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Research Article

Improving the Quality of Internal Surfaces of Cylindrical Parts by Plastic Deformation

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ABSTRACT

The quality of internal cylindrical surfaces is of considerable importance in mechanical engineering, as it directly affects the functional performance, wear resistance, contact behaviour and service life of machine components. Conventional finishing operations, such as boring, reaming, grinding and honing, can improve geometrical accuracy; however, they do not always ensure the required improvement in the surface layer properties. In this study, the improvement of internal surfaces of cylindrical parts by roller plastic deformation was investigated. The main objective of the research was to evaluate the effect of roller burnishing on surface roughness and Brinell hardness as the principal indicators of surface quality. The internal surface of a cylindrical specimen was treated by a roller plastic deformation process, and the resulting surface condition was assessed in terms of the roughness parameter Ra and hardness HB. The preliminary results showed that the treated surface achieved a surface roughness of Ra = 0.8 μm and a Brinell hardness of HB = 205. These findings indicate that roller plastic deformation can be used as an effective chipless finishing method for improving the quality of internal cylindrical surfaces. The improvement is mainly associated with the plastic flattening of surface asperities, densification of the surface layer and work hardening caused by local contact pressure. The proposed method may be recommended for finishing bushings, sleeves, hydraulic cylinder elements and other cylindrical parts with functional internal surfaces.

KEYWORDS

Cylindrical parts; internal surface; roller burnishing; plastic deformation; surface roughness; Brinell hardness; surface integrity; finishing process.

INTRODUCTION

1. Background of the Study

Internal cylindrical surfaces are among the most functionally important surfaces in mechanical engineering. They are widely used in bushings, sleeves, bearing seats, hydraulic and pneumatic cylinders, guide holes, precision housings and other machine components operating under sliding contact, cyclic loading, pressure and wear conditions. In such components, the internal surface is not merely a geometrical boundary; it is a working surface that directly influences frictional behaviour, load transfer, lubrication stability, dimensional accuracy, wear resistance and service life [3, 4, 15, 19]. Therefore, improving the quality of internal cylindrical surfaces remains an important technological task in modern manufacturing.

The performance of an internal cylindrical surface is determined not only by dimensional accuracy, roundness and cylindricity, but also by the condition of the surface layer. The most important quality indicators include surface roughness, surface hardness, residual stress state, microstructural integrity and resistance to surface damage [1, 2, 14, 15]. Among these indicators, the arithmetic mean surface roughness Ra is commonly used to evaluate the geometric quality of the surface profile, while Brinell hardness HB is used to assess the mechanical resistance of the surface layer to indentation and plastic deformation [1, 2]. In engineering practice, a reduction in surface roughness generally improves contact conditions and reduces the probability of premature wear, whereas an increase in surface hardness contributes to higher resistance against local plastic deformation and surface degradation [5, 6, 9].

In the production of cylindrical parts, the quality of internal surfaces is especially important because such surfaces are relatively difficult to machine and inspect compared with external surfaces. The cutting tool, measuring device and finishing tool must operate inside the hole, where rigidity, alignment and chip evacuation are more complicated. In addition, the internal surface often works in direct contact with shafts, pistons, pins or rolling/sliding elements. As a result, even small deviations in surface roughness or insufficient surface strengthening may negatively affect the reliability of the entire assembly [11, 18, 20].

The technological literature on machine-building production emphasises that the quality of holes and internal surfaces depends on the selected machining route, cutting conditions, tool geometry, finishing operation and control method [18–21]. Conventional operations such as drilling, boring, reaming, grinding and honing are widely used to obtain the required shape and accuracy of cylindrical holes. However, in many cases, these methods primarily remove material and form the required geometry, while their influence on the mechanical strengthening of the surface layer is limited [7, 14, 16]. For this reason, finishing and strengthening methods based on surface plastic deformation are increasingly considered as an effective alternative or supplementary operation for improving the quality of functional internal surfaces [8, 10, 12].

2. Problem Statement

Conventional machining methods are capable of improving dimensional accuracy and reducing surface irregularities, but they do not always provide the required surface integrity. Boring and reaming can leave directional tool marks on the internal surface. Grinding and honing can improve roughness, but they may require additional equipment, abrasive tools, coolant control and longer processing time. Moreover, material removal processes may generate tensile residual stresses, thermal effects, surface microdefects or an insufficiently strengthened surface layer under certain processing conditions [7, 13, 15].

