



Analysis of the Vacuum Pump Impeller Repair Process to Improve Component Performance

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ABSTRACT

The repair process for a vacuum pump impeller is necessary to address damage caused by wear, erosion, and geometric distortion that can reduce the pump's efficiency. This study aims to analyze the repair process of a vacuum pump impeller to restore the impeller's performance. The methods used include visual inspection, dimensional measurement, process planning, and implementation of the repair process. The repair stages include initial cleaning, welding build-up on the vanes, reshaping using a lathe machine, pressing the bushing onto the shaft, and finishing with grinding. The repair focuses on the vanes and the shaft, as these two parts experience the highest level of wear. The study results indicate that the implemented repair process stages were able to restore dimensions, improve surface quality, and enhance the performance of the vacuum pump impeller.

Keywords: process stages; repair; vacuum pump impeller.

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1. Introduction

Vacuum pumps are vital pieces of equipment in the chemical, manufacturing, pharmaceutical, and production-processing industries because they generate low-pressure conditions to support fluid transfer processes and maintain operational stability. The performance of a vacuum pump is strongly influenced by the condition of its impeller, which is the primary component responsible for driving fluid within the pump chamber [1]. Previous studies have indicated that more than 40% of pump failures are attributable to impeller damage, including wear, erosion, cavitation, and geometric distortion resulting from long-term operation [2]. Such damage directly reduces suction capacity, increases vibration, decreases energy efficiency, and potentially causes further damage to other components. Therefore, maintaining

impeller reliability is essential for reducing maintenance costs and maximizing pump service life [3].

As industrial demand for vacuum pumps capable of continuous operation increases, various impeller repair methods have been developed to restore components to a condition that approaches the original manufacturer's specifications. Common repair techniques include weld build-up, reshaping, precision machining, and finishing processes using lathes and grinding machines [4]. However, several studies have reported that the quality of field repairs is often inconsistent in terms of material deposition quality, geometric accuracy, and surface roughness after machining [5]. These issues can compromise post-repair impeller performance and increase the risk of rotational imbalance during operation [6].

This gap highlights the need for a more comprehensive analysis of the impeller repair process, encompassing damage identification, material deposition method selection, geometric restoration, and finishing operations. The evaluation of finishing processes is particularly important because they directly affect surface quality, rotational balance, and the hydrodynamic efficiency of the impeller [7]. Meanwhile, previous studies have primarily focused on types of impeller damage or pump performance analysis, with limited in-depth discussion of the integration of repair and finishing processes as a unified repair procedure for vacuum pump impellers. Consequently, opportunities remain to improve the impeller repair standards currently applied in industrial practice [8].

Therefore, this study focuses on analyzing the repair-to-finishing process of a vacuum pump impeller to improve component performance and restore optimal operating conditions. The study not only evaluates the effectiveness of the repair methods employed but also identifies critical impeller components that are susceptible to damage, such as vanes, hubs, and shrouds. Furthermore, this study is expected to provide recommendations for a more efficient, precise, and standardized repair procedure that can serve as a reference for industrial maintenance technicians in improving vacuum pump reliability in industrial environments.

2. Methodology of Research

This study was conducted from August 18 to September 18, 2025, at Jamroni Lathe and Welding Workshop, located at Jl. Kolonel Sugiono No. 102, Purwanto, Sukun District, Malang City, East Java, Indonesia. The research object was a single liquid-ring vacuum pump impeller of the cylindrical, multi-vane

type, made of FC-25 cast iron, with a diameter of 305 mm, a length of 370 mm, and a configuration of 18 vanes. The vacuum pump impeller exhibited several forms of damage resulting from long-term operation, including erosion and corrosion on the vanes, shaft wear, and geometric alterations in the shroud. Figure 1 shows the standard impeller geometry and configuration used as the reference for this study.

To provide a clearer overview of the repair sequence, a research flowchart was developed to systematically illustrate each stage of the process. The flowchart of the research procedure is presented in Figure 2

2.1. Initial Inspection and Identification of Damage

The initial stage involved a visual inspection of the impeller to determine the types and extent of damage, including abrasive wear, corrosion, erosion, and geometric deformation affecting the impeller vanes and shaft. This identification process was essential for determining the required repair procedures and assessing whether the component remained suitable for repair.

