



International Journal of Engineering, Science and Humanities

An international peer reviewed, refereed, open-access journal
Impact Factor 8.3 www.ijesh.com ISSN: 2250-3552

Ballizing Process Parameters and Their Influence on Rotating Machined Components: A Comprehensive Review

Varun Kumar Gupta

Research Scholar, Department of Mechanical Engineering, Shri Siddhi Vinayak Institute of
Technology, Bareilly-243001 (U.P.)

Mr. Amit Sharma

Assistant Professor, Department of Mechanical Engineering, Shri Siddhi Vinayak Institute of
Technology, Bareilly-243001 (U.P.)

Dr. Sudhakar Jain

Associate Professor
Shri Siddhi Vinayak Institute of Technology, Bareilly

Abstract

The ballizing process is a mechanical surface enhancement technique widely used to improve the surface integrity and functional performance of machined components through controlled plastic deformation. This review presents a comprehensive analysis of ballizing process parameters and their influence on rotating machined components, which are commonly employed in automotive, aerospace, and precision engineering applications. Key process parameters such as ballizing force, feed rate, ball diameter, lubrication conditions, number of passes, and workpiece material properties are critically examined to understand their effects on surface roughness, residual stress distribution, surface hardness, dimensional accuracy, and dynamic behavior. The review highlights that optimized ballizing conditions lead to significant improvements in surface finish, induction of beneficial compressive residual stresses, enhanced fatigue life, and improved wear resistance of rotating components. Conversely, improper parameter selection may result in over-deformation, surface damage, and reduced component reliability. Recent advancements in experimental techniques, numerical modeling, and hybrid ballizing approaches are also discussed to illustrate the evolving scope of this process in modern manufacturing. By synthesizing findings from existing literature, this review identifies key research trends, limitations, and future directions, providing valuable insights for process optimization and industrial implementation of ballizing in high-performance rotating machined components.

Keywords: Ballizing process; Rotating machined components; Surface integrity; Process parameters



International Journal of Engineering, Science and Humanities

An international peer reviewed, refereed, open-access journal
Impact Factor 8.3 www.ijesh.com **ISSN: 2250-3552**

Introduction

The ballizing process is a mechanical surface enhancement technique widely employed in precision manufacturing to improve the surface integrity and functional performance of machined components. It involves the controlled plastic deformation of a pre-machined surface using a hardened ball that is forced against the workpiece under a predetermined load. This process is particularly effective in reducing surface roughness, inducing beneficial compressive residual stresses, and enhancing surface hardness without material removal. In recent years, ballizing has gained increased attention due to its simplicity, cost-effectiveness, and ability to significantly improve fatigue life and wear resistance of components. Rotating machined components such as shafts, spindles, axles, and bearing elements are especially critical in engineering applications, as they are continuously subjected to cyclic loading, frictional forces, and dynamic stresses. Any surface imperfections or residual tensile stresses in such components can lead to premature failure, vibration issues, and reduced service life. Consequently, surface finishing processes like ballizing play a vital role in ensuring reliability and performance in sectors such as automotive, aerospace, power transmission, and machine tools.

However, such a high dependence on process parameters as the force of ballizing, feed rate, tool geometry, conditions of lubrication, the properties of the workpiece material, and rotational properties of the component will significantly determine how well the ballizing process is carried out. These parameter variations can have significant impact on the surface roughness, microstructure of the subsurface, distribution of residual stresses, and dynamic response of rotating components. Even though several experimental and analytical investigations were conducted on individual components of ballizing, the results reported may be inconsistent because of the variation in the materials, tooling setups, and experimental requirements. Additionally, the increased focus on rapid machining and lightweight rotating systems has brought in newer issues to deal with the behavior of vibration, dimensional stability, and surface durability. It is thus important to have a concerted synthesis of existing research in order to have a systematic understanding of the impact of the ballizing parameters on the surface integrity and functional behavior of rotating machined components. The purpose of this review is critically evaluate and summarize the currently available data on ballizing process parameters, establish the key trends and research gaps, and offer a high-quality reference base to the researcher and practice professionals in need of streamlining the process of ballizing operations in developing high-tech manufacturing settings solely to rotate the component.

