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CURRENT TRENDS IN THE DEVELOPMENT OF COLD HARDENING TOOLS

BY

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Abstract. Hardening by cold plastic deformation represents an essential technology for enhancing the performance of components operating under demanding conditions, ensuring superior resistance to wear, fatigue, and corrosion. Specialized hardening tools, designed for a diverse range of applications—internal, external, flat, or threaded surfaces—play a decisive role in the efficiency of this process. The complexity of these tools stems from the necessity to ensure dimensional precision, the uniformity of the hardened layer, and adaptability to various component geometries. This paper presents an analysis of existing constructive solutions for hardening tools, correlated with modern technological requirements, highlighting trends in architecture optimization and their prospective applications in contemporary industry. The study proposes a synthesis of the current state of the art regarding hardening tools, utilizing an idea diagram for a clear and accessible organization of the various possible solutions.

Keywords: modern burnishing tools, methods of burnishing, burnishing technology capabilities.

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1. Introduction

Cold hardening ranks among the well-established methods for enhancing the reliability of metallic components subjected to intense loading regimes. The process involves applying controlled mechanical loads to the surface layer, inducing localized plastic deformation and generating compressive residual stresses. These effects lead to microstructural strengthening, an increase in the hardness of the affected layer, and improved fatigue behavior. Consequently, this technology represents a competitive solution for extending the service life of critical components, being widely applied in industries where strength and reliability requirements are exceptionally demanding (Nagîț *et al.*, 2022; Raza and Kumar, 2022).

Typically, tools designed for this technology feature deforming elements such as balls, rollers, or diamond tips, configured either individually or in multiple arrays. The type of deforming element is determined based on the tool's specific application. It has been concluded that a roller-type deforming element is more advantageous than a ball (Oteny *et al.*, 2017) for burnishing internal surfaces, whereas diamond-tipped tools are more efficient than roller-based ones, at least for external cylindrical processing (Duncheva *et al.*, 2024).

Furthermore, an adjustment mechanism may be present—utilizing a mandrel and screw, an eccentric, an elastic element, etc. (Grădinaru and Nagîț, 2025)—to increase the versatility of tools with multiple deforming elements. This is particularly relevant when processing internal cylindrical surfaces, where versatility is highly important given the challenge of processing a wide range of diameters with a single tool.

Alongside theoretical contributions and academic research, the field of cold hardening currently benefits from substantial industrial support through the direct involvement of international companies, recognized for their expertise and tradition in developing advanced technological solutions. These organizations are not limited to manufacturing dedicated tools and equipment; they also offer comprehensive services, including technical consulting, process customization, and the integration of technologies into modern manufacturing workflows.

Among the main market competitors is HEF Group (France), with vast experience in surface treatments, Cogsdill (USA), known for its diverse range of burnishing tools, as well as Japanese companies Sugino and YAMATO Roll, which have developed highly reliable and globally appreciated technologies. Furthermore, the European industry is well represented by firms such as EcoRoll and Baubles Group (Germany), both specializing in the design of high-precision solutions, while the Asian market also features RBT Burnishing Tool (China), providing a competitive and adaptability-oriented offering.

Over time, the idea diagram method has been a point of interest for numerous researchers, being fast adopted into the specialized literature. Among the relevant contributions are the works of Belous (Belous, 1986), who provided

some of the first systematic approaches in this regard, as well as the subsequent study by Nagîț (Nagîț, 2001), which expanded the applicability of this method in the analysis and synthesis of technological processes.

The present paper aims to synthesize the current state of development of surface hardening tools, with the objective of highlighting the solutions used in relation to the diversity of processed surface types and current trends in tool development for this operation. For a clear and accessible representation, the idea diagram is utilized as a conceptual organization tool, facilitating the structuring and correlation of various technological variants.

2. Cold Hardening Tools Evolution

Surface hardening by plastic deformation has ancient origins; thousands of years ago, people observed that repeatedly striking metals—such as copper, bronze, or steel—increased their hardness and strength. This method was employed in the crafting of weapons, tools, and ornaments. Although applied without theoretical knowledge, it already provided a practical advantage in terms of durability.

In 1983, Dickinson & Adams patented a device for hardening internal cylindrical surfaces using roller-type active elements (Dickinson and Adams, 1983), which enabled precise control over the affected layer and reduced surface defects. Consequently, the technique has evolved from empirical practices to modern, patented industrial methods, widely utilized to extend the service life of metallic components.

