing operation, the micro-geometric form error present on the internal cylindrical surface plays a critical role in the selection of process parameters and the planning of machining stages. While the initial honing operation is typically performed using conventional methods and equipment, the finishing and fine-honing stages require the optimization of the kinematic scheme, process parameters, and other technological factors to ensure high dimensional accuracy and surface quality [10, 12, 21]. In this regard, it is considered necessary for the honing head to be able to operate in "floating" honing head mode in order to increase the processing accuracy in the honing operation of internal cylindrical surfaces. All machining operations were executed using a SHDS Skiving and Roller Burnishing Machine supplied by Sunnen Products Company (USA) (Fig.1).

During the honing operation, a water-oil emulsion of "Mobilmet 426 honing oil" was utilized as the cutting fluid and lubricant. Given that the ratio of the workpiece length (L=1510 mm) to its radius (r=125 mm) is approximately ≈12, the component is classified as rigid, thereby enabling the execution of a single-pass, positional honing cycle under controlled kinematic and loading conditions.

The "SASh" ratio coefficient, introduced by the author, is utilized to achieve optimal dimensional accuracy and microgeometric surface quality by considering the mathematical-functional interrelations among part length, diameter, honing stone length, and other technological parameters [5, 6, 8]. In numerous cases, this coefficient is further refined based on the material's physical and mechanical properties.

During the honing process, the dispersion patterns of various form error values exhibit distinct characteristics. The close approximation of the actual distribution of geometric dimensions to theoretical distribution laws constitutes clear evidence of the stability of the honing process. It is observed that, within the examined operation, the magnitude of geometric form errors is reduced by approximately 14–27%.

The normal execution of the honing operation may, however, create conditions for the emergence of other types of errors that lead to a deterioration in the accuracy and surface quality characteristics of the machined components. The analyzed data indicate that dimensional variation - specifically, the reduction of form errors during the honing operation - possesses greater significance compared to other abrasive machining processes and, in most cases, remains minor, accounting for only a small proportion of the specified tolerance limits.

The reduction in abrasive grain size has a positive effect on surface quality; however, it may lead to a decrease in productivity and other technological performance



Figure 1 SHDS Skiving and Roller Burnishing Machine branded CNC honing machine.

indicators. Therefore, relatively coarse abrasive grains are recommended for roughing operations, whereas the finest grains should be employed during finishing processes (Table 2). The contact pressure of the honing stones on the workpiece surface is often controlled using hydraulic or pneumatic regulators. This approach ensures both the attenuation of sudden impacts and the uniform distribution of pressure across the machined surface.

Table 2: Selecting the grade of diamond powder in stones for honing

Part of the materials	types of operation	Diamond grades
hardened and nitride steel 58-65 HRC	*roughing* *semi-finishing* *finishing*	*AC 15, APK4* *AC 20, AC 32* *AC 6, APB1*
hardened steel 46-52 HRC	*roughing* *semi-finishing* *finishing*	*AC 15, AC 20* *AC6, APB1* *AC 4, ACM*
chrome coating	*roughing* *semi-finishing* *finishing*	*AC 15, APB1* *AC6, APB1* *AC 4, ACM*

The results of experimental studies demonstrate that the formation of form errors in longitudinal sections differs in nature from that observed in transverse sections. In the grinding of thin-walled and non-rigid workpieces, elastic-plastic deformations directed from the interior to the exterior must be minimized, which necessitates the selection of relatively low specific pressures; otherwise, the microgeometrical characteristics of the surface may be compromised. In this context, uneven wear of the grinding stones along their longitudinal dimension can be observed. During the automation of the process, the traditional passive measurement-monitoring method must unambiguously be replaced by an active measurement-control approach [1, 13, 15, 17, 22, 23, 24, 25]. This is also related to the fact that in passive monitoring, the machining process is stopped for inspection, whereas in an active control system, automatic regulation occurs during the machining process, allowing real-time monitoring of the measurement results.

Analysis of the micro-geometric errors of components at various stages of the honing operation indicates that significant variations are observed during the initial and semi-finishing operations, whereas minor variations occur in the final stages. This pattern is consistent with practical observations, as the initial and semi-finishing operations have the most pronounced effect on the form errors of the components, while the final operations primarily influence the formation of the surface layer quality. The foregoing demonstrates that the occurrence of different form errors follows certain mathematical laws and must be managed using appropriate technological methods. When employing various laws of mathematical statistics to enhance precision, it is essential to adjust them and take them into account during the design and planning of technological processes [9, 11, 16,18, 20].