Background and Motivation

High performance rotating machined components have in modern manufacturing industries become a more sought-after requirement owing to their wide use in the automotive, aerospace, power generation and precision engineering industry. Shafts, spindles, crankshafts, and bearing



International Journal of Engineering, Science and Humanities

An international peer reviewed, refereed, open-access journal
Impact Factor 8.3 www.ijesh.com **ISSN: 2250-3552**

components are subjected to cyclic loads, friction, thermal effects and dynamic stresses and they work in continuous rotational movement. These components are of critical interest in terms of the functional performance, fatigue life, wear resistance and vibration behavior that depends on the surface condition of these components. The traditional machining processes usually leave surface flaws, tensile residual stress and microstructure flaws that may serve as stress concentration positions and cause premature failure. Consequently, surface improvement procedures that have been implemented after machining are necessary in order to address high level of quality and reliability. Blasting has taken one among these methods to be effective and cost-effective in enhancing the integrity of surfaces without any change in geometry or material removal.

The interest to pay attention to the ballizing process is based on the high reliance on the process parameters and its dominant impact on the working of rotating elements. The degree of plastic deformation, and surface characteristics are dependent on parameters like applied force, feed rate, ball diameter, lubrication conditions and properties of the workpiece material. Poor choice of these parameters can cause excessive deformation, surface damage or poor stress distributions whereas optimized conditions can result in much smoother surfaces, compressive residual loading, and greater dynamic stability. Although the topics of ballizing have increasingly been studied, the current research is usually disjointed, and there is no general agreement on the best parameter values in the various rotating applications. Moreover, the growing popularity of the use of high speed rotating systems and lightweight materials has exacerbated the necessity of a better insight into the way the parameters of ballizing influence vibration response and long-term durability. Thus, the overall analysis of the ballizing process characteristics and their effects on rotating machined parts is inspired by the necessity to fill the gaps in the knowledge and to help to optimize the process and direct the future research to the more efficient and reliable manufacturing solutions.

Literature Review

This piece of work brought out the impact of tool geometry and rotating movement on material flow behavior. Later studies by Hewidy (2000) though on the subject of electrochemical machining however, offered valuable perspective on the controlling of surface and thickness and later, hybrid and post machining finishing methods including ballizing. All these preliminary studies helped to define that plastic deformation-based finishing methods could refine surface characteristics without its removal, and that it is applicable in thin-walled and precision parts. Although Aparicio et al. (2003) act in the biomedical setting, additional information about the surface treatment parameters and their effect on surface integrity and corrosion behavior was provided, which confirms the wider applicability of the controlled surface deformation processes in the functional performance enhancement.



International Journal of Engineering, Science and Humanities

An international peer reviewed, refereed, open-access journal
Impact Factor 8.3 www.ijesh.com **ISSN: 2250-3552**

The focus of research later changed to evaluate the impact of ballizing on geometrical accuracy and surface integrity of tubular elements. Dyl (2013) examined how the geometric structure of steel tubes can be positively influenced by the ballizing process and found that the roundness and surface finish of tubes as well as dimensional variations could be significantly decreased. On the same note Edriys and Fattouh (2013) contended the properties of finished holes that are generated by ballizing and established that the best process parameters lead to reduced roughness of the surface and creation of positive compressive residual stresses. These investigations validated ballizing as a replacement of traditional finishing methods like honing and grinding, especially internal cylindrical surfaces. This insight was further promoted by the work Alshareef (2020) did to model the consideration of ball-burnishing factors influencing stress residues in AISI 8620 steel and proved the decisive role of such parameters as force and feed rate in the determination of the depths and magnitudes of stress. These studies collectively identified a good association between ballizing parameters and the enhancement of surface integrity, fatigue resistance, and dimensional stability.

The more recent studies have extended the use of ballizing to finishing to the form making and hybrid manufacturing processes. Abd-Eltwab et al. (2019) investigated a multi-spinning method via telescopic mandrel, emphasizing the ability of the techniques of controlled deformation to be incorporated into the forming operations. Subsequently, their research (2022) was directly devoted to tube-end forming based on the ballizing process, and it includes the experimental results that ballizing can be used to meet both the goal of forming and the surface finishing. Abd-Eltwab et al. (2024) supported these results because they examined the process of producing tubes with a double wall through a squeeze ballizing method. Their construction showed an improved bonding quality, better surface finish, and the best performance of the mechanical performance of the double-walled structures. On the same note, Abo Hussain and Elsheikh (2024) reviewed tube-end forming by ballizing and its ability to produce uniform deformation with minimum defects. All these studies point to the fact that ballizing is no longer a secondary operation in finishing, but a multipurpose process that can both shape, strengthen and finish an item in one process.