After the damage had been identified, the repair objectives were established. These objectives included restoring the impeller to its original dimensions, recovering the pump's suction performance, reducing vibration caused by rotational imbalance, and extending the component's service life

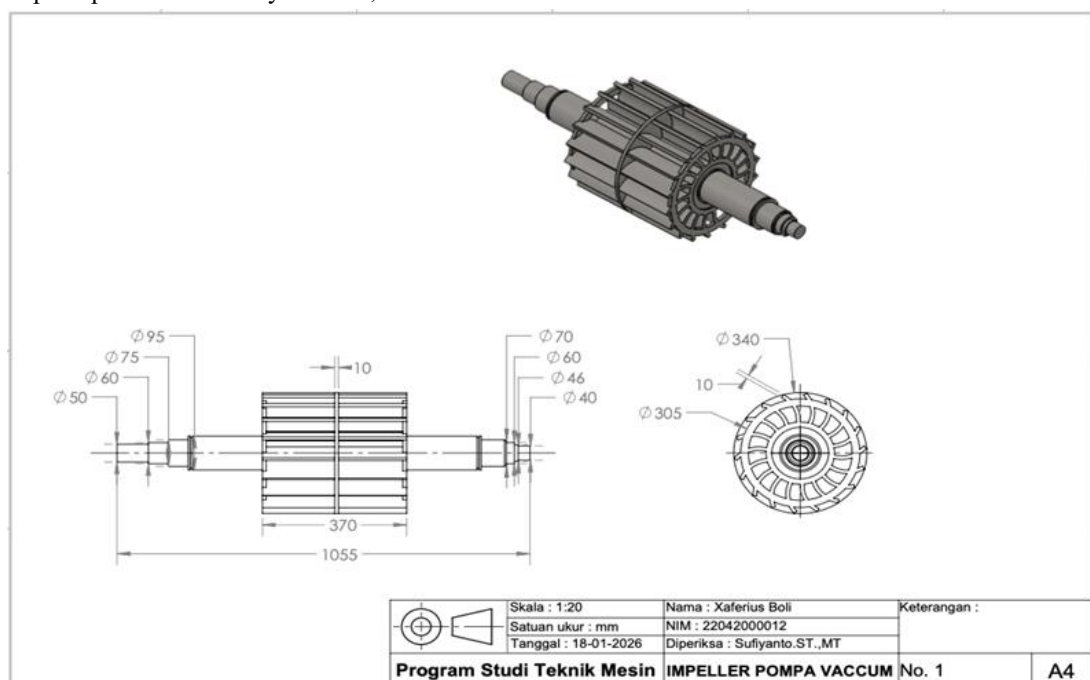


Figure 1. Shape and Configuration of the Vacuum Pump Impeller

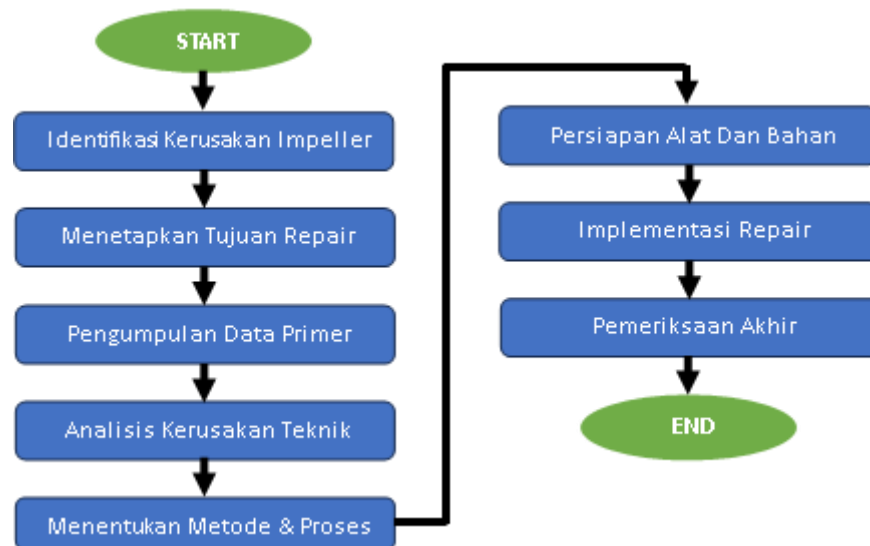


Figure 2. Research Flowchart

Data were collected through direct field measurements, including the actual impeller dimensions, degree of wear, surface condition, and photographic documentation. Measuring instruments, such as vernier calipers and micrometers, were used to obtain accurate technical data as the basis for further analysis. Based on the analysis results, appropriate repair methods were selected, including weld build-up for material deposition and reshaping through machining to restore the original geometry. The repair planning process included the selection of electrode types, welding current, material deposition techniques, and work sequence.

This stage also involved preparing the necessary equipment, including a metal inert gas (MIG) welding machine, a lathe, an angle grinder, and measuring instruments. Supporting materials, such as welding electrodes compatible with the impeller material, surface cleaning agents, and personal protective equipment, were also prepared. Proper preparation was essential to ensure that the repair process could be performed safely and effectively.

