GUIDELINES FOR DESIGN LOW COST MICROMECHANICS

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I. ABSTRACT

The problem of development microequipment is discussed. This paper contains description of the main problems connected with micro mechanical equipment developing, requirements to the micro machine tools properties, design and control systems of the prototypes of first generation machine tools, and applications of micro equipment. The mayor idea of this paper is to show the experience of the Laboratory of Mechatronics and Micromechanics in Center of Applied Sciences and Technological Development, UNAM, in development of different kinds of microequipment that include prototypes and models of CNC machines, manipulators for micromechanics, grippers and motors.

II. INTRODUCTION

At present in the world new technology direction is formed: creation of microfactories [1-8]. Micro devices are necessary for different field of production, for example, in watch industry, in automotive industry, in medical facilities, in biology investigation etc. Mechanical parts will become smaller in the future. It is possible to produce microcomponents with ordinary equipment but it is very difficult to provide high level of precision. We propose that micro mechanical equipment is to be made as a sequential generations of micro machine tools and micro assembly devices. Each next generation must have smaller sizes than previous one and must be produced by the equipment of previous generation [8].

In Japan the conception was proposed how to reduce the size of small parts production equipment to a level comparable with the size of the parts to be produced for the purpose of drastically saving energy, space and resources throughout the production plant [1]. It is simpler to provide high precision with micro devices, than with conventional ones.

Now exists the approach to manufacture the low cost micro components of sub millimeter sizes with using modern micro electronic technology. This approach is used very widely for manufacturing micro sensors and micro actuators, but it has some limitations connected with the problems of 3-D components manufacturing. This technology makes it possible to produce flat components. So it is very difficult to make automatic assembly of micro devices, because of 2-Dimensions. Our approach has no such problems, but demands low cost micro equipment, which is absent at present. In the article [8] main principles of such equipment creation are proposed.

III. THE MAIN REQUIREMENTS TO THE MICRO MACHINE TOOLS (MMT)

At first, the micro machine tools (MMT) must be sufficiently precise. This characteristic must be considered always in relation with the cost of MMT. We develop and produce the first generation of MMT. The equipment for producing components having overall sizes from some hundred microns to some millimeters must provide accuracy of some microns [1, 5].

Developed MMT, at least the machine tools of first generation, must be multifunctional. The simplest multifunctional MMT must have four or five degrees of freedom (DOF) 3-translation axes and one or two rotary axes. MMT must use the simplest types of stepping motors and the contact sensors. It's preferable not use industrial motors and sensors because the next generation of micro equipment will demand the technology of producing of all micro equipment components using the same micro equipment.

It's important to ensure the simplicity of manufacturing and assembly of MMT. For this purpose all the complementary components of the machine tool must be as simple as possible. For mass parallel manufacturing process it's necessary to develop such a system of sensors and such adaptive control system, which facilitate combining of huge number of MMT in the frame of desktop micro factory, controlled by one operator.

IV. STATE OF THE ARTS IN THE MMT DEVELOPMENT

Mechatronics Laboratory (CCADET, UNAM) had developed and tested some prototypes of first generation machine tools. The main idea was to make prototypes as simple as possible, and to use minimum of industrial components, for scaling down developed micro machine tool in future generations.

CNC PROTOTYPE

The prototype is shown in the figure 1. On the base (1) the guides (2), (4), (6), for 3 carriages (3), (5), (7) are installed by the sequential scheme, i.e. each subsequent guide is installed on the previous carriage for to provide translation movements along the axis X, Y, Z. The spindle case (10) with spindle (11) also are installed on the base. The drives for carriages and for spindle use stepping motors (8) with gearboxes (9). The spindle has clamp for to grip workpiece by turning, drill by drilling or mill by milling. Support (12) has the cutter and two parallels metal pins for measurement of turned work piece diameter. For milling and drilling special gripper for workpiece should be installed on the carriage (7). The major part of the components of the MMT is made in brass and aluminum.

COMPONENTS

The main components of the prototype are:

1. Stepping motors. We make our stepping motors with 4 steps per revolution and they can be forced to make 8 half steps. They are used in the mode of high-speed rotation.
2. Carriage. The guides for carriage were made as the round bars. It simplifies the manufacturing, assembly and scaling down processes. For reasons of robustness we decided to include some balls to compensate errors of guide’s adjustment.