Simultaneously, scientists have studied ballizing and analogue burnishing on the background of high-tech materials and hybrid production. Ali et al. (2023) examined severe plastic deformation of AL/CU bimetallic tube cladding and emphasized the importance of the processes of deformation-based improvement of interfacial bonding and mechanical performance. Their results do not specifically investigate the relevance of the multi-material system to the controlled plastic deformation, but their findings suggest the relevance of the latter. Davoodi et al. (2023) gave a general overview of internal surface finishing methods on additively manufactured metallic components and found that ballizing and burnishing are promising options to



International Journal of Engineering, Science and Humanities

An international peer reviewed, refereed, open-access journal
Impact Factor 8.3 www.ijesh.com **ISSN: 2250-3552**

overcoming the poor surface quality of additive manufacturing. The article by Varpe et al. (2021) summarized the impact of burnishing on friction stir welded components and indicated that the intervention yielded consistent improvements in the surface integrity, residual stress state, and fatigue life, which are also similar to the ballizing results. All these studies indicate that ballizing is becoming more applicable in contemporary manufacturing scenarios of high performance components, advanced materials, and hybrid processes.

Other recent developments are focused on numerical modeling, accuracy of measurement, and process integration. Daemi et al. (2020) provided high-precision techniques to measure hardness, thus making the available techniques more accurate to measure the surface and subsurface alterations due to processes like ballizing. El-Abden and Abdel-Rahman (2023) paid attention to the finishing of non-ferrous internal surfaces by ballizing confirming the usefulness of this method in a broader material range. Rotary ballizing and double-walled tube structures are discussed in the emerging literature, including works by Elmetwally et al. (2025) and Dardaei Joghann et al. (2025) through numerical and experimental methods, highlighting the maturity of the development of the field of ballizing. Even though several of the referenced materials are concerned with wider manufacturing or even aren't in the field of science, the overall literature indicates a consistent trend toward more mechanistic insight, increased applications and greater control over the ballizing processes. All in all, the relevance of the ballizing parameters in the determination of the surface integrity, geometric accuracy, and functional performance is highly supported by existing studies, which also demonstrate the necessity of additional systematic reviews and comparative studies specifically in the field of rotating machined components.

Definition of Ballizing

Ballizing is a manufacturing surface finishing and improvement procedure that is used in manufacturing to enhance the surface integrity of machined parts by controlled plastic deformation. In this procedure, a hard and well polished ball, usually of carbide or bearing steel, is forced against the surface of a previously machined workpiece under a given load and transferred along the surface in a controlled manner. Ballingizing, unlike normal finishing processes like grinding or honing, leaves no material behind, rather than leaving the surface having its asperities filled out, ballizing plastically deforms them flattening the peaks and filling the dales in the surface. This provides a finish surface that is smoother and has better dimensional accuracy without altering the original geometry of the component.

Ballizing has the main goal of improving surface characteristics i.e. surface roughness, surface hardness, and distribution of surface residual stress. The rolling action of the ball causes localized deformation of the plastic that creates positive compressive residual stress in the surface and subsurface layers which is very helpful in enhancing fatigue strength, wear resistance, and crack initiation resistance. Ballizing has been found to be quite effective on



International Journal of Engineering, Science and Humanities

An international peer reviewed, refereed, open-access journal
Impact Factor 8.3 www.ijesh.com **ISSN: 2250-3552**

internal and external cylindrical surfaces, so it is quite applicable to rotating machined items like shafts, bores, spindles as well as bearing seats. Its simplicity, low cost of tools and compatibility with the conventional machine tools has made ballizing popular in the automotive, aerospace and precision engineering sectors. The process parameters that affect its performance highly include the applied force, the feed rate, the ball size, the lubrication and the workpiece material, and thus it requires keen control in order to achieve the best performance.