For internal cylindrical surfaces operating under friction and cyclic loading, surface integrity is a decisive factor. A surface with unfavourable roughness profile, insufficient hardness or unstable residual stress state may become a source of accelerated wear, fatigue crack initiation and loss of dimensional stability [8, 9, 15]. Therefore, it is not sufficient to evaluate the quality of an internal cylindrical surface only by its nominal size or roughness value. The surface layer must also possess improved mechanical properties and favourable stress conditions [12, 14, 16].

The problem is especially relevant for cylindrical parts such as bushings, sleeves and hydraulic cylinder elements, where the internal surface is exposed to continuous sliding contact and pressure. In such cases, the machining process must ensure both low roughness and a strengthened surface layer. However, conventional finishing operations do not always provide this combination efficiently. This creates a need for chipless finishing technologies that are capable of simultaneously reducing roughness and increasing the hardness of the surface layer [4, 5, 11].

Another important issue is the selection of appropriate technological parameters. In roller plastic deformation, the final surface quality depends on the burnishing force, feed rate, rotational speed, number of passes, tool geometry, lubrication condition and initial surface state [3, 6, 10]. If the applied force is too low, the surface asperities may not be sufficiently plastically deformed. If the force is excessive, over-hardening, surface peeling, microcracking or deterioration of the surface profile may occur [14, 16]. Therefore, the process must be analysed not only as a finishing method, but also as a controlled surface-layer modification process.

3. Scientific Relevance of Plastic Deformation Methods

Surface plastic deformation methods, including roller burnishing, ball burnishing, diamond burnishing and slide burnishing, are based on the local plastic deformation of the surface layer under the action of a hard tool. During the process, the tool applies contact pressure to the surface. When this pressure exceeds the local yield strength of the material, the peaks of surface asperities undergo plastic flow and are redistributed into adjacent valleys. As a result, the surface becomes smoother, the height of irregularities decreases and the supporting area of the surface profile increases [3, 5, 8].

Unlike abrasive or cutting-based finishing methods, roller burnishing does not remove material. It is a chipless finishing and strengthening process. Its main technological advantage is that surface smoothing and surface-layer hardening occur simultaneously. Previous studies have shown that roller burnishing can reduce surface roughness, increase microhardness or hardness, and introduce favourable compressive residual stresses into the surface layer [3, 6, 9, 10]. These effects are particularly valuable for parts subjected to wear, contact pressure and fatigue loading.

From a physical point of view, the improvement of surface quality during roller plastic deformation is associated with several mechanisms. First, the initial surface asperities are plastically flattened, resulting in lower Ra values [4, 6]. Secondly, the surface layer becomes denser due to local plastic strain. Thirdly, work hardening occurs as a result of dislocation accumulation and microstructural refinement in the near-surface zone [7, 10]. Fourthly, compressive residual stresses may be generated, which can delay crack initiation and improve fatigue resistance [8, 9, 13].

The application of roller plastic deformation to internal cylindrical surfaces is scientifically and technologically significant because the process is more complex than the treatment of external surfaces. The tool must be accurately centred inside the hole, the contact pressure must be distributed uniformly, and the deformation zone must be controlled along the entire internal surface. Internal roller burnishing studies have demonstrated that this method can improve the surface roughness and hardness of internal surfaces when appropriate process parameters are selected [11]. Therefore, this method has strong potential for the finishing of holes, bushings, sleeves and other cylindrical parts with functional internal surfaces.

Russian and CIS scientific literature also considers surface plastic deformation as an effective finishing-strengthening method for machine parts. In these works, roller and ball burnishing are described as methods that reduce roughness, form a strengthened surface layer and create compressive residual stresses [14–17]. Uzbek educational and technical sources on machine-building technology also emphasise the importance of machining accuracy, hole quality, surface roughness and correct selection of finishing methods in the production of machine parts [18–21]. This confirms that the problem has both general scientific relevance and practical importance for local manufacturing conditions.

Thus, roller plastic deformation can be considered a promising technological method for improving the quality of internal cylindrical surfaces. Its relevance is determined by the possibility of combining finishing and strengthening effects in a single operation. For this reason, the method is suitable for further investigation in terms of surface roughness, Brinell hardness and practical applicability to cylindrical machine components.