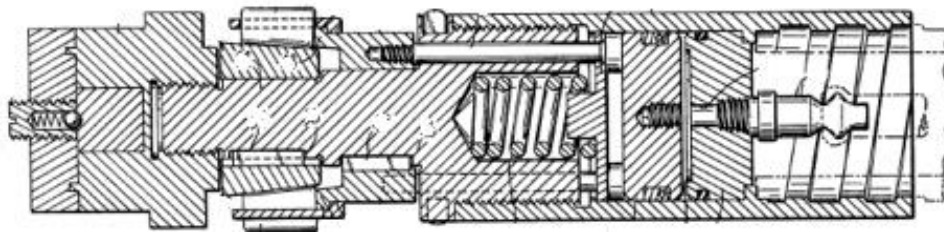


Fig. 1 – Internal surfaces rolling tool (Dickinson and Adams, 1983).

Fig. 1 presents a hardening tool characterized by a robust and complex architecture, typical of the industrial era when mechanical durability was the primary focus. The device incorporates a force system based on a helical compression spring, guide rods, and interconnected pistons, all encapsulated within a massive housing that ensures the stability of the plastic deformation process. Adjustment is carried out via threaded mechanisms and locking screws, providing a reliable technical solution for that period, yet requiring laborious

manual calibration and methodical maintenance due to the high number of components in relative motion.

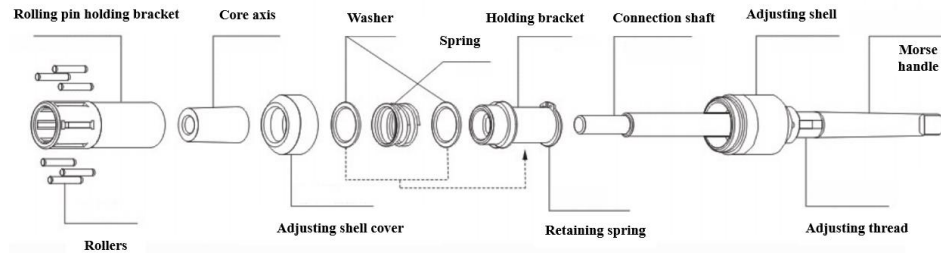


Fig. 2 – Modern rolling tool
(RBT-IDT Internal Diameter Roller Burnishing Tools for Through Hole, ID Burnishing Tools Manufacturer -).

Fig. 2, representing the contemporary tool manufactured by RBT Burnishing Tools, illustrates a modern vision focused on modularity and the simplification of the operational workflow through an easy-to-assemble design. Its structure emphasizes the efficiency of the active components, such as the burnishing rollers (rolling pins) and the holding bracket, and features a Morse taper shank (Morse taper toolholder) for rapid integration into modern CNC machine tools. The adjustment system is much more intuitive, utilizing a fine adjustment mechanism (adjusting thread) that allows the operator to achieve micron-level precision in a reduced timeframe, reflecting the current trend toward optimizing production setup times.

Analyzing the constructive evolution of these tools, it can be seen that the basic kinematic principle and the pre-loading concept have remained intact; both variants utilize a tapered central mandrel to radially expand a set of rollers inside a cage, while employing a spring-loaded system to ensure constant contact pressure and deviation compensation. What has fundamentally changed is the overall architecture and operational ergonomics: the modern device has abandoned the cumbersome internal structure, complex mechanisms, and massive volumes of classic models in favor of a modular, simplified, and significantly more compact design. Consequently, laborious internal adjustments have been replaced by much more intuitive external fine-adjustment mechanisms, and the integration of standardized clamping interfaces (such as the Morse taper shank) highlights a clear transition toward rapid adaptability and seamless integration into contemporary CNC machine tools.

Fig. 3 illustrates a diverse range of workpiece geometries suitable for cold roller burnishing, demonstrating the versatility of the process across different part profiles. The schematic details distinct target geometries, including internal and external conical features (bores and shafts), flat (plane) and spherical surfaces, as well as specific topological requirements like custom profiles and

fillet radii. Furthermore, the diagram highlights complex part designs that necessitate combined or simultaneous multi-feature operations. These advanced configurations include multi-diameter bores, profiles requiring the concurrent processing of internal (ID) and external diameters (ED), and combined surfaces.