As with any machining process, honing is governed by a set of specific quality requirements. In particular, the degrees of freedom of the honing head, the number, size, and configuration of the honing stones, as well as the stepless control of the axial reciprocating and rotational velocities of the head, exert a significant influence on the dimensional accuracy of the machined workpiece. The determination of the optimal values of the main input parameters of the honing process - namely, the reciprocating

speed of the honing head (Vrec.sp.), the rotational speed (Vrot.), the specific pressure applied to the surface (Ps.pr.), the abrasive grain size (Z), and the processing time (T)-is of critical importance for both productivity and surface quality control. In this context, active experiments were conducted to investigate the influence of various levels of these parameters on the surface roughness, and the results are presented in Figures 2–6.

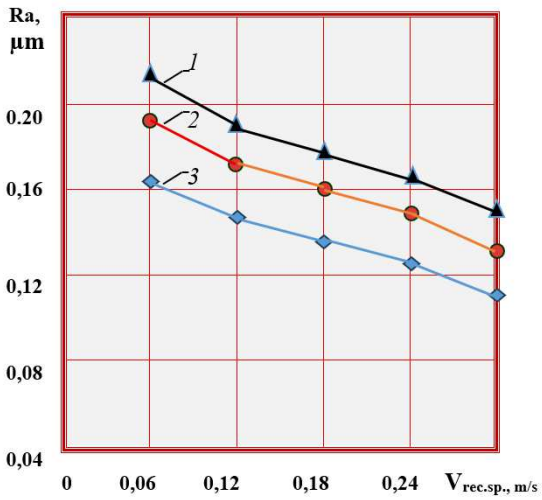

Figure 2 Dependence of surface roughness R_a on reciprocating feed speed. Curves 1–3 correspond to workpiece batches with different initial surface roughness R_a.

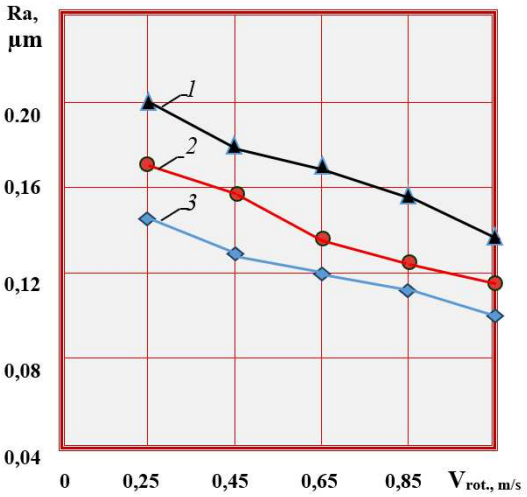

Figure 3 Dependence of surface roughness R_a on workpiece rotational speed. Curves 1–3 correspond to workpiece batches with different initial surface roughness R_a.

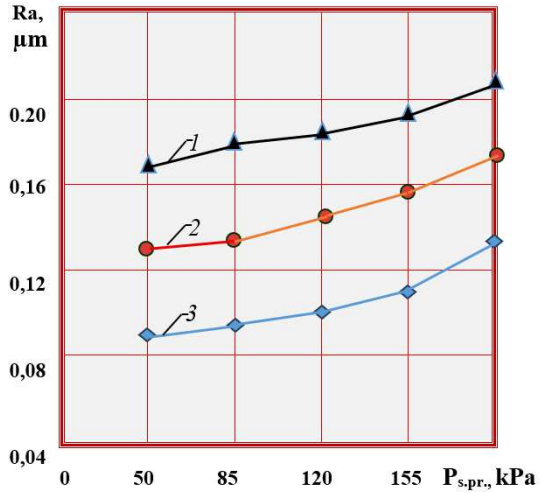

Figure 4 Dependence of surface roughness R_a on specific pressure. Curves 1–3 correspond to workpiece batches with different initial surface roughness R_a.