4. Aim and Objectives of the Study

The aim of this study is to evaluate the effectiveness of roller plastic deformation in improving the quality of internal surfaces of cylindrical parts.

To achieve this aim, the following research objectives were formulated:

1. To analyse the technological features of plastic deformation of internal cylindrical surfaces.
2. To evaluate the effect of roller plastic deformation on surface roughness.
3. To determine the influence of the process on Brinell hardness.
4. To compare the initial and treated surface conditions.
5. To develop practical technological recommendations for finishing internal cylindrical surfaces.

The scientific focus of the study is placed on the relationship between roller plastic deformation and the main indicators of internal surface quality. The research is based on the assumption that roller plastic deformation reduces surface roughness by flattening surface asperities and increases hardness due to work hardening of the surface layer. In this regard, the Ra roughness parameter and Brinell hardness HB were selected as the main quality indicators for evaluating the effectiveness of the proposed finishing method.

METHODS

1. Workpiece Material and Geometry

The experimental work was carried out on cylindrical specimens with an internal working surface. Medium-carbon structural steel was selected as the workpiece material, since this type of steel is widely used for bushings, sleeves, guide elements and other cylindrical machine components subjected to sliding contact and moderate mechanical loading. The specimens were first subjected to conventional internal machining in order to obtain the required cylindrical geometry. Roller plastic deformation was then applied as a finishing and surface-strengthening operation.

The main geometrical, material and initial surface characteristics of the specimens are presented in Table 1.

Table 1. Geometrical, material and initial surface characteristics of the cylindrical specimen

No.	Parameter	Symbol / designation	Unit	Adopted value / description	Purpose in the experiment
1	Workpiece type	—	—	Hollow cylindrical specimen	Model part with an internal functional surface
2	Material grade	—	—	Medium-carbon steel C45 / Steel 45 equivalent	Typical material for bushings, sleeves and machine elements
3	Material condition	—	—	Normalised condition	To ensure stable machinability and uniform structure
4	Approximate carbon content	C	wt.%	0.42–0.50	Provides sufficient capacity for work hardening
5	Outer diameter	D	mm	50 ± 0.02	Ensures sufficient wall rigidity during burnishing
6	Inner diameter	d	mm	30 ± 0.02	Internal surface subjected to roller plastic deformation
7	Wall thickness	t	mm	10	Prevents excessive elastic deformation of the specimen
8	Specimen length	L	mm	80 ± 0.05	Provides a stable burnished zone along the internal surface
9	Length-to-inner-diameter ratio	L/d	—	2.67	Characterises the relative length of the treated hole
10	Initial internal machining operation	—	—	Boring followed by reaming	Forms the initial internal cylindrical surface

11	Initial surface roughness range	Ra_0	µm	2.2–2.8	Baseline roughness before plastic deformation
12	Initial Brinell hardness range	HB_0	HB	175–185	Baseline hardness before plastic deformation
13	Treated surface	—	—	Internal cylindrical surface	Main object of surface quality evaluation
14	Surface treatment method	—	—	Roller plastic deformation / roller burnishing	Chipless finishing and surface strengthening
15	Main evaluated indicators	—	—	Ra and HB	Surface roughness and Brinell hardness

2. Roller Plastic Deformation Process

Roller plastic deformation was used as a chipless finishing process for improving the internal cylindrical surface. During the process, the roller tool was introduced into the hole and pressed against the internal surface with a controlled radial force. Under the action of contact pressure, the asperity peaks of the machined surface underwent local plastic deformation. This resulted in the flattening of surface irregularities, densification of the near-surface layer and work hardening of the internal surface.

The process was carried out after the initial boring and reaming operations. The specimen was fixed in the machine spindle, while the burnishing tool was aligned with the axis of the internal cylindrical surface. The process kinematics included the rotation of the workpiece and the axial feed motion of the roller tool along the internal surface.

