RECONFIGURABLE ULTRAPRECISION LATHE QUALITY EVALUATION THROUGH COMPARISON BETWEEN ITS MACHINED PARTS AGAINST A REFERENCE

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Abstract. *The Precision Engineering Laboratory (LMP) at Federal University of Santa Catarina (UFSC), doesn`t have an adequate system to permit a quality evaluation for ultraprecision machined parts. In the Metrology Laboratory (Labmetro), at the same University, a special measurement system was developed to control cilindricity errors of machined parts, based on optical principles and with adequate uncertainties. To calibrate this measurement system, a reference cylinder was needed. This reference part was produced by an ultraprecision machine in Germany and has the quality certificate that assures its form errors. In a way to compare machined parts produced by the reconfigurable ultraprecision lathe from LMP, a sample with the same outer dimensions was machined and some tests were done using the measuring system, allowing some conclusions about the local ultraprecision lathe quality, which was assembled based on a design methodology to reconfigurable precision systems, where unused components from different systems were assembled to compose the machine, with a relative low cost design. The measurement system and the reconfigurable ultraprecision lathe will be described and the comparison results will be shown.*

Keywords: U*ltraprecision machining, Cilindricity, Form measurements.*

1. Introduction

The ultraprecision lathe of the Precision Engineering Laboratory is a modular lathe. This condition allows the lathe to be adapted for different cinematic configurations, in order to optimize the machining results for each different type of required component. In the current lathe configuration it is possible to manufacture plain, conical mirrors (internal and external) and cylindrical.

The surface quality of the machined parts in this machine is being improved during the researches, with the application of more resources and researchers work in the machine. The efforts of several researchers that had helped to construct the machine had resulted in an ultraprecision lathe with low cost, simpler maintenance and big flexibility.

Methods of evaluation for ultraprecision machined parts quality are difficult and expensive, mainly for involving measurements in sub-micrometric scale.

In the Metrology Laboratory (LABMETRO) of the UFSC, a device was developed to measure the cylinder form errors of machined parts, with high resolution and low measurement uncertainty. With this resource, it is possible to evaluate the quality of the cylindrical form of parts from comparisons with a standard part also machined by ultraprecision in dedicated machines. The standard part used as reference to the developed measurement system was manufactured in Germany.

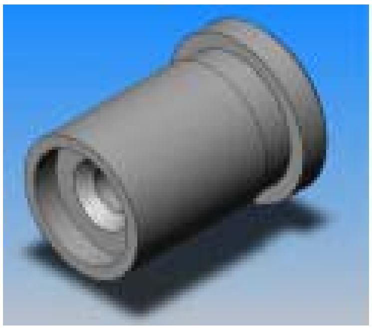
2. The ultraprecision lathe and the preparation for the machining

The ultraprecision lathe developed in the LMP is shown in figure 1. Basically, the lathe consists of a set of crossed prismatic slipping guides, on which is mounted a tool holder. There is an assembly plan in the same basis, where a dividing table with high quality of angular positioning is placed. The angular table only serves for positioning. The spindle is mounted over the angular positioning table.

Figure 1. Lateral view of the ultraprecision lathe

The spindle is aerostatic and possesses integrated and independent drive. To carry through the cylinder machining, it is enough to dislocate the spindle in a way that its rotation axle stay parallel to the rectilinear movement direction of the machine main carriage.

In accordance with the geometric specifications from the standard cylinder necessary to the measurement system developed in the Labmetro, the part was prepared with a pre machining, as it shows figure 2. The part material is the aluminum alloy AW-7022 (AlZnMgCu0,5), ideal to the ultraprecision machining.



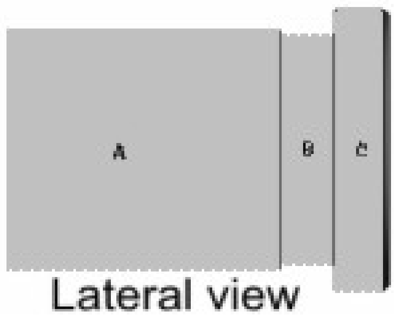


Figure 2. Standard cylinder to be machining by ultraprecision

The standard cylinder to be machined has three distinct regions. The region A is where the ultraprecision machining will be carried through. Region B serves to cutting tool exit and region C is a flange for concentric assembly adjustment in the system part holder, which is fixed in the spindle face.

