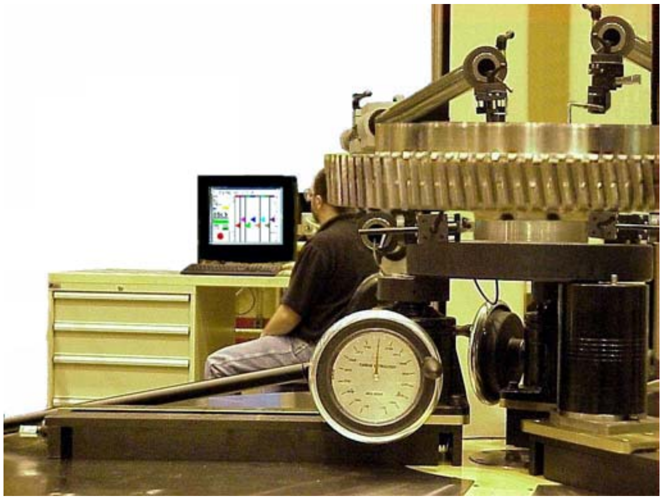
Metrology

Why Not CMM?

Circular Geometry Inspection offers a number of advantages over CMM technology in the measurement of turbine rotors



For the turbine builder who has just invested heavily in a **Coordinate Measuring Machine (CMM)**, the first question asked is always why CMMs are inadequate to measure turbine rotor disks. "I've just spent a fortune on this CMM," he says. "Is another large workstation really necessary to characterize the geometry of disks for stacking?"

Early days: Measurement of power generation turbine disks into the 1980's was usually accomplished on a tilted table with the outer circumference of the part resting on two precision bearing rollers. As the part was rotated, eight or twelve measurements were made on each surface, one at a time, read from dial indicators, or in later years from electronic gauge heads with analog readouts. Results were recorded by hand on a paper form. Since both sides of the disk could not be measured at the same time, the disk had to be flipped over, the indicators re-set, and the process repeated. With this method, any errors in the rollers was transmitted into the data, operators readings of the indicators varied, and measurement of the second part surfaces, after a complete repositioning of the part and indicators, meant more chances for error. Even the pencil-and-paper recording of the data was subject to illegible handwriting, transposition and other errors. Manufactures of smaller and lighter weight aircraft turbine engine parts, at this time, were able to utilize air bearing rotary inspection tables in lieu of the slanted roller tables. The air bearing tables eliminated some of the error associated with the rollers but offered only a small advance in the manual technology.

With either manual method, measurement resolution was limited to .0001" and repeatability was .0005" at best. The low number of points measured on each surface of the part did not adequately characterize the surface features of the disk – a big problem when it came to "stacking" the disks into a rotor assembly. Stacking predictions, after all, can only be as accurate as the measurements on which they are based and manual methods simply did not produce sufficient resolution to allow proper stacking of the individual disks into a rotor assembly. Clearly a better method was required.

At this same time, CMMs were taking dramatic steps forward thanks to advances in computer and motion control technology. CMMs, with their Cartesian X-Y-Z measurements, soon had the ability to take several measurements per minute with resolutions of .0001 inches and repeatability much better than that of the old manual methods. The use of CMMs to characterize disks seemed to be a natural next step in disk measurement and some turbine manufacturers spent millions of dollars on the technology.

The obvious problem with using a CMM to characterize a circular part is the number of points that can be taken within a given period of time. Because locating the CMM probe must be accomplished by very precisely controlled movements in all three axes (X, Y, Z), data gathering in the best of cases is limited to 50-60 points per minute on each surface. While this is a useful increase in the volume of data compared with eight and twelve point methods, it still falls short of the number of measurements required to adequately characterize a surface in a reasonable amount of time. Because the "bottom" of the disk cannot be measured, the disk must be flipped to obtain measurements of the second side, and once all the data is gathered there is no facility within the system to relate the measurements to each other, meaning the data will have to be downloaded into other software for analysis of flatness, parallelism, concentricity, eccentricity, and other standard measurements

Circular Geometry Inspection (CGI) was developed to address the shortcomings of both the manual methods and CMM analysis.

TM's current Paragon V2 CGI system, thanks to its high-speed, high-accuracy computerized data acquisition system, can take 153,000 readings per second on eight surfaces simultaneously, resulting in 36,000 measurements on each measured surface of the wheel with a shop floor measurement resolution of about .000008" *. The eight surfaces of a large turbine disk can be measured in 90 seconds and with proper fixturing the part does not have to be flipped to measure the "bottom" surface (see photo above.) The surfaces are then related to each other in the manner programmed by the User using standard ISO methods. Results are delivered in 2-3 seconds.

This is hundreds of thousands of times more data than can be taken by hand in the same amount of time and, thanks to 140x over-sampling, a thousand times greater than CMM methods. The surfaces are automatically related to each other, eliminating additional data manipulation in extenal software. Repeatability of the measurements is vastly improved as well. In tests done one month apart on a jet engine component, the component and its fixtures having been put on and taken off the workstation numerous times in the interim, **Paragon** consistently repeated Runout measurements to .000010 inches and .1 degree of angle.** Try that on a CMM.

How much does CGI cost? One TM customer spent over $4,000,000 and a number of years trying without success to develop CMM technology for turbine disk measurement. They replaced their CMM with a $380,000 **Paragon** workstation and never looked back.

COMPARISON OF DATA RATES

	Pts/sec	Pts/surface	# surfaces	Total pts/disk/90 secs
Manual 8 pt	**.1 - .2**	**8**	**1**	**9 - 12**
Manual 12 pt	**.05 -.1**	**12**	**1**	**9 - 12**
CMM	**.25 – 1**	**as p'gmd**	**1**	**90**
Paragon V2	**153,000**	**36,000**	**8**	**110,160,000**

*Based on shop floor measurements done by General Electric Company using TM's Paragon system.
**Testing at Rolls-Royce, Derby, UK.

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