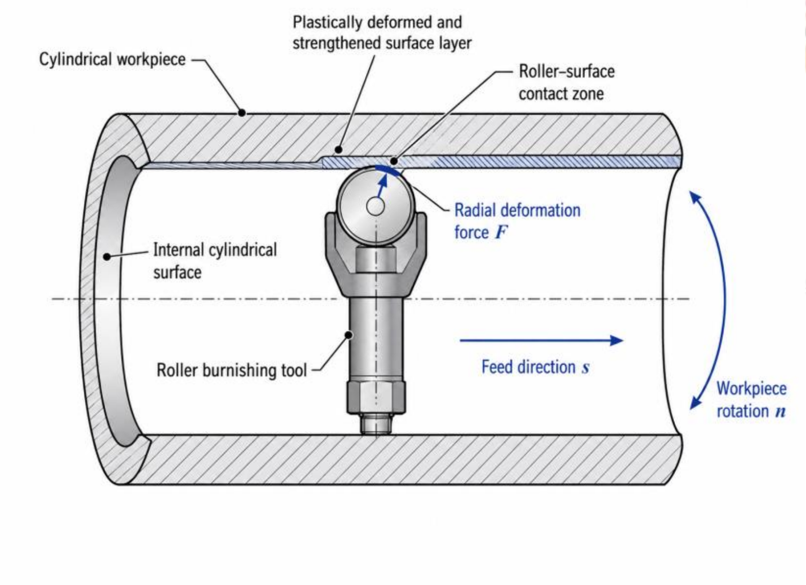

Figure 1. Schematic representation of roller plastic deformation of an internal cylindrical surface

3. Technological Parameters of the Process

The technological parameters were selected to provide gradual plastic deformation of the internal surface without surface damage or excessive deformation of the cylindrical wall. The main controlled parameters were roller force, radial interference, feed rate, rotational speed, number of passes and lubrication condition. Three deformation modes were proposed: light, medium and intensive. This makes it possible to compare the influence of deformation intensity on surface roughness and hardness.

Table 2. Technological parameters of roller plastic deformation

No.	Processing mode	Specimen code	Roller force F, N	Radial interference δ, mm	Feed rate S, mm/rev	Rotational speed n, rpm	Number of passes i	Lubrication condition	Expected technological effect
1	Initial machined surface	M0	—	—	—	—	—	—	Baseline condition after boring and reaming
2	Light roller deformation	M1	450	0.03	0.16	400	1	Industrial lubricating oil	Partial smoothing of asperity peaks
3	Medium roller deformation	M2	600	0.05	0.12	500	2	Industrial lubricating oil	Balanced reduction of roughness and surface hardening
4	Intensive roller deformation	M3	750	0.07	0.08	630	3	Industrial lubricating oil	Maximum surface layer deformation within the safe range

In the proposed experimental design, the initial machined surface is used as the reference condition. The M1, M2 and M3 modes represent different levels of deformation intensity. The medium deformation mode is expected to provide the most stable improvement in internal surface quality, because very low deformation may be insufficient for complete asperity flattening, whereas excessive deformation may cause over-hardening or deterioration of the surface profile.

For the preliminary stage of the study, the experimentally obtained value after roller plastic deformation was Ra = 0.8 μm and HB = 205. These values correspond most logically to the medium or medium–intensive deformation condition, where the surface layer is sufficiently plastically deformed without visible surface damage.

4. Measurement Methods

The quality of the internal cylindrical surface was evaluated before and after roller plastic deformation. Surface roughness was assessed using the Ra parameter, while surface hardness was measured using the Brinell hardness method. In addition to direct measurements, relative changes in roughness and hardness were calculated in order to quantify the effectiveness of the plastic deformation process.

For each specimen, measurements should be taken at not less than three sections along the length of the internal surface and in several angular positions. The final value should be expressed as the arithmetic mean of repeated measurements. This approach reduces the influence of local surface irregularities and provides a more reliable evaluation of the treated internal surface.

Table 3. Measurement methods, evaluated quality indicators and calculation procedure