The system part holder is shown in figure 3. There is a passing hole in the center of the part holder with a thread. A screw crosses the part to be machined and is fixed in this thread, having guaranteed the clamping rigidity.

The cutting tool is fixed as shows figure 4. For the height adjustment, out of use standard blocks are used. The cutting tool is a diamond monocrystalline with unique edge. In figure 4 it can also be identified a little tube that is used for cutting fluid injection and the chip removal system.

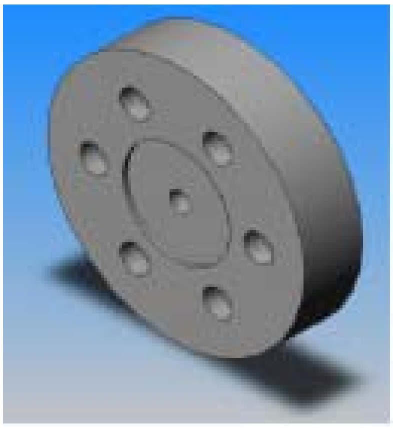


Figure 3. Clanping part system

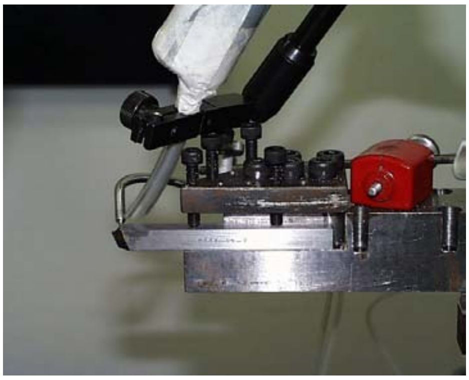


Figure 4. Cutting Tool with fluid aspersion and chip withdrawal systems

Figure 5 shows the cylinder machined by ultraprecision in the LMP lathe. The machining was carried through with cutting depth of 5 µm for roughing and 2,5 µm for finishing. The spindle rotation was of 3000 rpm and the feed speed was of 20 mm/min.

Figure 5 - Cylinder machined in the LMP

3. The measurement system

The measurement system, as shown on figure 6, consists of an incoherent light interferometer for cylindrical form measurement. The system is based on the principle of 3D scanning technique for interferometer, thus the longitudinal scanning are transformed into radial scanning. The hardware control, processing and result manipulations are effected by software.

