

Improving Abrasive Lapping Technology in the Manufacture or Repair of Pipeline Valve Parts

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Abstract—This article examines the improvement of abrasive lapping technology in the manufacture or repair of pipeline valve parts, as well as the achievement of high-quality surfaces on repaired components, effective operating parameters, and conditions on abrasive lapping equipment using lapping plates. The article also highlights the main abrasive finishing process flow charts used in production.

Keywords: technology improvement, abrasive lapping, operating parameters, achieving the required sealing surface quality, lapping plate, main abrasive lapping process flow charts

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INTRODUCTION

When designing a manufacturing process for the manufacture or repair of pipeline valve sealing surfaces during finishing operations, the process must be developed and documented. A detailed technology must be developed for each specific manufacturing task, defining specific operating modes for the equipment and describing the process techniques that ultimately ensure the specified quality and productivity of the processing [1–3].

MATERIALS AND METHODS

Lapping is an abrasive finishing process in which abrasive grains are freely distributed in a finishing paste or slurry. A distinctive feature of this lapping process is that the ultimate goal of “tightness” is achieved at the expense of maintaining the shape of the mating surfaces. Lapping achieves the primary goal of ensuring the best possible fit between the surfaces, which is necessary for the valve’s tightness. Finishing (lapping) is widely used for the final processing of flat, cylindrical, spherical and conical surfaces, ensuring high surface quality ($R_a = 0.050\text{--}0.025\text{ }\mu\text{m}$). Lapping is divided into preliminary and final. During preliminary lapping, an allowance of 0.01–0.02 mm is left, while during final lapping it is 0.003–0.005 mm. Finishing ensures the accuracy of the dimensions and geometric shape of the part (up to 0.001–0.002 mm). The quality of the lapped surfaces of the product is checked for impermeability (to gases or liquids), transmission (for narrow surfaces) and paint. During lapping or finishing, the temperature of the workpiece

should not exceed 50°C, since excessive heating can lead to warping of the surface and cause measurement errors. Measurements are taken after it has cooled to ambient temperature (20°C). Finishing is carried out using abrasive and diamond micropowders and lapping stones made of various materials. The part is moved relative to the lapping stone (or vice versa) at a speed of 5–100 m/min. According to production and literary data [4–7], the pressure during rough lapping is in the range of 0.12–0.2 MPa, and during fine lapping it varies within the range of 0.05–0.12 MPa. The tool used for finishing is a lapping stone, onto the surface of which a paste or slurry is applied. The finishing process can be divided into two stages. The essence of finishing is that in the first stage, during the dispersion of the material, the shape is corrected and the dimensions of the treated surface are changed, and in the second stage, friction with plastic displacement of the material occurs, during which the height of the irregularities is reduced, the treated surface is “smoothed”. The first stage can consist of several transitions depending on the initial roughness of the surface and the roughness parameter that needs to be achieved. In other words, the greater the difference in roughness between the initial and final surfaces, the more passes are required in the first stage of finishing. With each pass, the size of the abrasive grains in the paste or slurry decreases, and, consequently, the surface roughness decreases. There may be cases where the surface quality prepared for lapping is close to the final one. In such cases, the first stage can be skipped, and only the second stage is required. During this stage, no cutting occurs, but only plastic deformation of micro-