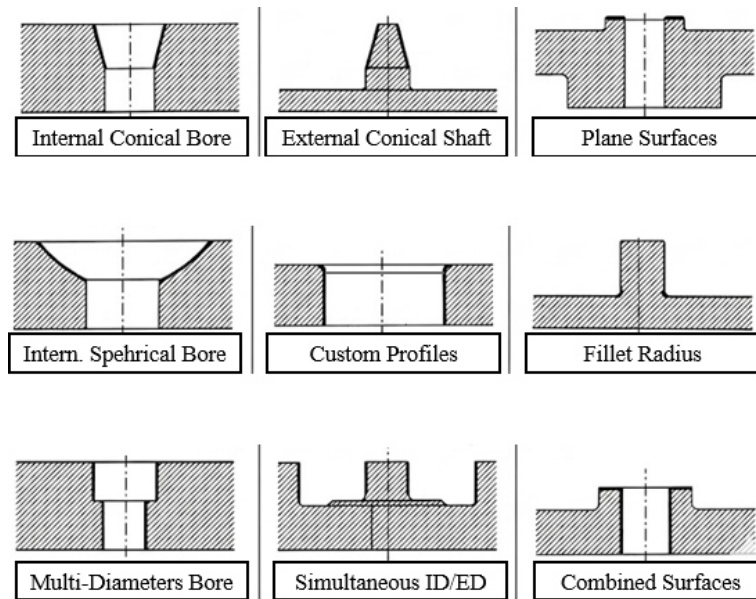


Fig. 3 – Overview of some cold hardening capabilities
(Adapted after Cogsdill Tool Catalogue, 2026).

3. Current State of Tools for Cold Hardening Using the Idea Diagram

To conduct a detailed analysis of the current state of the art regarding devices used in cold burnishing, the technical catalogs and solution portfolios offered by several manufacturers active in this industrial field were consulted. Following the comparative study, the processed surface was established as the primary classification criterion for these devices. Consequently, dedicated tools were identified for: flat surfaces, cylindrical surfaces (internal or external), threads, complex geometry surfaces (spherical, conical—internal or external, fillet radii, etc.), as well as universal tools capable of processing multiple types of surfaces, or combined cutting and hardening tools—also designed for internal cylindrical surfaces.

To facilitate the analysis and provide a clear visual representation, the solutions were organized in the form of an idea diagram (Fig. 6). Given the complexity and the considerable dimensions that including all constructive variants would have entailed, the diagram presents only one representative

solution for each type of device, thus avoiding the redundancy caused by the existence of similar models from different manufacturers.

The first column illustrates the solutions intended for the hardening of flat surfaces, featuring devices equipped with multiple diamond tips, cylindrical roller or disc-roller deforming elements.

The second column includes tools for hardening external cylindrical surfaces. A notable contribution is the device designed to accommodate workpiece insertion for external processing. Additionally, variants are available with a single deforming element or multiple active elements, utilizing rollers or diamond tips, as well as devices capable of processing workpieces of considerable length or shafts of varying diameters.

For the hardening of internal cylindrical surfaces (the third column), tools with a single deforming element are used, alongside multi-element variants, either standardized or specialized for very small parts (up to 5 mm in diameter). Furthermore, combined cutting and hardening tools are currently available, designed to reduce working times while ensuring increased efficiency and productivity.

The fourth column is dedicated to specialized devices designed for cold thread forming, utilizing roller-type active elements to generate threads through plastic deformation rather than material removal. To accommodate a wide range of workpiece specifications and technical requirements, these tools are highly adaptable and can be configured with either a single forming roller or a more complex system utilizing multiple synchronized rollers.

A recent trend in the field of mechanical machining is the development of specialized tools for complex geometry surfaces. This trend includes the innovation of equipment designed for processing conical surfaces (both internal and external), spherical surfaces, or fillet radii, with an eloquent example of internal conical processing illustrated in Fig. 4. These advanced devices are typically equipped with multiple deforming elements, which significantly expands the applicability domain of cold burnishing. By using these new constructive configurations, it becomes possible to uniformly treat areas considered technologically difficult.

From a kinematic perspective, the conceptual working scheme highlights a complex interaction of relative motions required to perform the roller burnishing process. The operation involves a primary motion, namely the rotation of the workpiece (denoted as I, n), which provides the relative working speed. Simultaneously, the tool equipped with cylindrical rollers executes an axial feed motion (denoted as II, f) towards the inside of the part, allowing the progressive penetration and contact of the active elements with the bore wall. The system also features a rotational motion of the tool rollers (denoted as III, n_r), an essential movement to ensure the continuous rolling of the rollers on the conical surface and to reduce the forces during the process.

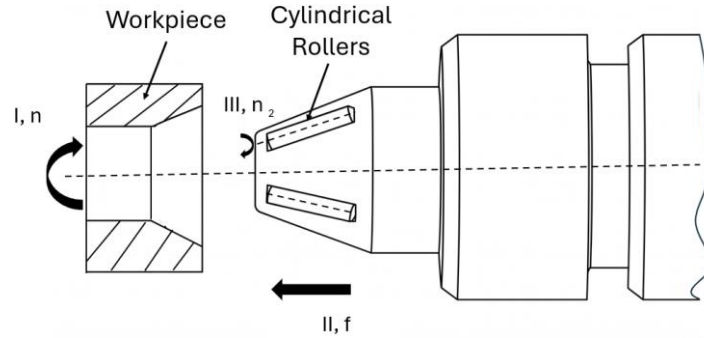


Fig. 4 – Internal conical surfaces rolling – conceptual working scheme
(Adapted after Sugino Tool Catalogue, 2026).