Fundamentals of Ballizing in Machining

The principle of the controlled plastic deformation of a machined surface by compressive contact stresses is the basis of ballizing. The workpiece surface is compressed in this process by a hardened spherical ball against surface with a set force and travels either in a linear or rotary direction on the surface. At a force that is higher than the yield strength of the material used as the workpiece, plastic deformation at local levels, both on the surface and the sub-surface, takes place. Asperity peaks formed by previous machining processes are plastically smoothed out, and the material set in neighboring lows, which lead to the creation of a smoother and more uniform surface profile. Ballingizing, unlike abrasive finishing processes, does not entail cutting or removal of material and hence enables the process to maintain dimensional accuracy as well as enhance the surface quality. Hertzian contact mechanics dictate the extent and distribution of deformation with the ball diameter, the force that is applied, and the elastic characteristics of the ball and the work piece controlling the extent of the contact zone and the stress field formed in the process.

Regarding machining, it may be ballized as a secondary or post-machining process using standard machine tools including lathes, milling machines or ballizing specific attachments. The process being done on internal and external cylindrical surfaces, flat surfaces as well as complex geometries, so it is extremely diverse in the field of industrial applications. The important operational variables are ballizing force, feed rate, speed, passes made and lubrication conditions. The lubrication is also essential as it lessens the friction between the ball and the work piece, limits heat production and eliminates surface damage by means of scoring or galling. The material of tools and their hardness are also crucial factors to consider; the ball has to be much harder than the piece of work in order to be able to cause plastic deformation without damaging the tool. In rotating machined parts, the rotational speed needs to be synchronized with the feed rate so that there is uniform treatment of the surface and to prevent uneven deformation or waviness at the surface.

The basic advantages of ballizing are based on the possibility to alter not only the topography features but also the material characteristics of the subsurface. Plastic deformation induced in the process of ballizing creates compressive residual stresses under the surface that are known to slow the crack initiation and propagation through cyclic loading conditions. Ballingzing is



International Journal of Engineering, Science and Humanities

An international peer reviewed, refereed, open-access journal
Impact Factor 8.3 www.ijesh.com **ISSN: 2250-3552**

particularly beneficial in rotating parts that are prone to fatigue and dynamic stress. Also the work hardening effect generated during deformation enhances the surface hardness and wear resistance and fretting. Microstructural perfection close to the surface layer can also arise based on the nature of the material and the intensity of the process and can further increase the mechanical performance. Nevertheless, too much ballizing force or an incorrect choice of parameters may result in over-deformation or the surface cracking or dimensional distortion. Thus, to optimize the process and have a high degree of reliability in machined rotating components functioning under high levels of demand, the basic mechanics and interactions that are involved in the ballizing process must be fully understood.

Process Parameters in Ballizing

The success of the ballizing process is greatly determined by the selection and control of ballizing process parameters since these parameters are directly related to the level of plastic deformation, surface integrity, and performance of machined components. Blasting force is the most vital of all the parameters. It decides the contact pressure between the ball and the work piece surface. In the case where the force applied is stronger than the yield strength of the material, plastic deformation takes place resulting in a decrease in the roughness of the surface and the development of compressive residual stresses. Lack of force causes the lack of deformation and consequent little surface restoration, but excessive force can lead to over-deformation, surface damage, dimensional error, or subsurface cracking. So a good choice of force level depending on both work part material properties and component geometry is necessary.

The other crucial parameter is the feed rate and determines the spacing among the consecutive contact tracks of the ball on the surface. A slower feed rate tends to give higher surface finish because there is more overlap between ball tracks leading to more uniform deformation. But, too low feed rates can raise the processing time and cost. On the contrary, it may cause uneven surface treatment in case of higher feed rates and rougher residual. Feed rate is closely the same with the ballizing speed, especially where rotating machined parts are involved. Adequate synchronization of rotational speed and feed gives a regular surface coverage and eliminates surface waviness or non-uniform deformation. Also, passes contribute to the improvement of surface qualities; further repetitions can in turn lower roughness and augment compressive stresses, yet numerous repetitions can lead to strain hardening or distortion.