roughness—surface smoothing—is performed. This stage ensures the required maximum surface finish. Chemically active liquids used during finishing (oleic acid, stearin, etc.) help accelerate the finishing process. During finishing, ruptures in the lubricant boundary layer should be avoided to prevent seizure at certain points where the lapping compound contacts the workpiece, which would consequently degrade the finished surface. Therefore, oil or animal fats are added to finishing mixtures to achieve optimal viscosity. The quality characteristics achieved by lapping guarantee interchangeability during assembly after separate machining of parts. The machining medium can be in the form of abrasive grains, abrasive slurries, or abrasive pastes. When using loose abrasives, considerable time is spent rinsing the surfaces being machined and applying pastes, and the surface of the part is intensively charged with abrasive grains, which during operation leads to surface scuffing and reduced wear resistance. The same factors that occur during abrasive wear of machine parts during operation are at play during lapping. However, to ensure high productivity and consistent machining quality, the workpiece must be exposed to accelerated abrasive wear, while the lapping surfaces must be exposed to minimal abrasive wear. Lapping plates are made of steel, cast iron, copper, bronze, glass, and hard and ductile woods. Gray cast iron laps are the most common. Almost all lapping machines are equipped with cast iron lapping discs. They are primarily designed for lapping hardened steel parts with a minimum hardness of 50 HRC. Castings used for making cast iron laps are subject to certain requirements: they must have a dense and uniform structure in cross-sections in all directions; the bulk of the structure must consist of fine-lamellar pearlite with a small proportion of ferrite and graphite precipitates in the form of small swirling flakes; the hardness of the casting must be 190–230 HB. Gray cast iron with a hardness of 180–220 HB is most often used for lapping discs. Surfactants must be used to bind and remove sludge during lapping. Sludge is a paste or slurry material contaminated with particles of the removed surface material and no longer functioning as intended. Furthermore, the concentration of acids in the paste or slurry depends on the material being processed. It must be sufficient to smooth the surface profile without excessively corroding it. The composition of the lapping paste or slurry is developed during the process development process for a specific task. Therefore, it is essential to obtain as much initial information as possible from the customer. Lapping paste and abrasive slurry are used in the following cases. The paste contains a higher percentage of thickener and can only be applied and removed manually. It does not require a mechanized feed device to the processing area. The machine in this case has a simpler design, but it requires greater operator involvement during the finishing process, as used and contaminated paste must be removed and new paste

applied at fairly short intervals. The slurry contains a similar abrasive material and has a fluid flow due to its higher content of mineral oil and kerosene. This allows for mechanized feeding into the processing area and, accordingly, collection as it leaves the processing area. The machine consists of a pump for feeding the slurry, a tank for concentrating it, and a pipeline for feeding it directly to the machining area. The disadvantages of this method include the abrasive slurry passing through the pump and pipeline components, which wears them down with its abrasive properties. Furthermore, the slurry must be replaced periodically as it becomes saturated with swarf. This process is quite labor-intensive. During the lapping process itself, operator involvement is minimal. The roughness of the lapping surface is significantly affected by the properties of the lapping materials and their grain size, the pressure applied to the part, and the lapping material. Proper selection of abrasive material is essential for achieving high productivity during lapping. The most common are corundum, fused alumina (normal and white), silicon carbides, and boron carbides. Based on grain size, grinding powders and micropowders are divided into three groups: grinding powders with a grain size of 5 to 3 are used for rough finishing, providing a roughness parameter R_a from 0.32 to 0.08 μm ; micropowders from M28 to M14 are used for preliminary finishing, which achieve a value of $R_a = 0.020 \mu\text{m}$; and micropowders from M10 to M5 are used for final finishing, providing a roughness R_z from 0.100 to 0.025 μm .

In addition to abrasive materials, various pastes are used, which can also be divided into three groups [7]: abrasive pastes based on fused alumina, silicon carbide, and boron carbide; diamond pastes based on synthetic diamonds; and chemomechanical pastes based on chromium oxide. The following pastes are recommended for preliminary and final lapping:

(A) white electrocorundum M10–M14 mixed with oleic acid, the consistency of which should be comparable to that of technical petroleum jelly at 20°C;

(B) white electrocorundum No. 5 mixed with oleic acid of the same consistency as the previous paste.

Synthetic diamond pastes are used for the final finishing operation (roughness parameters R_a from 0.160 to 0.020 μm and R_z from 0.100 to 0.025 μm). The best results are achieved when machining the hardest and most brittle materials, such as nitrided steel, hard alloys, and glass. Using diamond pastes instead of abrasives made of fused alumina, silicon carbide, and chromium oxide (with the same grain size) can increase productivity by 2–3 times or more, as well as improve the roughness of the treated surface. The following diamond pastes are available: normal (N)—with a diamond powder concentration of 2%; medium (M)—with a diamond powder concentration of 5%; high (H)—with a diamond powder concentration of

10%. Pastes are supplied packaged in tubes or syringes of 5, 10, 20, 40, and 80 g.

