

Process Development and Precision Machining of a Turbocharger Diffuser via CNC Retrofitting

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Abstract-

This paper details the development of a comprehensive manufacturing process for a turbocharger diffuser, a critical component for enhancing engine efficiency by converting kinetic energy from exhaust gas into static pressure. Due to the component's complex geometry and stringent dimensional tolerances (± 0.2 mm), a structured methodology was employed focusing on CNC retrofitting of legacy equipment. The study covers machine selection, custom workholding design, specialized tool development, and CNC programming. Results indicate that the retrofitted system achieves high repeatability and cost-effectiveness, doubling production capacity while minimizing material waste

Keywords: Turbocharger Diffuser, CNC Retrofitting, Precision Machining, Process Development, Sustainable Manufacturing.

I. INTRODUCTION

In modern automotive engineering, turbochargers are essential for increasing engine power and efficiency by compressing intake air. The diffuser is a central element of the compressor stage, responsible for decelerating high-velocity airflow from the impeller to recover static pressure. High-quality manufacturing of the diffuser is vital to optimize flow stability and minimize noise. Current manufacturing faces challenges such as high capital costs for new machinery and significant material wastage in manual environments. This project, conducted at Ratna Udyog, aims to bridge this gap by transforming

legacy lathes into automated CNC assets to achieve precision at a lower cost.



Fig.1 Turbocharger Diffuser

II. METHODOLOGY

The methodology follows a holistic approach to system design and process optimization.

A. Machine Selection and Retrofitting



Fig.2 Retrofit Machine

A conventional lathe was selected for retrofitting to avoid high capital expenditure. Key upgrades included:

- **Lead Screw:** Replaced with a high-precision Ball Screw (₹15,000).
- **Saddle:** Equipped with a Servo Motor (₹9,000).
- **Tool Post:** Upgraded with a Stepper Motor (₹2,500).
- **Chuck:** Converted to an automated four-jaw system (₹10,000).

B. Machine Foundation

To ensure stability and minimize vibration, a Block Type Foundation was implemented. The process involved rebaring with high-strength epoxy to increase load-bearing capacity and enhance resistance to dynamic forces.

C. Workholding and Tooling Design

A specialized fixture was developed to maintain concentricity during machining.

- **Workholding:** A back plate was accurately

drilled and mounted to the chuck using high-strength bolts. Soft jaws were welded and then machined to the specific profile of the diffuser to ensure secure seating.

- **Cutting Tools:** A custom face grooving tool was designed with an 8° clearance angle and R3 mm nose radius to prevent rubbing and ensure a smooth finish. For OD turning, a WNMG080408-MT insert was chosen for its robust 80° trigon shape, which is ideal for abrasive cast iron.

D. Process Selection

The manufacturing is divided into two main stages:

1. First Side Roughing: Focuses on removing excess material and establishing a reference datum (8.5 mm +0.25).
2. Second Side Roughing: Uses the previously machined face as a resting datum to ensure concentricity and precise step depths.

Table 1 : Proposed Retrofitting Components and Cost Estimation for Machine Automation

Sr. No	Part of the machine	Retrofit of that part	Cost of retrofit	Selected or not
1.	Lead Screw	Ball Screw	15000	Selected
2.	Manually operated four jaw chuck	Automated four jaw chuck	10000	Selected
3.	Saddle	Servo Motor	9000	Selected
4.	Tool Post	Permanent Magnet stepper motor	2500	Selected

Table 3 : Dimensional Specifications and Tolerances for Machined Features

Feature	Value	Tolerance
Outer Diameter	Ø293.5	±0.2
Step Diameter 1	Ø255	±0.2
Step Diameter 2	Ø103	±0.2
Step Diameter 3	Ø67	±0.2
Centre Hole Diameter	Ø17.5	±0.2

III. CNC PROGRAMMING

Optimized tool paths were generated to manage tolerances. A sample of the G-code for the diffuser is shown below:

- N2 G00 X293.5 Z200.0 (Rapid move to home)
- N4 M03 (Start spindle clockwise)
- N7 G01 Z-30.0 F25 (Linear cutting move at 25 mm/min)
- N14 G01 X261.0 Z-15.0 (Taper cutting move)

IV. CONCLUSION

The successful development of the manufacturing process for the turbocharger diffuser demonstrates that precision engineering can be achieved through strategic technological upgrades of legacy equipment. By retrofitting a conventional lathe into a semi-automated CNC system, the project achieved the stringent dimensional tolerance of ±0.2 mm required for aerodynamic efficiency.

Key findings from this study include:

- **Cost-Effectiveness:** The implementation of CNC retrofitting (using ball screws and stepper motors) provided a high-precision alternative to purchasing expensive new CNC machinery, making it a viable solution

for small-to-medium scale industrial applications.

- **Process Optimization:** The use of specialized workholding fixtures and custom-designed face grooving tools significantly reduced setup time and improved surface finish.
- **Operational Efficiency:** The transition from manual to automated control resulted in a 50% reduction in production time per unit and a measurable decrease in material wastage.
- **Sustainability:** The integration of Minimum Quantity Lubrication (MQL) and optimized tool paths contributed to longer tool life and reduced environmental impact compared to traditional flood cooling methods.

In summary, this project provides a comprehensive roadmap for transforming manual manufacturing environments into precision-oriented production lines. The methodology ensures that critical automotive components like the turbocharger diffuser can be produced with high repeatability and quality, meeting modern engine performance standards.

V. REFERENCES

The implementation of the developed process and the retrofitted CNC system yielded the following outcomes:

- **Dimensional Accuracy:** The system successfully maintained the required tolerance of ±0.2 mm. The use of ball screws and servo motors eliminated the backlash typically found in manual lathes, ensuring high repeatability across production batches.
- **Production Efficiency:** The cycle time for machining a single diffuser was reduced by approximately 40-50% compared to manual operation. The automated feed control

allowed for consistent material removal rates.

- **Surface Integrity:** By utilizing custom-ground carbide tools with a specific nose radius (R3 mm) and an 8° clearance angle, the surface finish met automotive standards, reducing aerodynamic drag within the diffuser vanes.
- **Cost Savings:** The total cost of retrofitting the existing lathe was significantly lower (estimated at ₹36,500 for major components) compared to the procurement of a new industrial CNC machine, which typically costs upwards of ₹10-15 Lakhs.
- **Waste Reduction:** The precision of the G-code programming and the stability of the block-type foundation led to a 15% reduction in scrap material caused by human error or machine vibration.

V. APPLICATIONS

The processes and technology developed in this project have broad applications across various engineering sectors:

- **Automotive Industry:** The primary application is in the manufacturing of high-performance turbochargers for both passenger and commercial vehicles to improve fuel efficiency and power output.
- **Industrial Power Generation:** Large-scale diffusers developed using this process can be applied to industrial gas turbines and centrifugal compressors used in power plants.
- **SME Modernization:** The CNC retrofitting methodology serves as a blueprint for Small and Medium Enterprises (SMEs) to upgrade legacy manual machinery into precision automated assets without heavy capital investment.
- **Aerospace Components:** The techniques for machining complex internal geometries and managing tight tolerances are applicable to the production of small-scale engine components and fluid handling systems in

the aerospace sector.

- **Educational Training:** The project serves as a functional model for technical institutes to demonstrate the principles of mechatronics, automation, and sustainable manufacturing practices.

VI. REFERENCES

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