FIRST GENERATION MICRO-MACHINE TOOL CHARACTERIZATION

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1. INTRODUCTION

The development of methodologies to characterize micro-systems has become a need for the investigation around the world. UNAM has been developed an investigation line focused on the technology generation for micro-equipment at Mechatronics Laboratory of the Center of Instruments. As result of this investigation has been developed a micro-machine tool of first generation with three work axes, which is automated with the help of stepping motors. Until this moment there are few methodologies that allow to evaluate the capacities of these kind of devices, so that, here we present a proposition of characterization of a micro-machine tool.

2. CASE OF STUDY

The development of micro-mechanic systems is pointed out as a part of the researching lines of the Mechatronics Laboratory at the Instruments Center, UNAM. Its main goal is to generate the high performance technology in order to fabricate pieces of smaller dimensions than one millimeter. Those pieces are used in the development of the completely automated production technology and they are focused on the development of equipment and instruments, highly efficient and low cost. During the last year it has been developed a prototype of a micro-machine tool with the capability of performing machining such as lathe, milling, and drilling. This work (lathe, milling, drilling) depends on the kind of tool and the configuration, which the equipment works with. Some specifications to the first generation micro-machine tool prototype were proposed by the Mechatronics Laboratory at the Instruments Center. Those specifications are: Capability of producing pieces on a size range from 100 micrometers to 5 millimeters; 2 micrometers resolution; the equipment must have 4 grades of freedom (3 translation axes and, at least, one rotation axe.); the prototype must include automation software; and the automation software must work on a Pentium system with 32 RAM megabytes.

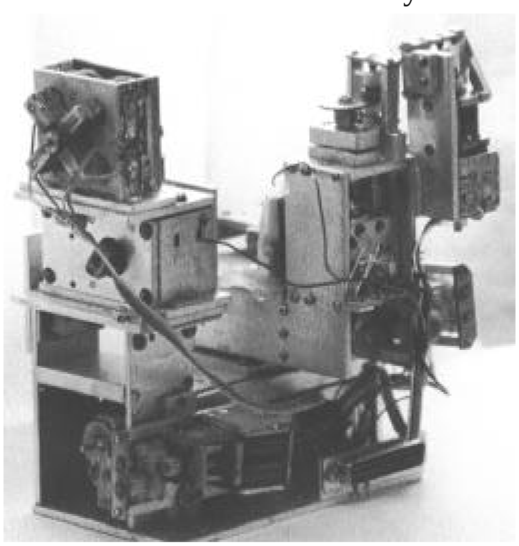

Figure 1. Micro-machining center developed by the Mechanic Engineer Laboratory at the Instruments Center

As a result of the application of those specifications, we obtained a micro-machining prototype on the approximated dimensions of 130x160x85 ?mm^3? (figure 1).

Some pieces have been fabricated on an automatic way with this equipment but the real characteristics of the machine were unknown. Therefore, it is necessary to characterize it as well as to establish the performance parameters in order to use that information for the software design to reduce errors, for the establishing of error sources, and for the improvements proposal. This study is the main part of this paper.

3. CHARACTERIZATION

There are two methods for machine characterization. The first one is called 'direct method', which is focused on the quantification of each one of the qualities of the machines, through this quantification, we can estimate precisely the machine errors. The second method is called 'indirect method', and it helps to determine the work accuracy and the machine tool capability [1].

We tested the micro-machine tool by indirect method. In other words, we characterized the micro-machine tool by evaluating test pieces producing with the same equipment. Once that was made, we knew some characteristics of the equipment.

According to the parameters that the proposed method gave us we were capable to know the following characteristics of the equipment:

Positional characteristics: "Y" axis accuracy, resolution (linear displacement for each motor step) and Backlash.

Geometric inspection: Geometric analysis of the pieces fabricated on the equipment and of its conceptual design in order to know the accuracy characteristic by comparing both pieces.

The characterization tests of the micro-machining center prototype were made on the base of the fabrication of 20 similar pieces with approximately known geometric characteristics. With the help of statistic analysis we determined the needed parameters. The testing piece implemented to determine the positional characteristics was a cylindrical shape with 3 radial marks, as is shown in the figure 2.

For the geometric inspection study, micro-rings were designed. Those rings were employed in a micro-mechanic filter, which is an application of this technology. This measurements were made with an optical contrast. The solid model of a micro-ring is shown on the figure 3. This kind of pieces was tested with a profile projector.

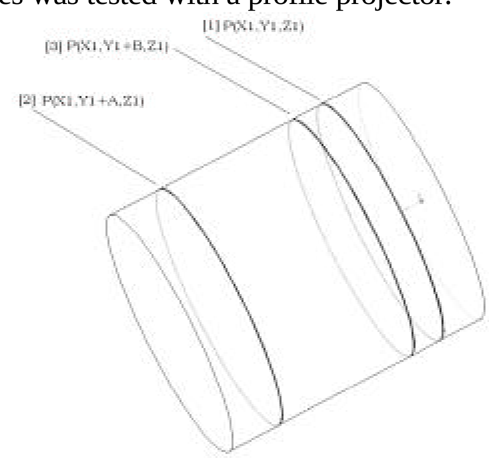

Figure 2: Testing piece used to determine the positional characteristics of the micro-machining center.