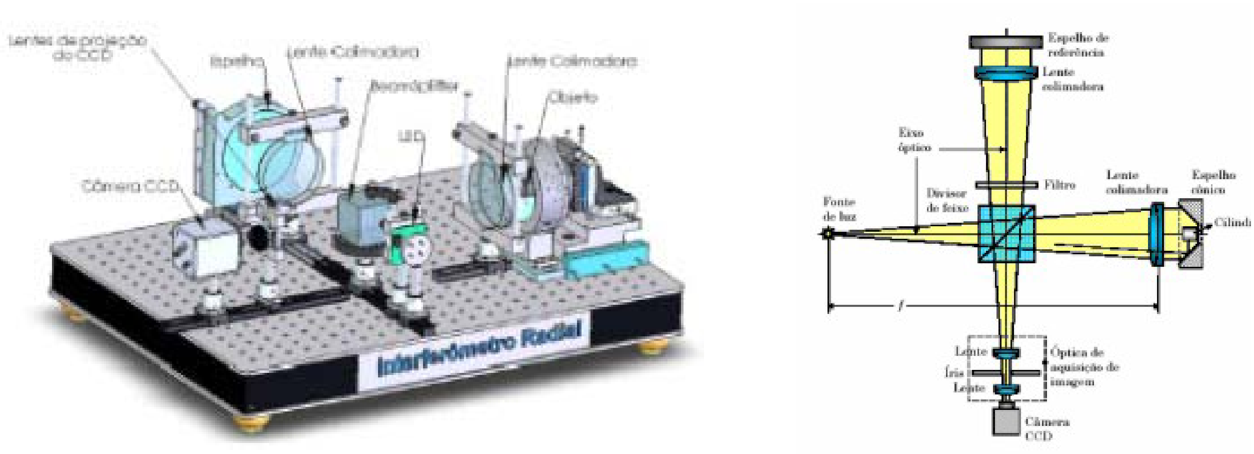


Figure 6. Interferometer of incoherent light

The measurement theory for the part cylinder error form is based on the interference that occurs when two or more waves overlaps in the space. In the interferometer case, a luminous source is lighted equally in a reference plain mirror and in the cylindrical part, as it shows figure 7. As the part and the reference mirror are equidistant, the light reflected for the plain mirror and for the part it arrives at the CCD camera that captures the image almost at the same time. The capture of the interference between these two overlapping waves is then analyzed, and can be interpolated and manipulated by software.

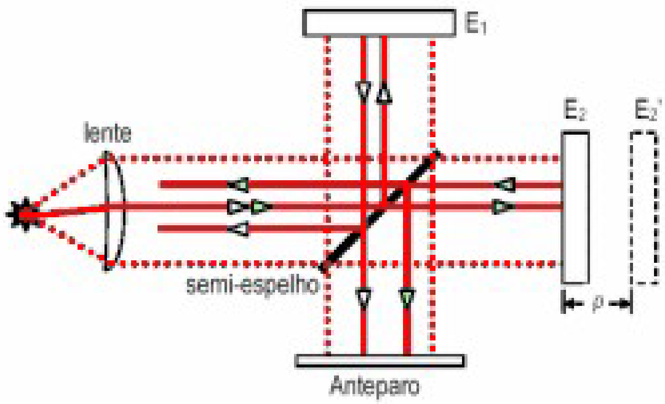


Figure 7. Incoherent light reflection project

The radial interferometer principle (incoherent light interferometer capable to measure cylindrical parts) is based on the interpolation of a 45° conical mirror in the arm of the interferometer where it is the part. A cylinder, whose cylindrical surface desires to evaluate, is located in the center of this conical mirror. Figures 8 it illustrates a sketch of the conical mirror and shows how it and the cylindrical part are located in the interferometer.

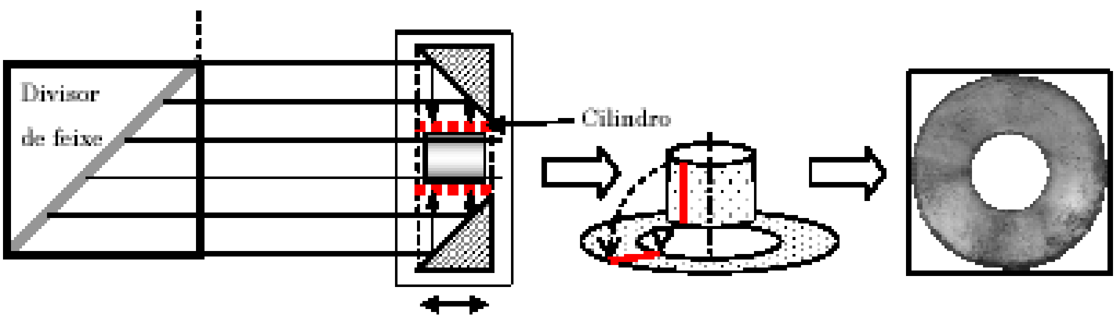


Figure 8 - Positioning of the cylinder

The measurement result has the form of a designed ring, whose relief represents the variations of the cylinder ray. The formation of this ring results from the fact of the seen camera image is the planning of the cylindrical part, carried through for the 45°conical mirror. Figure 9 represents this designed ring.