The repair process was carried out according to the established procedures, beginning with cleaning the damaged areas, followed by weld build-up, controlled cooling, rough machining, and finishing. The equipment used included a welding machine, a lathe, a press-fit tool, and an angle grinder. Each stage was followed by a visual inspection to ensure that no additional defects had occurred.

The final stage involved remeasuring the impeller dimensions, assessing surface roughness, conducting a rotational imbalance test, and verifying weld quality.

These inspections were intended to determine whether the repaired impeller met the required operational specifications and was ready for reinstallation in the vacuum pump.

3. Result and Discussion

vanes and shaft, as shown in Figure 3. The damage identified on the impeller included wear and corrosion on the vane and shaft surfaces. An analysis of the repair process was necessary to determine the appropriate sequence of repair operations to restore the impeller's geometry and functionality in accordance with operational requirements. Figure 4 presents the flowchart of the repair process developed based on the results of this analysis.



Figure 3. Impeller Damage

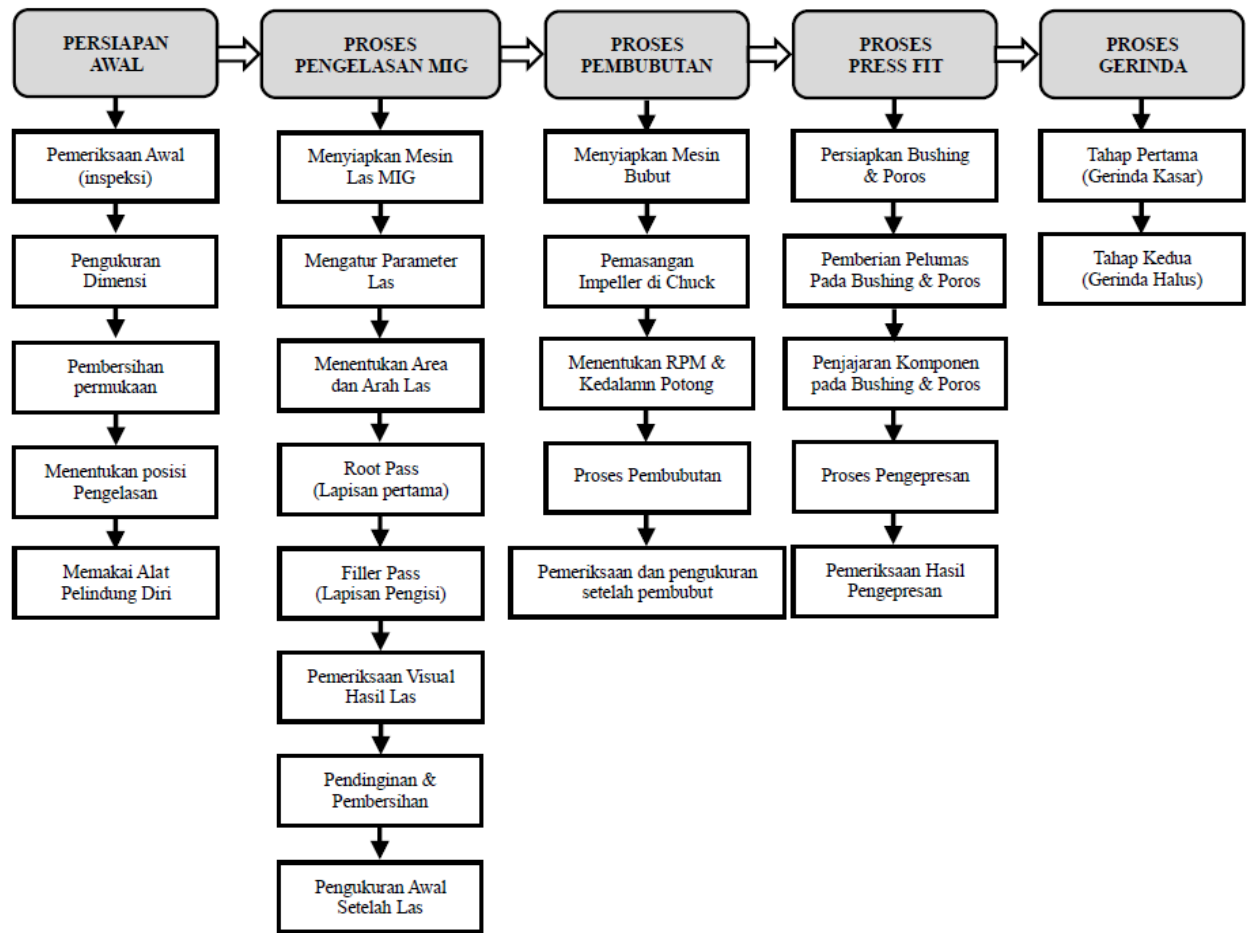


Figure 4. Repair Process Flowchart

The first stage of the repair process involved visual inspection and dimensional measurements to accurately determine the extent of the damage. Measurements using vernier calipers and micrometers revealed a reduction in vane dimensions of approximately 2.5 mm compared with the standard dimensions, as well as significant wear on the shaft surface caused by friction. The visual inspection and dimensional measurement procedures are shown in Figure 5.