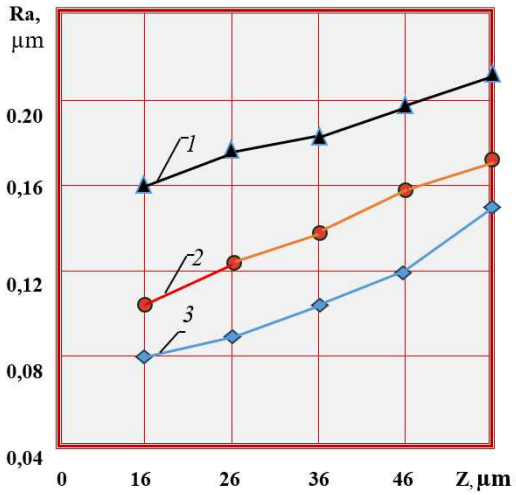

Figure 5 Dependence of surface roughness R_a on the grit size of lapping pastes. Curves 1–3 correspond to workpiece batches with different initial surface roughness R_a.

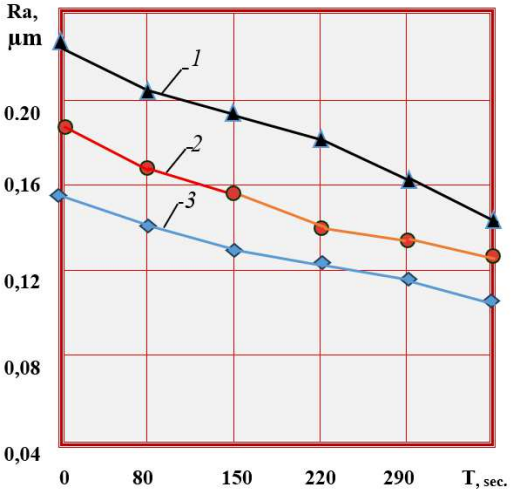

Figure 6 Dependence of surface roughness R_a on machining time. Curves 1–3 correspond to workpiece batches with different initial surface roughness R_a.

5 Results

The results indicate that operating the honing head in a "floating" mode, combined with the optimization of technological parameters, significantly enhances product quality, process stability, and productivity. Consequently, modern honing technologies ensure the high-precision machining of internal cylindrical surfaces and reliable operational performance. In modern machine-building industries, one of the principal directions of technological advancement is the optimization and development of finishing processes for the functional surfaces of machine components, as well as the ensuring of their mechanical quality and operational performance. The honing operation enhances the geometric accuracy of components, minimizes surface micro-roughness, thereby ensuring the stability of the manufactured parts' quality and increasing the reliability of technological processes.

The formation of a stable machining outcome in the honing process depends on the selection of technologically justified and mathematically calculated optimal operating conditions. A rational machining regime should ensure both the economic efficiency of the process and optimal quality indicators, including surface roughness and dimensional accuracy.

References

[1] Aziz S.Sh. Accuracy and regularity of its formation at processing with lapping surface of machine details. Machines, units and processes. Design, creation and modernization, 2020, No3, pp.30-35.

[2] Amanov, Y.A., Hashimov, E.G., Aliyev, A.M., Ismayil, I.A. Tribological characterization of surface layer hardness and wear resistance under abrasive scratching // International Journal on Technical and Physical Problems of Engineering. 2025, 17(3), pp. 414–420

[3] Aziz S.Sh, The general regularity of surface layer work hardening in the honing operation of medium carbon steels, RT&A, Special Issue 2025, No. 7 (83), Volume 20, https://www.scopus.com/pages/publications/105008113631?origin=resultslist

[4] Aziz S.Sh., Characteristics of Quality Formation in Processing of 32CrMoV12-10 Steel by Honing, Key Engineering Materials, Switzerland, 2024, Vol 979, https://www.scopus.com/pages/publications/85204774070?origin=resultslist

[5] Aziz S.Sh., Improving surface quality in flat grinding operations using modern technological methods, Machine Science, AzTU, Baku-2024, No.2, https://elibrary.ru/item.asp?id=80352379

[6] Bakhshali, V., Aslanov, E., Hasanov, F., & Ismayil, I. (2024, August). Thermodynamical Analysis of the Reciprocating Machines Using Computer Software. In International Conference on Theory and Application of Soft Computing,

Computing with Words and Perceptions (pp. 169-174). Cham: Springer Nature Switzerland.

[7] Eziz, S. Sh. Kinematic features of the lapping process and determination of its basic parameters // - Moskow: Computational Nanotechnology, - 2020. No.3 (Vol.7), - p. 11-16. 11-16

[8] Eziz, S. Sh. Theoretical studies of the dynamic characteristics of the internal lapping process // - Magnitogorsk: Vestnik of Nosov Magnitogorsk State Technical University, - 2020. No.2 (Vol.18), - p. 30-37

[9] Aziz S., Agayev A. (2025) Modern technological methods of formation and reduction of residual stresses in aluminum alloys. Machine science, No 1, pp. 74–79.