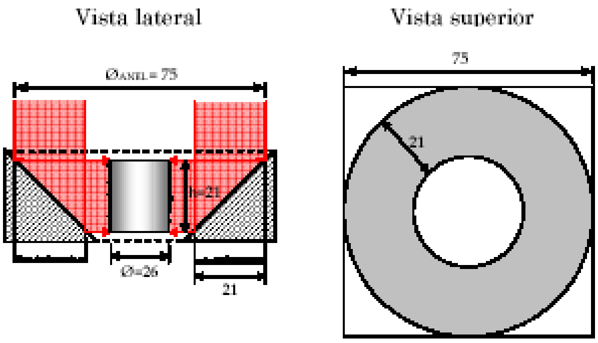


Figure 9 - Definition measurement area

After getting the cloud points in ring form, is necessary to make the mathematical reconstruction of the cylinder, to get the desired cylindrical form. The radial resolution of the measurement depends on the resolution of the camera (figure 10), while the resolution in the measurement of depth depends on the resolution of the interferometer principle.

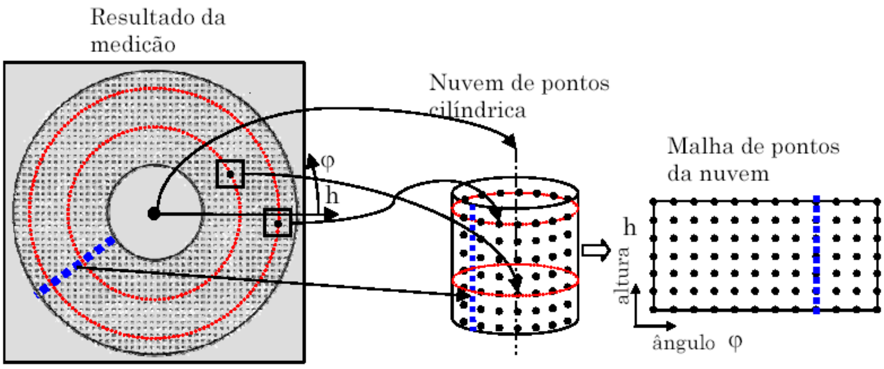


Figure 10 - Representation of the measurement resolution

4. Results

Figure 11 shows 3D representation of measured forms from both cylinders, the one machined in Germany and the other, machined in LMP.

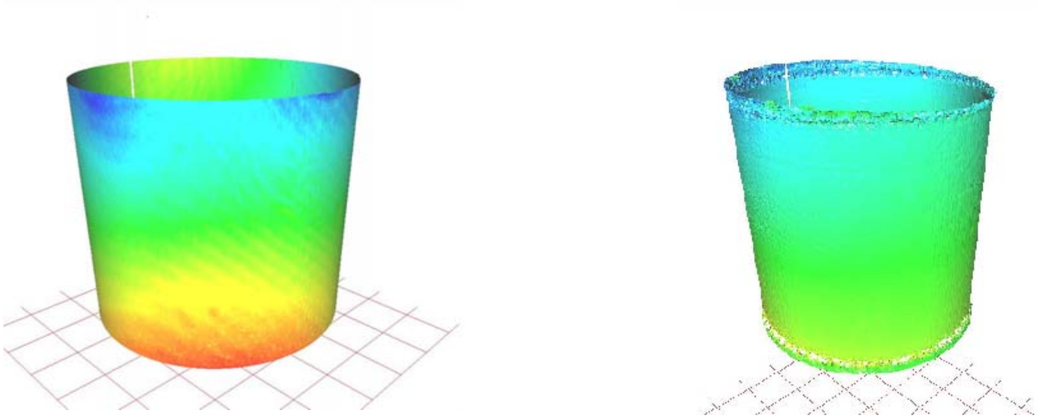


Figure 11. Topography representation for both cylinders

In figure 12, a direct comparison is done, representing the form deviations measured. As expected, the cylinder machined in Germany and with a dedicated machine has lower form errors, with three times better values of global error, in order or 0,3 µm, against 1 µm measured in the LMP cylinder.