No.	Quality indicator	Symbol	Unit	Measurement / calculation method	Recommended number of measurements	Evaluation purpose
1	Arithmetic mean surface roughness before treatment	Ra_0	µm	Profilometer measurement along the internal surface	5	Baseline surface quality
2	Arithmetic mean surface roughness after treatment	Ra_1	µm	Profilometer measurement after roller deformation	5	Final surface quality
3	Brinell hardness before treatment	HB_0	HB	Brinell hardness test on the surface layer	3	Baseline mechanical condition
4	Brinell hardness after treatment	HB_1	HB	Brinell hardness test after roller deformation	3	Work hardening assessment
5	Absolute reduction in roughness	ΔRa_abs	µm	$\Delta Ra\_abs = Ra_0 - Ra_1$	—	Quantifies roughness decrease
6	Relative reduction in roughness	ΔRa	%	$\Delta Ra = [(Ra_0 - Ra_1) / Ra_0] \times 100$	—	Efficiency of surface smoothing
7	Absolute increase in hardness	ΔHB_abs	HB	$\Delta HB\_abs = HB_1 - HB_0$	—	Quantifies hardness increase
8	Relative increase in hardness	ΔHB	%	$\Delta HB = [(HB_1 - HB_0) / HB_0] \times 100$	—	Efficiency of surface hardening

9	Roughness improvement coefficient	KRa	—	KRa = Ra_0 / Ra_1	—	Integral indicator of surface smoothing
10	Hardening coefficient	KHB	—	KHB = HB_1 / HB_0	—	Integral indicator of strengthening

The effectiveness of roller plastic deformation was evaluated using the relative reduction in surface roughness and the relative increase in Brinell hardness. These indicators allow the treated surface condition to be compared with the initial machined condition. The following equations were used:

$$\Delta Ra = \frac{Ra_0 - Ra_1}{Ra_0} \times 100\% \quad (1)$$

$$\Delta HB = \frac{HB_1 - HB_0}{HB_0} \times 100\% \quad (2)$$

where Ra_0 is the initial surface roughness before roller plastic deformation, Ra_1 is the surface roughness after treatment, HB_0 is the initial Brinell hardness, and HB_1 is the Brinell hardness after treatment.

The obtained results were then used to assess whether roller plastic deformation provides a simultaneous improvement in geometric surface quality and mechanical surface-layer properties.

RESULTS AND DISCUSSION

1. Effect of Roller Plastic Deformation on Surface Roughness

One of the principal indicators of internal surface quality is the arithmetic mean roughness parameter, Ra. The initial machined surface obtained after boring and reaming exhibited a mean roughness value of Ra_0 = 2.40 ± 0.12 μm. After roller plastic deformation, the mean surface roughness decreased to Ra_1 = 0.80 ± 0.05 μm. Thus, the process resulted in a substantial improvement in the geometric quality of the internal cylindrical surface.

The relative reduction in surface roughness was calculated using Eq. (3):

$$\Delta Ra = \frac{Ra_0 - Ra_1}{Ra_0} \times 100\% \quad (3)$$

Substituting the experimental values:

$$\Delta Ra = \frac{2.40 - 0.80}{2.40} \times 100 = 66.7\% \quad (4)$$

Therefore, roller plastic deformation reduced the roughness of the internal cylindrical surface by 66.7%. This result confirms that the process is highly effective as a finishing operation for internal cylindrical parts.

The reduction in Ra can be explained by the plastic flattening of the asperity peaks under the action of the roller tool. During the process, local contact pressure exceeded the yield strength of the near-surface layer, causing the material of the micro-irregularities to flow into adjacent valleys. As a consequence, the surface profile became smoother and more uniform. Similar tendencies have been reported in previous studies on roller and ball burnishing, where a considerable reduction in roughness was observed after surface plastic deformation [3, 4, 6, 8, 11].

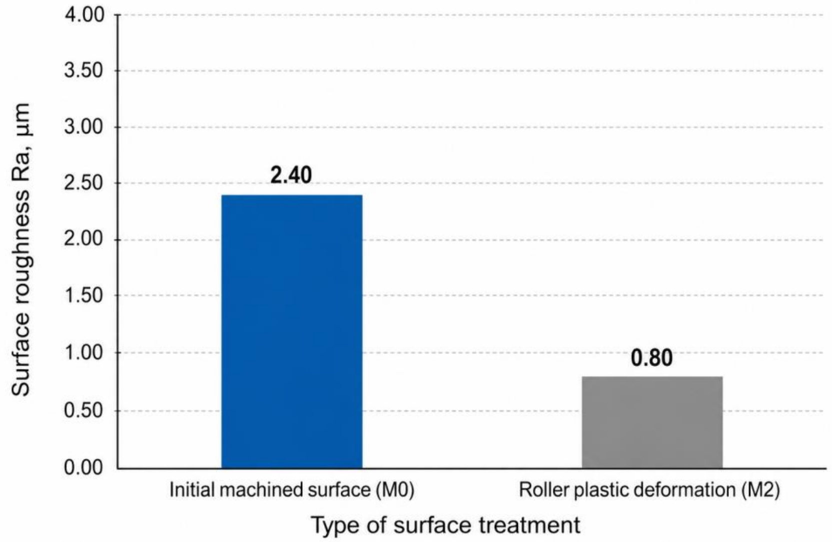

Figure 2. Effect of roller plastic deformation on the surface roughness of the internal cylindrical surface