The diameter of the ball and the material of the tools used also have a great influence on the ballizing result. Bigger balls result in greater contact zone and deeper penetration of stress that may be advantageous in fatigue resistance, and smaller balls are better in finer surface finishes on precision components. The material used as a ball has to be much harder than the workpiece to avoid wearing of the tools and to provide good deformation. Conditions of lubrication are also



International Journal of Engineering, Science and Humanities

An international peer reviewed, refereed, open-access journal
Impact Factor 8.3 www.ijesh.com **ISSN: 2250-3552**

important because adequate lubrication decreases friction, heat, and danger of surface deformity like galling or scoring. The response to ballizing is heavily dependent on the working-material property of the workpiece such as hardness, ductility and microstructure. The softer and more ductile materials tend to develop more surface improvement whereas harder materials demand more forces and tighter control of the parameters.

Effects of Ballizing Parameters on Surface Integrity

The effects of ballizing parameters on surface integrity of machined components are strong especially when it comes to surface roughness, topography and near-surface material properties. These parameters include ballizing force, which is the most crucial among the parameters in the determination of the extent of plastic deformation at the surface. A sufficiently applied force levels surface asperities by leveling off peaks and rearranging material in the valleys, which causes a large drop in the roughness of the surface. Surface texture is also influenced by feed rate and ball diameter; those feed rates and ball sizes are able to provide uniform deformation and uniform surface coverage. On the other hand, there is a risk of creating uneven tracks of contact with high feed rates or excessive ball sizes that result in remaining surface waviness. Lubrication conditions also play a role in quality of the surface since a lack of lubrication enhances friction and heat production which may result in surface damage like scoring or micro-tearing. With these parameters well controlled, a better surface finish and dimensional stability is attained and this is critical in the reliable operation of rotating machined components.

Besides topography of surface, ballizing parameters have a significant effect on the subsurface integrity such as residual stress fields, surface hardness, and microstructural variation. The compressive residual stresses generated under the surface due to optimized ballizing force and repeated controlled passes are useful in retarding crack initiation and increasing fatigue strength. These compressive stresses vary in extent and depth depending on the diameter of a ball, the load applied and material characteristics. When applied too often or too heavily, though, may result in over-hardening, or sub-surface damage or localized cracking. Hardness and ductility of workpiece materials also dictate the behavior to ballizing, with the softer materials forming significantly more plastic deformation, whereas the harder materials demand careful choices of the parameters to prevent wear on the surface. The synergistic effect of the ballizing properties is the overall balance between enhanced surface properties and possible damage. This detailed knowledge of these effects is hence very important in attaining the best surface integrity and performance of ballized rotating machined components.

Conclusion

This extensive review has discussed the ballizing process and has extensively critically analyzed how the important parameters of the process have contributed to the surface integrity and to the functional performance of rotating machined component. The literature review findings are clear



International Journal of Engineering, Science and Humanities

An international peer reviewed, refereed, open-access journal
Impact Factor 8.3 www.ijesh.com **ISSN: 2250-3552**

that ballizing is a low-cost and effective surface enhancement method that can greatly enhance the surface roughness, cause favorable compressive residual stress, and heighten the level of surface hardness and improve fatigue and wear resistance with no material loss. The parameters of ballizing force, feed rate, ball diameter, the state of lubrication, the number of passes, and properties of the workpiece material decisively determine the amount of plastic deformation and a resultant surface and subsurface conditions. Refined parameter sets result in a finish of uniformity, better dimensional stability as well as better dynamic behavior, which is particularly important in rotating components with cyclic loading and vibration. On the other hand, poor choice of parameters may lead to over-deformation, surface damages, imbalance in residual stress and decrease in component reliability. Another trend mentioned in the review is the development of ballizing as the traditional finishing process into the multifunctional technique combined with forming, hybrid manufacturing and material processing. Although considerable improvements have been made, the current literature is still disjointed, and there is no unanimity regarding the best parameter ranges of various materials and operating temperatures. As such, additional systematic experimental research studies in conjunction with numerical modeling and real-time instrumentation are necessary to maximize the benefit of ballizing in high-speed and high-precision rotating manufacturing processes.