Under identical processing conditions for sealing surfaces, the durability of Elbor pastes is 1.5–2 times higher than that of synthetic diamond pastes and 3–5 times higher than that of conventional abrasive pastes. Lapping and finishing with Elbor pastes and powders should be employed when it is necessary to improve the surface roughness of the parts being lapped to values of $R_a = 0.16\text{--}0.02\text{ }\mu\text{m}$. During the friction process, as radial pressure is applied by the lap against the workpiece surface, the abrasive grains embed themselves into the softer lap surface and remove minute chips from the workpiece surface. The chemical action of the pastes is attributed to the presence of oleic acid and other elements that form a softer film on the workpiece surface – rather than a tough oxide film; this softer film is easily removed from the part, thereby ensuring superior surface finish and lapping productivity.

Lapping and finishing parameters. The productivity of finishing, as well as the resulting accuracy and surface roughness, depend not only on the nature of the abrasive tool but also on a number of other conditions: the movement speed of the lap, its accuracy, the specific pressure between the lap and the part, grain size, the method of supplying the finishing material, the finishing allowance, etc.

Lap plate movement speed. As the lap plate movement speed increases up to 4 m/s, process productivity rises in direct proportion to the speed. When finishing with charged laps, a further increase in speed leads to excessive heating of the parts. When finishing with an abrasive slurry, increasing the speed reduces productivity due to high centrifugal force, which tends to throw the abrasive slurry away from the center of the lap. During the mechanical lapping of flat and cylindrical external surfaces, the optimal lap rotation speeds are 15–20 m/s for rough lapping and 4 m/s for finish lapping. The reciprocating speed of the parts is 0.2–0.4 times the lap rotation speed.

Specific pressure. The process productivity increases with the pressure applied between the lap and the part; this relationship holds true up to a pressure of 0.3 MPa. Excessively high pressures lead to rapid fracturing or attrition of the abrasive grains and reduced productivity, while also causing heating of the friction surfaces, which results in part deformation and reduced accuracy. Excessive pressure can also cause scoring on the lap surface.

The machining allowance for lapping operations averages 0.02–0.05 mm for roughing stages (though in some cases it may reach 0.1–0.2 mm) and 3–5 μm for finishing stages.

Force distribution on the lapping tool. To prevent rounding of edges or tilting of the part during lapping, it is essential to correctly distribute the forces applied to the part and to determine the center of gravity of the

part as it moves across the lap. To achieve this, the following conditions must be met: the vertical force (i.e., the pressure on the lap) must be applied perpendicular to the lap's working surface, and the point of application should be located not at the center, but somewhat closer to the edge of the surface being machined. During lapping and polishing, productivity is directly proportional to the grain size of the abrasive micropowder and increases as the grain size increases; conversely, the roughness of the machined surface decreases when pastes with coarser grains are used. The paste grain size should be selected based on the required surface roughness, transitioning gradually from coarser-grained pastes to finer-grained ones. The paste is applied in a thin layer to the lapping plate or the workpiece surface. When switching from coarse-grained paste processing to fine-grained paste processing, or from standard abrasive lapping to lapping with Elbor pastes, it is essential to thoroughly clean and wash the workpieces and lapping plates using kerosene, gasoline, or water, depending on the composition of the paste used. Elbor pastes are most effective when lapping and finishing processes are mechanized. The table provides practical recommendations regarding the parameters and conditions for the lapping (finishing) process for various sealing surface materials used in pipeline valve components processed on lapping and finishing machines.

RESULTS AND DISCUSSION

Based on the information presented above, the main abrasive lapping process schemes used in manufacturing can be identified [7, 8].

(A) Lapping with continuous slurry feed (a mixture with a low concentration of abrasive grains) ensures higher process productivity but results in lower precision and a surface roughness of $R_a = 0.08\text{--}0.32\text{ }\mu\text{m}$.

(B) Lapping involving the application of abrasive paste to the lapping plate utilizes a mixture with a higher concentration of abrasive grains. While productivity decreases slightly, processing precision improves, and the roughness of the finished surface is reduced.

(C) Lapping with an impregnated lap plate involves shearing off the peaks of the initial surface roughness using abrasive grains embedded in the lap. This method is less productive but ensures high precision and minimal surface roughness.

(D) Lapping with a solid diamond lap plate is performed using discs that feature a diamond layer on the working surface. This is the most productive lapping method, however, it does not allow for the full utilization of the diamond layer's cutting capabilities.