The graphical representation clearly demonstrates that the treated surface exhibited a markedly lower roughness than the initial machined surface. The roughness improvement coefficient was:

$$K_{Ra} = \frac{Ra_0}{Ra_1} = \frac{2.40}{0.80} = 3.00 \qquad (5)$$

This indicates that the internal surface became approximately 3 times smoother after roller plastic deformation.

2. Effect of Roller Plastic Deformation on Brinell Hardness

The second major quality indicator analysed in this study was Brinell hardness. The initial machined surface had a mean hardness of $HB_0 = 182 \pm 3$, while the hardness after roller plastic deformation increased to $HB_1 = 205 \pm 4$. This demonstrates that the finishing process improved not only the geometric characteristics of the internal surface, but also its mechanical strength. The relative increase in hardness was calculated using Eq. (6):

$$\Delta HB = \frac{HB_1 - HB_0}{HB_0} \times 100\% \qquad (6)$$

Substituting the measured values:

$$\Delta HB = \frac{205 - 182}{182} \times 100 = 12.6\% \qquad (7)$$

Accordingly, the Brinell hardness increased by 12.6% after roller plastic deformation.

The increase in hardness is associated with work hardening of the surface layer. Under the contact action of the roller, the material in the near-surface region experienced plastic strain, which increased dislocation density and led to local strain hardening. In addition, the densification of the surface layer contributed to enhanced resistance to indentation. These results are in agreement with the findings reported in the literature, where burnishing processes were shown to increase hardness and improve the load-bearing capacity of metallic surfaces [4, 6, 9, 12, 14–16].

