KMM GROUP LTD.

Case Study

Grinding a Multi-Eccentric Shaft for a Space Related Compressor Prototype

BACKGROUND

The part itself fit comfortably in one hand, but the print suggested a level of difficulty far beyond its size. Five different diameters had to be ground on separate centerlines, with each eccentric feature timed to align precisely with the others under extremely tight tolerance limits. Once diameter and runout requirements were layered together, the process became one where every grinding pass had to behave exactly as expected, because there was little opportunity to recover material once the final approach began.

The part supported a space related compressor prototype connected to closed-loop water generation research. Compressed gases would contribute to systems designed to produce usable water in environments where carrying supply weight becomes impractical. The larger concept focused on proving whether a compact compressor system could help close that loop.

The initial assessment suggested the geometry was theoretically achievable, but only if grinding and inspection could be controlled carefully enough to keep all five eccentric features timed together through final size.

> "It's very rare that you see five different diameters not on the same center line, and then to be controlled by very tight constraints on tolerance, on diameter and run out."
>
> - John Shegda, CEO KMM Group

CHALLENGES

The difficulty was not concentrated in one feature. Geometry, tolerance interaction, and inspection requirements each narrowed the available process window.

Multi-Eccentric Geometry

Five separate diameters had to be generated from one primary shaft axis, with each feature positioned on a different centerline and phased precisely to the others. Several features were offset 180 degrees apart, meaning dimensional accuracy alone was not enough. Their angular relationship also had to remain consistent through the length of the part.

"When you have a really tight diameter tolerance and a tight runout, you get one shot." - John Shegda

Stacked Tolerance Limits

Critical tolerances allowed very little room for adjustment once grinding began:

- .00012" true position
- .00012" runout
- .0002" cylindricity
- .0003" total diameter tolerance
- 8 RMS surface finish

Because diameter and runout had to succeed together, removing additional material to correct one condition could immediately jeopardize another.

Secondary Features Expanded the Grinding Work

Beyond the primary eccentric diameters, smaller grooves and secondary features also had to be produced from offset positions. Some required extremely narrow grinding wheels and additional setup attention, even when those features carried wider tolerances than the main functional surfaces.

These secondary details increased cycle time because they still had to follow the same eccentric geometry already established by the primary grinding sequence.

SOLUTION

Initial operations focused on establishing a stable concentric foundation through mill-turn processing, followed by heat treatment to bring the 440C material to its required hardness range. These steps created the reference geometry, but they did not address the core challenge of the part.

All critical features tied to eccentricity were generated during OD grinding. Each diameter had to be approached as part of a larger system, where positional accuracy and feature timing were linked. Material removal could not be treated as an isolated operation. Every pass influenced the next.

Because both diameter and runout tolerances were tightly constrained, the process required incremental progression. Features were brought close to size in controlled steps, with repeated measurement between passes to confirm stability before committing to final dimensions. The progression followed a structured three-pass approach—rough, semi-finish, and final—with each stage tightening control and bringing the geometry closer to its required condition. At every step, each eccentric feature had to be accounted for to maintain alignment across the part. This approach reduced the risk of removing material that could not be recovered.

Grinding strategy also had to account for phased relationships between features, including diameters positioned opposite one another. Maintaining that relationship required careful setup control and consistent process behavior throughout the sequence.

MEASUREMENT

Standard inspection methods could confirm individual features, but no single system available could fully verify all five eccentric diameters together in their phased relationship. The requirement was not only to measure size and location, but to confirm that each feature returned to the correct position relative to the others.

A hybrid inspection approach was developed to bridge that gap. The part was mounted between centers on a surface plate, creating a stable reference for rotation. From there, five high-resolution indicators were positioned across the eccentric features to track their movement simultaneously.

Each indicator was set using precision height measurement equipment so that its zero position represented the correct geometric relationship for that feature. As the shaft was rotated, all five indicators moved independently until reaching a single point where they returned to zero together. That moment confirmed that the eccentric features were not only within tolerance individually, but properly aligned as a system.

Supporting measurements were taken using CMM inspection, high-precision micrometers, and height masters to verify individual dimensions and establish baseline accuracy.

This approach required both calculation and careful setup. It also demonstrated that inspection can become a parallel engineering problem when part geometry extends beyond the limits of standard verification methods.

> **"They all come back to zero at exactly the same point."**
>
> **- John Shegda, CEO KMM Group**

RESULTS

Experience played a central role in navigating these decisions. Small variables such as part deflection, heat generation, and wheel interaction could shift results at the micron level. Adjustments were made in response to how the part behaved in-process, not just how it was defined on the print.

The result was a grinding approach that prioritized control over speed, allowing each feature to be brought into tolerance while preserving alignment across all five eccentric diameters. In parts where geometry, tolerance, and sequence are tightly linked, success depends on how the process is managed between cuts, not just how it begins.

CAPABILITY PROVEN THROUGH PROCESS

Complex parts rarely fail because of a single feature. When geometry, tolerance, and sequence are tightly linked, outcomes depend on how the system behaves as a whole.

This project began as first article work, but it required the same level of control expected in production environments where repeatability and reliability are critical. The geometry limited process flexibility, and the tolerance structure required each operation to behave consistently from start to finish.

Several practical capabilities were reinforced through the work:

- Managing multi-axis geometry where features do not share a common centerline
- Grinding under stacked tolerance conditions with minimal opportunity for correction
- Adjusting process strategy in response to real-time part behavior
- Developing inspection methods when standard approaches cannot fully verify results

The experience also highlighted a broader consideration for engineers and supply chain teams. Parts that appear feasible in concept often require multiple process pathways to reach a stable outcome in practice. When only one approach is available, risk increases. When several viable paths exist, the likelihood of success improves.

Projects tied to space-related systems, including fluid control, motion components, and high-precision assemblies, often fall into this category. Success depends on the ability to adapt processes as well as execute them.

"If you only have one way to do it, that's risky. If you have two or three, you have a much better chance of success."
- John Shegda

GROUP LTD.

2200 Byberry Rd,
Hatboro, PA 19040

(888)-499-5657 toll free

info@kmmgrp.com

kmmgrp.com

/kmm-group