Subsequently, the work surfaces were cleaned using light grinding to remove rust, contaminants, and residual material, thereby ensuring optimal conditions for welding. This preparation stage was essential because the inspection results served as the basis for determining whether weld build-up, reshaping, or machining was required for each component.



Figure 5. Visual Inspection and Dimensional Measurement

The next stage involved weld build-up on the worn vanes using a WM315C MIG/MAG welding machine. Welding was performed using ER70S-6 filler wire with a diameter of 0.8 mm and a welding current of 80–120 A. The weld build-up process is shown in Figure 6. After the material deposition was completed, rough grinding was performed to remove excess weld material before proceeding to the vane geometry restoration stage.



Figure 6. Weld Build-Up Process on the Vanes

The subsequent stage involved geometric reshaping using a Yamazaki Machinery Works, Ltd. lathe. The depth of cut was set at 0.2–0.5 mm per pass to maintain surface finish quality and prevent excessive tool wear, while the spindle speed was adjusted according to the impeller diameter, within a range of 200–500 rpm. Turning was performed progressively from the outer region toward the center of the vane, with the application of cutting fluid to maintain temperature stability and machining quality. The geometric reshaping process is illustrated in Figure 7.

After the vane contour achieved the required level of dimensional accuracy, lathe machining was performed on the shaft to level the worn area before proceeding to the shaft press-fitting stage



Figure 7. Vane Geometry Restoration through Reshaping

The next step involved a press-fitting operation to install a bushing made from a steel pipe measuring 180 mm in length, 100 mm in diameter, and 5 mm in wall thickness. The bushing was first machined by turning to cut and level its ends and ensure that its length met the specified dimensions. After the bushing and shaft had been prepared, lubricant was applied to both components to facilitate installation and minimize excessive friction.

The shaft was then positioned vertically on the hydraulic press table to maintain alignment during installation. The bushing was placed at the designated mounting position on the shaft, after which controlled pressure was gradually applied using the hydraulic press. This procedure ensured that the bushing was fitted uniformly without causing deformation to the components. The process was intended to ensure that the bushing was securely installed on the shaft.

The bushing was installed with precision to achieve a secure interference-fit joint. The press-fitting process is shown in Figure 8. This was followed by lathe machining of the bushing installed on the shaft to restore the shaft dimensions to the specified standards. The shaft machining process is shown in Figure 9.



Figure 8. *Press-Fit Process*



Figure 9. *Shaft Machining (Turning) Process*

The next stage involved finishing using a handheld angle grinder. This grinding process aimed to improve the impeller surface quality to help restore optimal fluid flow within the pump. The process consisted of two stages: rough grinding and fine grinding. In the first stage, a coarse grinding wheel (grit size 36–60) was used to remove excess weld material, level metal protrusions, and restore the impeller surface contours. Excessive pressure was avoided to prevent alterations to the vane profile.

Once the surface had been leveled, the process continued with fine grinding using a finer grinding wheel (grit size 120–240) to remove coarse scratches, smooth the entire vane area and the outer surface of the impeller, and produce a clean, smoother finish. The finishing process using a handheld angle grinder is shown in Figure 10.



Figure 10. *Finishing Process*

The final stage of the impeller repair process began with remeasuring the component dimensions using vernier calipers and micrometers to ensure that all parts, particularly the vanes, outer diameter, and shaft surface, had been restored to within the specified tolerances. Subsequently, a simple balancing check was performed using a long metal bar positioned as a supporting lever to assess whether the impeller tended to rotate or tilt to one side while mounted on the lathe. If the impeller appeared to tilt or become heavier on one side, this indicated mass imbalance, necessitating additional fine grinding in specific areas.

This stage is illustrated in Figure 11, while the final result of the repair process is presented in Figure 12.



Figure 11. Final Stage of the Repair Process



Figure 12. Impeller After Repair

4. Conclusion

Based on the analysis and repair procedures performed, it can be concluded that repairing the vacuum pump impeller through initial inspection, weld build-up, geometric reshaping, bushing press-fitting, lathe machining, and grinding-based finishing effectively restored the component's geometry and functionality. Material deposition on the vanes, restoration of the geometric profile through turning, and installation of a bushing on the shaft addressed the observed wear and deformation. The finishing stage improved surface quality and contributed to the rotational stability of the impeller. Overall, the repair sequence successfully restored the impeller's performance and has the potential to extend the operational service life of the vacuum pump.

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