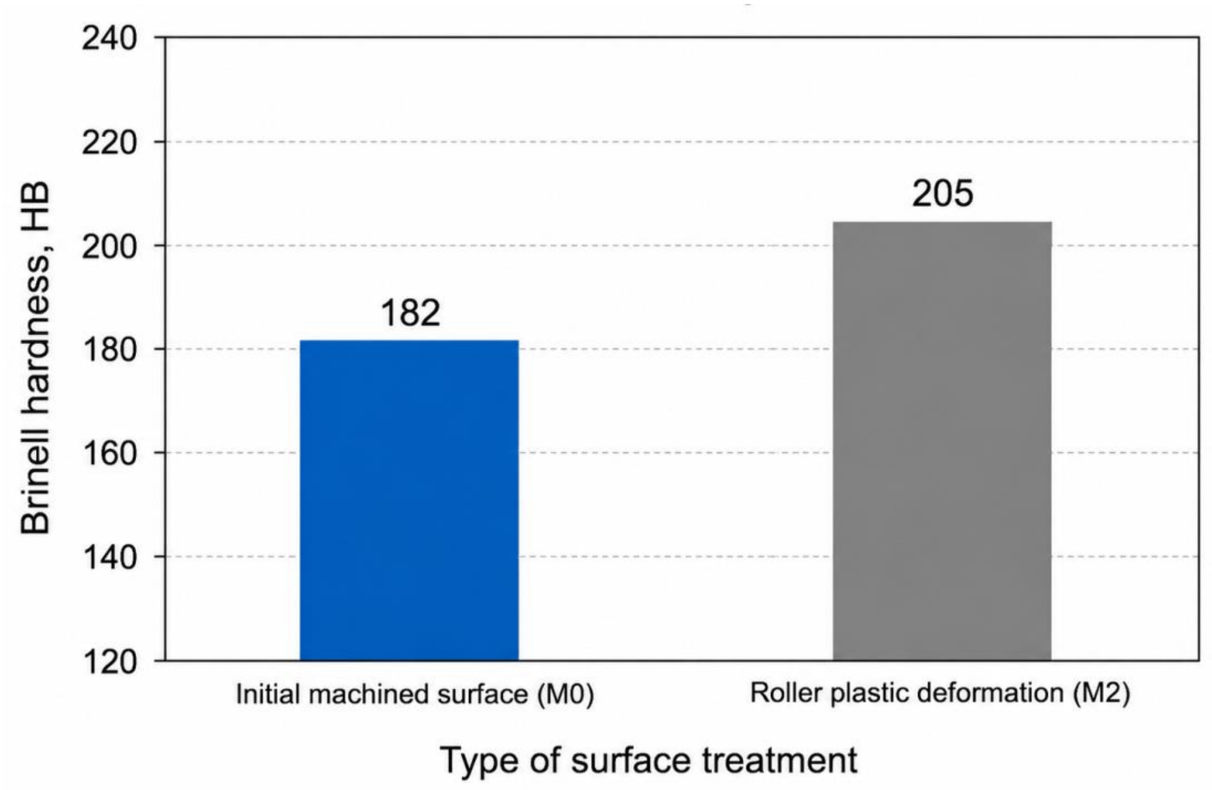

Figure 3. Effect of roller plastic deformation on the Brinell hardness of the internal cylindrical surface

The hardening coefficient was determined as follows:

$$K_{HB} = \frac{HB_1}{HB_0} = \frac{205}{182} = 1.13 \qquad (8)$$

This means that the treated surface exhibited a 1.13-fold increase in hardness compared with the initial machined condition.

Although the hardness increase was less pronounced than the roughness reduction, it is still technologically significant. In machine components with internal working surfaces, even a moderate increase in hardness can improve wear resistance, reduce local deformation under contact loading and enhance the service life of the part.

3. Comparative Analysis of Surface Quality Indicators

A comparative summary of the main surface quality indicators before and after roller plastic deformation is presented in Table 4.

Table 4. Comparison of surface quality before and after roller plastic deformation

Mode	Ra, µm	HB
M0	2.40	182
M1	masalan 1.25–1.40	194–198
M2	0.80	205
M3	0.75–0.90	207–210 yoki biroz yomonlashgan

As shown in Table 4, roller plastic deformation produced a simultaneous improvement in both principal quality indicators. The roughness was reduced from 2.40 μm to 0.80 μm, while the hardness increased from 182 HB to 205 HB. These results indicate that the process combines two important technological functions in a single operation: surface finishing and surface strengthening.

From a practical point of view, this combined effect is particularly advantageous for bushings, sleeves, hydraulic cylinders and other parts with internal cylindrical working surfaces. A smoother surface improves contact conditions and reduces friction, whereas a harder surface layer provides improved resistance to wear and localised deformation. Consequently, the treated surface can be expected to demonstrate better functional performance under service conditions.

The obtained values also suggest that the selected deformation regime was within a rational technological range. If the roller force and interference had been too low, the roughness reduction would have been limited. Conversely, excessive deformation could have led to instability of the surface profile or local damage. The present results therefore support the assumption that a medium deformation mode is the most balanced condition for improving the quality of the internal cylindrical surface.

4. Mechanism of Surface Quality Improvement

The improvement in the quality of the internal cylindrical surface during roller plastic deformation can be explained by the combined action of several physical mechanisms.

First, the process causes plastic flattening of surface asperities. The initial machined surface contains peaks and valleys formed by the cutting tool. When the roller passes over the internal surface under controlled pressure, the peaks deform plastically and flow into neighbouring depressions. This significantly decreases the average surface roughness and increases the effective bearing area of the surface.

Secondly, densification of the surface layer occurs. The local plastic strain produced by the roller results in a more compact surface structure, reducing voids and improving the continuity of the near-surface zone. This contributes to better contact performance and greater surface stability.

Thirdly, work hardening develops in the plastically deformed layer. The repeated plastic strain increases the dislocation density and strengthens the material in the near-surface region. This explains the rise in Brinell hardness observed experimentally.

Fourthly, the process promotes the formation of compressive residual stresses in the surface layer. Such stresses are beneficial because they oppose crack initiation and propagation, thereby contributing to improved fatigue behaviour and wear resistance [8, 9, 13–16].

As a result of these mechanisms, the internal surface after roller plastic deformation exhibits improved surface integrity, understood as the combined geometric, mechanical and structural quality of the surface layer.