[10] Rasulov N.M., Alekberov M.Z., Nadirov U.M. More Efficient Copy Grinding of Complex Surface. Russ. Engin. Res. 41, 829-831 (2021). https://link.springer.com/article/10.3103/S1068798X21090227

[11] Rasulov N.M., Nadirov U.M., Alakbarov M.Z., Improving the efficiency of grinding teeth by copying with the control of dynamic technological connections. SOCAR Proceedings. Special Issue 1 (2022) 029-035. DOI: 10.5510/OGP2022SI100697. https://proceedings.socar.az/en/journal/85

[12] Rasulov N.M., Nadirov U.M., Alekberov M.Z. Generalized Assessment of Machined Surfaces Quality. Russ. Engin. Res. 40, 822-825 (2020). https://link.springer.com/article/10.3103/S1068798X20100202

[13] Umid Yusif, Khalilov, A.H. Machine-Building Technology. Baku: AzPI, 2007. 121 pp.

[14] Yang, J., Tian, C., Wang, C. Nanometer lapping technology at high speed: [Electronic resource] / Science in China Series E: Technological Sciences-50(1), 2007. URL: https://sci-hub.se/https://doi.org/10.1007/s11431-007-2030-9

[15] Yusubov N.D., Abbasova H.M. Models of Machining Accuracy in Multi-Tool Adjustments. International Journal of Automotive and Mechanical Engineering (IJAME). vol. 17, no. 3, pp. 8067-8085, Oct. 2020. Malaysia.

[16] Yusubov N.D., Abbasova H.M., Dadashov R.Y. Theoretical basis for the development of an algorithmic unified complex of mathematical models of cutting forces// Machine Science. - 2023.- No. 1 – p. 55-60.

[17] Yusubov N.D., H. Abbasova H.M., "Models of Cutting Forces in The Matrix Theory of Multitool Machining Accuracy", Key Engineering Materials, Vol. 979, pp. 27-38, 2024. DOI: 10.4028/p-bW48Sb

[18] Zhang, Xueping Zhang, Free-floating dynamic material removal mechanism of the honing process, https://www.researchgate.net/publication/371907490_Free-floating_dynamic_material_removal_mechanism_of_the_honing_process

[19] Babayev, S.G., Sadygov, P.G. Lapping and Finishing of Machine Part Surfaces. Moscow: Mashinostroyeniye, 2002. – 128 p.

[20] Gafarov, A.M. Advanced Methods of Mechanical Processing: [in 2 volumes]. Baku: Elm, Vol. 1, 2011. – 286 p.

[21] Huseynov, A.., & Huseynli, F. (2025). Enhancing processing capacity of precision parts via vacuum laser diffusion boron-chromizing. Tribologia - Finnish Journal of Tribology, 42(3–4), 31–39. https://doi.org/10.30678/fjt.162698

[22] Huseynov, A., Huseynli, F., & Safarov, M. (2025). Reliability Prediction of Precision Parts of Fuel Pumps with Enhanced Surface Hardness Achieved Through Laser Technology. Tribologia - Finnish Journal of Tribology, 42(1–2), 64-71. https://doi.org/10.30678/fjt.152491

[23] Balabanov I., Movlazade V., Yusubov N., Abbasova H., Dadashov R., Huseynov R. (2025). Development of a Parametric Model for Calculating Cutting Forces in External Cylindrical Turning of 20CRMN Steel (1.7147) Using an SNMG 15 06 16-pr 4425 Insert, Reliability: Theory and Applications, Vol. 20, Issue 7, pp. 335-342.

[24] Yusubov N., Abbasova H., Dadashov R. (2025) Matrix Model of Accuracy in Machining Conical Surfaces on CNC Lathes, Reliability Theory and Applications, Vol. 20, Iss. 7, pp. 393-400.

[25] Dubrovin V., Kulakov B., Karpinsky A., Ardashev D., Degtyareva-kashutina A., Dadashov R. (2025). Modeling and simulation of ductile-iron blank casting processes for an electrohydraulic power amplifier body. Reliability: theory & applications, Vol. 20, Issue 7, pp. 274-280.

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