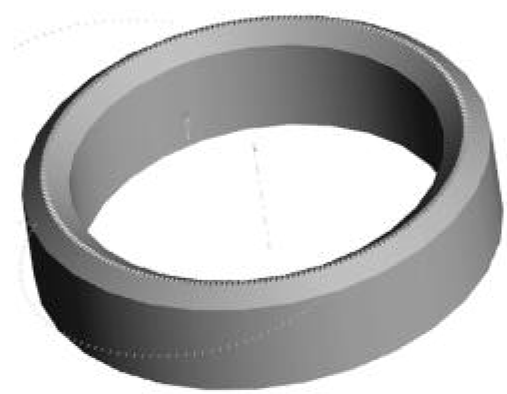

Figure 3. Testing piece for the geometric inspection

The test pieces machined shown below.

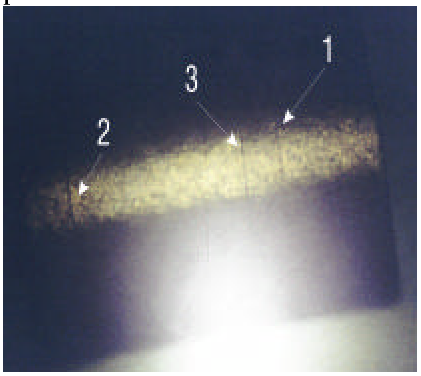

Figure 4. Testing piece used in the measurement of the determination of the positional characteristic tests.

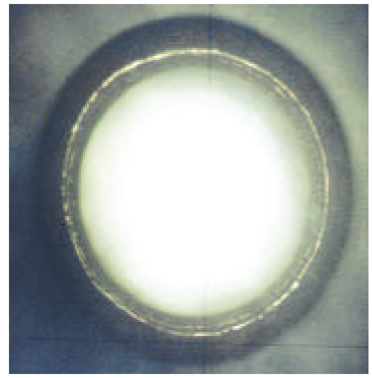

Figure 5. Testing piece used in the geometrical analysis.

4. RESULTS

The results shown below were determined by a statistic analysis of the parameters gotten with the help of the measurement tools. Among the different results we got from the statistic analysis, we focused on the average values and standard deviations.

A. Positional characteristics

The results of the positional characterization are shown below.

Accuracy	18.21 [?m]
Resolution	1.88 [?m]
Backlash	345.27 [?m]

To establish de accuracy in the "Y" axis we made measurement the distance between the 1 and 2 marks of de first test piece (1050 steps programmed). The accuracy is an average of the 3?[1], and it can work as the error of the "Y" axis working length because it was always machinated on different axis positions. The resolution was obtained by the relation between the distance 1-2 and the number of esteps programmed. In order to define the backlash presented on the "Y" axis, it was measured the distance between the marks 1 to 3 of the testing pieces.

After analyze the gotten results it was determined that there are different backlash error sources in the machining-center. The first source is located in the gear box. The second one, and the most important, is located between the transmission and the carrier on each axis. The third one is located between the leading screw and the nut that is coupled to the carrier on each axis.

B. Geometrical analysis

It is shown below a table containing the measurements effected to the testing micro-rings. The results of the measurements are shown on the table below.

[1] Standard deviation

Measurement name	Description
M	Exterior diameter of the micro-ring base.
S	Distance between the diameters (interior, and exterior of the micro-ring base)
N1, N2	Diameter conforming the conic cutting vertice located on the superior micro-ring's base
P	Distance between the conic cutting vertice and the interior diameter of the micro-ring´s base
Q	Height form the micro-ring's conic part

Table 1. The measurements to the testing micro-rings for determining the geometrical analysis.

Machining kind	Measurement average [?m]	Expected error ?[?m]
Cylinder machining (M)	1258.45	20.11
Drill machining (S)	205.47	38.28
Cone machining (N)	981.30	62.19
Cone machining (P)	64.63	37.00
Cone machining (Q)	476.79	34.82

Table 2. Measurement's results

Because the machining errors of the pieces correspond to the mode of machining, we found errors resulted of the kind of tool employed on the fabrication of the piece, besides the errors resulted of the micro-machining center characteristics. Therefore, the errors the micro-machining center showed are also related with the tools employed in the machining.

CONCLUSIONS

The proposal to characterize a micro-machining center was presented. This is an alternative permitting to know some parameters about this kind of devices like they are accuracy, backlash, among others. This parameters help us to develop improvements to reduce the micromachine tools errors via software or hardware. It's necessary development methodologies that permits to characterize micromachines tools by direct method to decrease de errors that depend on the design of the equipment. The development of micro-equipment raises the need of generating the technology that allows us to learn its behavior. As a part of our future work, it is going to be developed an auto-evaluation system for this equipment..

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