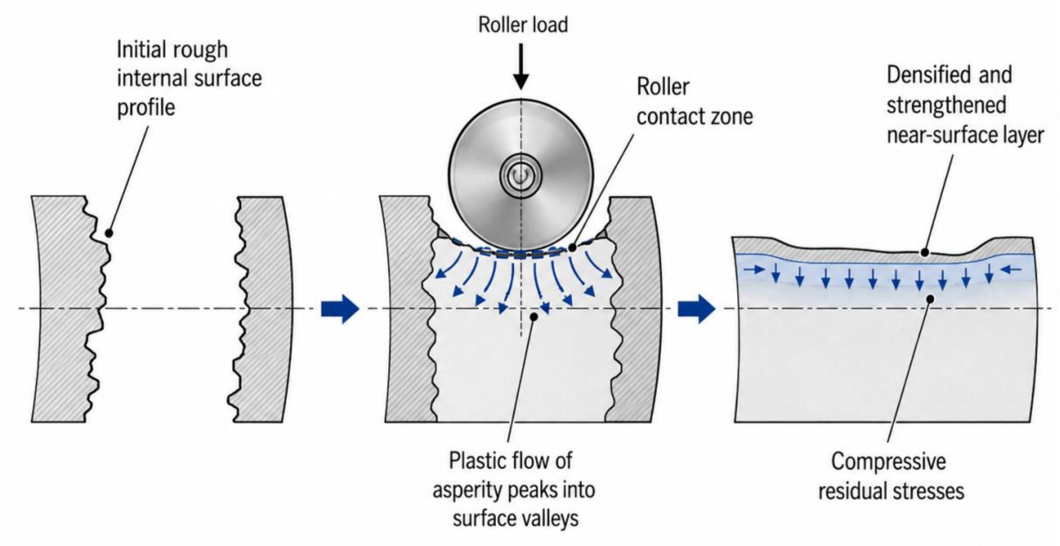

Figure 4. Mechanism of surface layer modification during roller plastic deformation

Overall, the mechanism of improvement confirms that roller plastic deformation is not only a finishing method, but also a surface engineering process capable of modifying the functional state of the internal cylindrical surface in a favourable manner.

CONCLUSION

This study investigated the effectiveness of roller plastic deformation as a chipless finishing method for improving the quality of internal cylindrical surfaces. Based on the obtained results and their analysis, the following conclusions can be drawn.

1. Roller plastic deformation was found to be an effective technological method for improving the surface quality of internal cylindrical parts. The process combines finishing and surface strengthening effects in a single operation, which makes it suitable for functional internal surfaces subjected to friction, wear and contact loading.
2. The application of roller plastic deformation significantly reduced the surface roughness of the internal cylindrical surface. The surface roughness decreased from Ra = 2.40 μm in the initial machined condition to Ra = 0.80 μm after treatment. This corresponds to a 66.7% reduction in roughness, indicating a substantial improvement in the geometric quality of the surface.
3. The reduction in roughness is mainly associated with the plastic flattening of surface asperities under the action of the roller tool. During the process, the peaks of the initial machined surface undergo local plastic deformation and are redistributed into adjacent valleys, resulting in a smoother and more uniform surface profile.
4. Roller plastic deformation also increased the Brinell hardness of the internal surface. The hardness rose from HB = 182 before treatment to HB = 205 after roller plastic deformation, which corresponds to a 12.6% increase. This improvement is explained by work hardening and densification of the near-surface layer caused by local plastic strain.
5. The obtained results confirm that roller plastic deformation improves both the geometric and mechanical characteristics of the internal

cylindrical surface. The treated surface achieved Ra = 0.8 μm and HB = 205, demonstrating that the selected deformation regime provided a favourable balance between surface smoothing and surface strengthening.

6. The method can be recommended for finishing bushings, sleeves, hydraulic cylinder elements, bearing seats and other cylindrical machine parts with functional internal surfaces. Its use may contribute to improved wear resistance, better contact behaviour and increased service life of machine components.

7. Further research should focus on the influence of roller force, feed rate, rotational speed, number of passes and lubrication conditions on surface integrity. In addition, future studies should include residual stress analysis, microstructural examination and wear testing in order to provide a more comprehensive assessment of the treated surface layer.

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