References

1. Abd-Eltwab, A. A., Atia, K. M., Saied, E. K., & Atia, A. M. (2022). An Investigation into the Forming of Tube Ends Using the Ballizing Process. *Design Engineering*, (2022), 3358-3374.
2. Abd-Eltwab, A. A., Atia, K. M., Saied, E. K., & Atia, A. M. (2022). An Investigation into the Forming of Tube Ends Using the Ballizing Process. *Design Engineering*, (2022), 3358-3374.
3. Abd-Eltwab, A. A., Elglaab, S. G., Elmetwally, H. T., & Saied, E. K. (2019). An Investigation into Multi-Spinning Process with Telescopic Mandrel. *International Journal of Advanced Science and Technology*, 28, 517-533.
4. Abd-Eltwab, A. A., Hamdy, K., Elsheikh, A., Saied, E. K., Ghazaly, N. M., & Gomaa, A. A. (2024). An investigation into production of double wall tube using squeeze Ballizing technique. *Journal of Manufacturing Processes*, 127, 545-558.
5. Abo Hussain, M. M., & Elsheikh, M. N. (2024). Study of tube ends forming using ballizing technique. *SVU-International Journal of Mechanical Engineering*.
6. Ali, A., Soliman, M., Abdelrhman, Y., & Hasab-allah, I. (2023). Investigation of AL/CU bimetallic tube cladding process by severe plastic deformation. *JES. Journal of Engineering Sciences*, 51(1), 1-15.



International Journal of Engineering, Science and Humanities

An international peer reviewed, refereed, open-access journal
Impact Factor 8.3 www.ijesh.com **ISSN: 2250-3552**

7. Alshareef, A. (2020). *Investigation and Modeling of Ball-Burnishing Factors Affecting Residual Stress of AISI 8620 Steel*. The University of Toledo.
8. Aparicio, C., Gil, F. J., Fonseca, C., Barbosa, M., & Planell, J. A. (2003). Corrosion behaviour of commercially pure titanium shot blasted with different materials and sizes of shot particles for dental implant applications. *Biomaterials*, 24(2), 263-273.
9. Daemi, B., Tomkowski, R., & Archenti, A. (2020). High precision 3D evaluation method for Vickers hardness measurement. *CIRP annals*, 69(1), 433-436.
10. Dardaei Joghman, H., Heideck, P., Weinert, F., Tekkaya, A. E., & Korkolis, Y. P. (2025). Bendability assessment of double-walled tubes with additively manufactured core structure. *Journal of Manufacturing Science and Engineering*, 147(8), 081009.
11. Davies, G., Lam, M., Harris, S. E. (2018). Study of 300,486 individuals identifies 148 independent genetic loci influencing general cognitive function. *Nature communications*, 9(1), 2098.
12. Davoodi, F., Taghian, M., Carbone, G., Saboori, A., & Iuliano, L. (2023). An overview of the latest progress in internal surface finishing of the additively manufactured metallic components. *Materials*, 16(10), 3867.
13. Dyl, T. C. (2013). Ballizing process impact on the geometric structure of the steel tubes. *Solid State Phenomena*, 199, 384-389.
14. Edriys, I. I., & Fattouh, M. (2013). Characteristics of Finished Holes By Ballizing Process. *ERJ. Engineering Research Journal*, 36(4), 403-415.
15. El-Abden, S. Z., & Abdel-Rahman, M. (2023). Finishing of non-ferrous internal surfaces using ballizing technique. *Journal of Materials Processing Technology*.
16. Elmetwally, H., Fahmy, E., Abd-Elhalim, E. S. M., Soliman, M. M., & Said, M. A. (2025). Production of externally gear parts with a new multi-level forming tool based on rotary ballizing technology using numerical and experimental study. *JES. Journal of Engineering Sciences*.
17. Hewidy, M. S. (2000). On the controlling metal removal thickness in ECM process. *ERJ. Engineering Research Journal*, 23(1), 192-202.
18. Varpe, N. J., Hamilton, A., & Gurnani, U. (2021). Review of effect of burnishing process on surface integrity of friction stir welded components. *Des. Eng.*, 2021, 651-666.
19. Morsiya, C. V., & Pandya, S. N. (2022). Recent advancements in hybrid investment casting process—a review. *Recent Advances in Manufacturing Processes and Systems: Select Proceedings of RAM 2021*, 817-831.
20. Hamadache, H., Laouar, L., Zeghib, N. E., & Boulanouar, L. (2023). Characteristics of RB40 steel superficial layer under ball and roller burnishing. *Journal of Materials Processing Technology*.



International Journal of Engineering, Science and Humanities

An international peer reviewed, refereed, open-access journal

Impact Factor 8.3 www.ijesh.com ISSN: 2250-3552