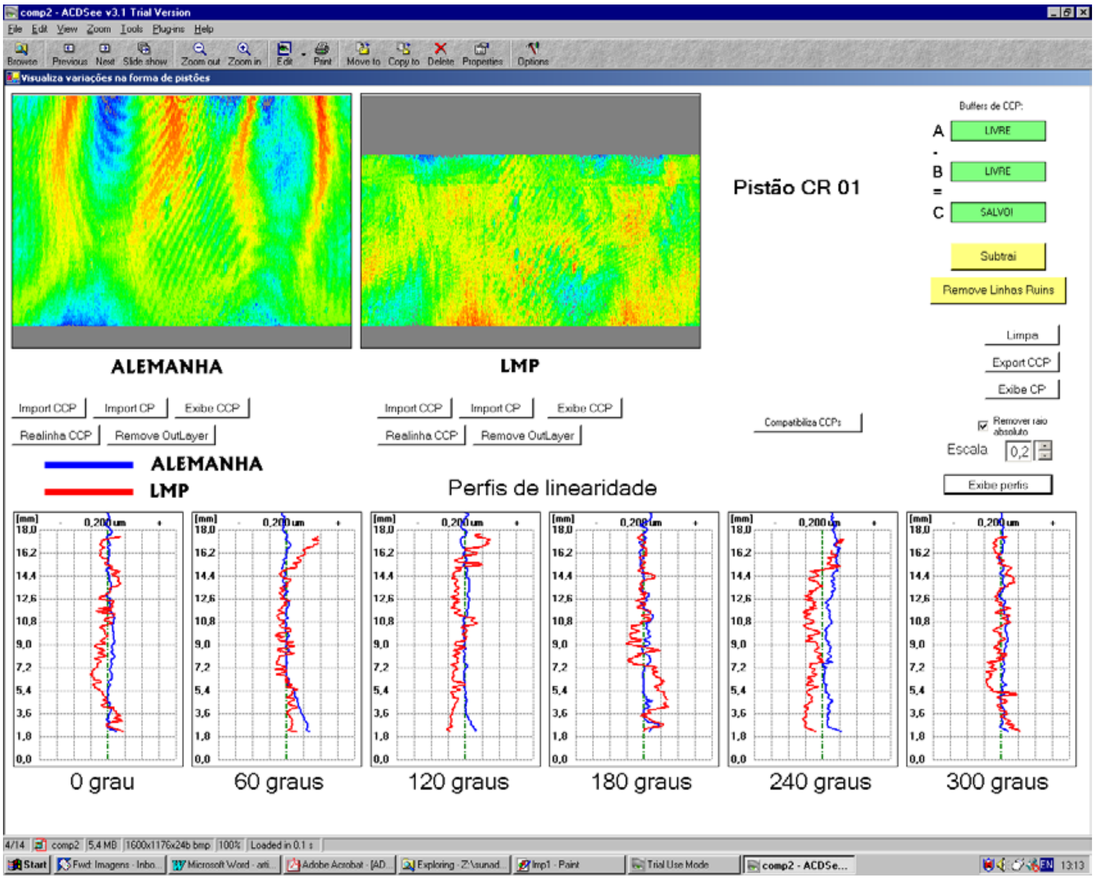


Figure 12. Comparison between machined cylinders

The comparison was done in the measurement system software. Profile linearity in different sections was compared. It can also be observed the distribution of topography errors by the color map.

5. Conclusions

The first main conclusion is about the measurement system quality, with appropriate uncertainties to precede precision measurements. The data treatment provided by the software is flexible and gives helping graphic analysis.

The main objective of this work is to show the comparison between parts machined in different equipments. The reference part was done in Germany by a commercial ultraprecision lathe with known quality assurance. The part machined in LMP was done in a machine obtained by assembling of parts coming from different equipments out of use. This machine was constructed with relative low cost and its results are considered very significant. Its development is still under way and the researches expect to achieve better results.

Now these results can be measured in comparison with reference parts.

6 – References

Pereira, M., "Metodologia de Projeto para Sistemas Mecânicos de Precisão Reconfiguráveis". Tese de doutorado. EMC – UFSC. Florianópolis 2004.

Slocum, A. 1992, Precision Machine Design, Prentice Hall, New Jersey, 1992.

Dalpont, A., "Desenvolvimento de um interferômetro de luz incoerente para medição de formas de cilindros". Dissertação de mestrado. Pos MCI,UFSC,2004.

7. Responsibility notice

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