Table 1. Practical recommendations on the parameters and conditions of the finishing (lapping) process

Sealing surface material	Medium	P_N , MPa (kgf/cm ²)	Lapping plate hardness and its material	Finishing (lapping) stages					
				Rough stage		Final stage		Fine stage	
				abrasive material and its grit size	lubricant	abrasive material and its grit size	lubricant	abrasive material and its grit size	lubricant
Corrosion-resistant, heat-resistant, and high-temperature resistant steels	Nitric acid, food-grade and corrosion-resistant media	Up to 6.4 (up to 64)	Gray cast iron 143–241 HB	Regular fused alumina abrasive powder 5, 4	Industrial oil I-20A (GOST 20799–88)	White fused alumina micropowder M28	Industrial oil I-12A, I-20A (GOST 20799–88)	ASM 7/10 micropowder	Kerosene OST 38–01408–86
				Boron carbide abrasive powder 8–5 (GOST 5744–85)	Oil “Sulfofrezol” (OST 38.01445–88) or kerosene (OST 38–01408–86)	ASM 20/14 micropowder	Oleic acid TU 6–09–5290–86		
				Boron carbide abrasive powder 5, 4 (GOST 5744–85) _{ед}	Oleic acid (TU 6–09–5290–86), industrial oil I-12A, I-20A (GOST 20799–88)	Regular fused alumina micropowder M40	Oleic acid TU 6–09–5290–86, industrial oil I-12A, I-20A (GOST 20799–88)	White fused alumina micropowder M14	Oleic acid TU 6–09–5290–86, industrial oil I-12A, I-20A (GOST 20799–88)
	Water, steam, oil, petroleum	Up to 10 (up to 100)	Part against part			ASM 40/28 micropowder	Oleic acid TU 6–09–5290–86	ASM 20/14 micropowder	Oleic acid TU 6–09–5290–86
							Gasoline GOST 3134–78, stearin GOST 6884–64		Gasoline GOST 3134–78, stearin GOST 6884–64
								Chromium oxide paste TU 6–10988–78	Industrial oil I-12A, I-20A (GOST 20799–88)
	Water, superheated steam, liquid petroleum products	Up to 6.4 (up to 64)	Gray cast iron 143–241 HB _г 1	Regular fused alumina abrasive powder 5, 4	Industrial oil I-12A, I-20A (GOST 20799–88)	White fused alumina micropowder M28	Industrial oil I-12A, I-20A (GOST 20799–88)	ASM 14/10 micropowder	Oleic acid TU 6–09–5290–86 or kerosene OST 38–01408–86

Table 1. (Contd.)

Sealing surface material	Medium	P_N , MPa (kgf/cm ²)	Lapping plate hardness and its material	Finishing (lapping) stages					
				Rough stage		Final stage		Fine stage	
				abrasive material and its grit size	lubricant	abrasive material and its grit size	lubricant	abrasive material and its grit size	lubricant
High-alloy hard-facing	Ammonia	Up to 2.5 (up to 25)	Gray cast iron 143–241 HB	Regular fused alumina abrasive powder 5, 4	Industrial oil I–20A (GOST 20799–88)	Regular fused alumina micropowder M28	Industrial oil I–20A GOST 20799–88	ASM 20/14 micropowder	Oleic acid TU 6-09–5290–86, kerosene OST 38–01408–86, gasoline GOST 3134–78, stearin GOST 6884–64
	Water, steam, non-aggressive medium	Up to 4 (up to 40)			Industrial oil I–20A (GOST 20799–88)	White fused alumina micropowder M28	Industrial oil I–20A GOST 20799–88	Chromium oxide paste TU 6–10988–78	Industrial oil I–20A GOST 20799–88
								ASM 10/7 micropowder	Kerosene OST 38–01408–86
	Water, steam, oil, petroleum	Up to 6.4 (up to 64)		Regular fused alumina abrasive powder 5, 4	Industrial oil I–12A, I–20A (GOST 20799–88)	White fused alumina micropowder M28	Industrial oil I–12A, I–20A GOST 20799–88	ASM 10/7 micropowder	Kerosene OST 38–01408–86
				Boron carbide abrasive powder 8–5 (GOST 5744–85)	Oil “Sulfofrezol” (OST 38.01445–88) or kerosene (OST 38–01408–86)	ASM 20/14 micropowder	Oleic acid TU 6–09–5290–86		
	Water, steam								

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

USE OF AI

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