The final column captures a major development direction: universal devices capable of processing multiple types of surfaces (Fig. 5). These generally utilize a single deforming element (diamond tip, disc-roller, or conical roller), although variants with multiple active rollers also exist. Their universality and versatility provide significant advantages in small-batch production, where reducing the initial tool investment is essential. In addition, some of these devices are designed with the capability to adjust the setting angle of the active element, thereby enhancing their adaptability to diverse technological applications.

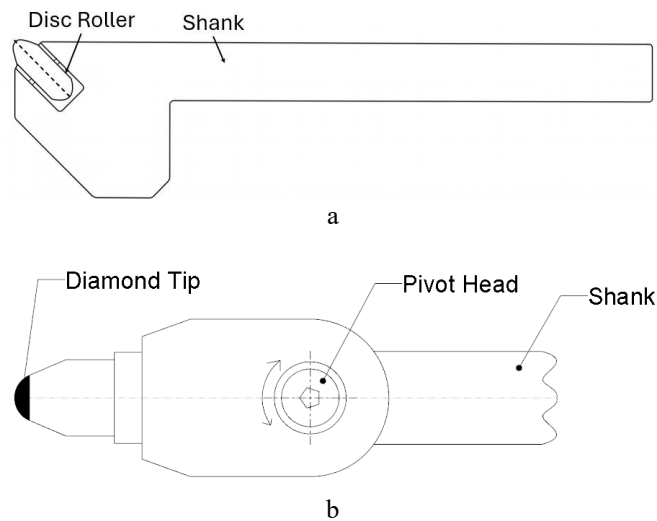


Fig. 5 – Universal burnishing tool; a- with single roller; b- with single diamond tip.
(Adapted after Sugino & RBT Burnishing Tools Catalogues, 2026).

4. Conclusions

The analysis of the evolution of cold surface hardening tools demonstrates that, although the basic principles remain rooted in solutions patented decades ago, contemporary design has focused massively on structural simplification and efficiency. Classic deforming elements, such as the ball, roller, or diamond tip, continue to be widely utilized, particularly in the machining of cylindrical surfaces. However, modern mechanisms have benefited from improvements that have enhanced their robustness and adjustment precision, adapting them to new industrial demands for tolerance and operational accessibility without altering the original functional concept.

A major direction in recent developments is the specialization of tools to cover atypical or highly precise machining operations. On the one hand, miniaturization is notable, materialized by the emergence of devices capable of hardening very small bores (under 5 mm)—an innovation that requires high manufacturing complexity to guarantee treatment uniformity. On the other hand, the field of applicability has expanded toward complex surfaces—such as threads, fillet radii, or spherical profiles—to meet the performance needs of advanced sectors, including the automotive, energy, and aeronautical industries.

In parallel with this specialization, the current trend is marked by the development of universal ("multi-surface") devices, designed to process multiple types of geometries using a single piece of equipment. Thanks to multiple adjustment systems and a modular design, these tools offer remarkable flexibility, making them highly cost-effective for research and small-batch production. For the future, research should focus on in-depth comparative studies of these solutions and on the development of new modular concepts to further increase versatility and technological efficiency.

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TENDINȚE ACTUALE ÎN DEZVOLTAREA SCULELOR DE DURIFICARE PLASTICĂ SUPERFICIALĂ LA RECE

(Rezumat)

Durificarea prin deformare plastică la rece reprezintă o tehnologie esențială pentru creșterea performanțelor pieselor utilizate în condiții solicitante, asigurând o rezistență superioară la uzură, oboseală și coroziune. Un rol determinant în eficiența procesului îl au sculele specializate pentru durificare, concepute pentru o gamă variată de aplicații: suprafețe interioare, exterioare, plane sau filetate. Complexitatea acestor scule derivă din necesitatea de a asigura precizie dimensională, uniformitatea stratului durificat și adaptabilitatea la diverse geometrii ale pieselor. În cadrul acestei lucrări se realizează o analiză asupra soluțiilor constructive existente pentru sculele de durificare, corelată cu cerințele tehnologice moderne, evidențiindu-se tendințele de optimizare a performanțelor și perspectivele lor de aplicare în industria contemporană.