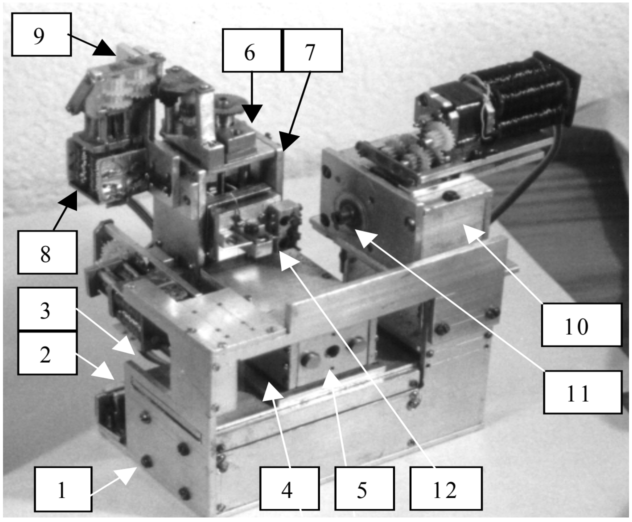

Fig. 1. CNC MMT

3. Transmission. It includes leading screws and gearboxes to reduce the speed of motors and increase the torque. All translation axes have the same configuration (gearbox, screw, stepping motor).

CONTROL

The feedback from the machine tool to the personal computer was realized on the base of four contact sensors, three of them are used to determine initial position of the carriages, and one is used to determine the moment of the contact of any tool with workpiece. This contact we used for determining relative positions of different instruments needed for the whole manufacturing process, and for measurements in the manufacturing process. We use electrical contact sensor and could have the feedback only from metal workpiece. If we need to make details from plastic, we made at first the same detail from metal, and then repeated the manufacturing process with plastic workpiesces. In principle it is possible to use other types of contact sensors (for example, acoustical contact sensor) to treatment the workpieces from any materials.
The control system, acquire the signals from sensors, using the PC´s parallel port. In order to realize the control of the MMT, we assigned a specific task for the A port (sends data form PC to MMT); the B port (receives data form sensors and motors); and, finally the C port (gives the control signals to the system).

DESCRIPTION

The MMT has 130×160×85mm, and is controlled by PC. The MMT has three translation axes (X, Y, and Z), and one rotational. The axis X and Z, have 20 mm of displacement, and Y-axis has 35 mm. All of them have the same configuration. The resolution is 1.87μm per step of the motor.

TEST PIECES

Examples of the pieces that were manufactured with this MMT are showed in Fig. 2. Those photos are compared with a match head.

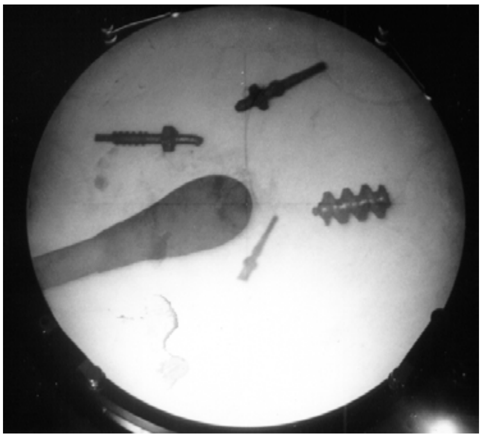

Fig. 2. Test pieces

V. GUIDELINES

On base of our experience with the showed machine, we propose some guidelines for develop low cost micromechanics. Most of all depends of the simplicity of the design. The simplicity was very important part to reduce the time of develop, and increase the viability of use same parts in many different parts of the machine. We used CAD software to improve and plan all the general schemes for new prototypes. We recommended the use of the same material in many parts of the prototypes for reduce problems associates with different thermal expansions.

In order to reduce the time of develop, we propose to include in the design processes, elements who could be reduced in sizes, and could have general applications in machines. We recommend to use simple elements for smooth displacements that require special attention to scalability and assembly.

We could resume the ideas in the next list:

1. Use of CAD Software
2. Use of same material in all parts as possible.
3. Design of pieces with general purpose
4. Simplicity of fix and assembly
5. Use of simple smooth elements (spheres and bars)
6. Use of simple elements to reduce backlash.

VI. CASE OF STUDY

In order to prove our guidelines for low cost micromechanics, we design a new prototype of MMT. This new prototype includes similar specifications, that the previous, but use the experience in design and test. First of all, we decide to change the main material to brass, in all parts as possible. With this change we propose to reduce the thermal variations of the machine. Then, we consider to use a new design with bars and spheres. This mechanism pretend reduce alignment and backlash problems.

The mayor idea consist in use a single bar with different points of fix. With that points we could use the bar like a converter of low velocity and high torque. In the figure 3 we show a general schema of this mechanism.

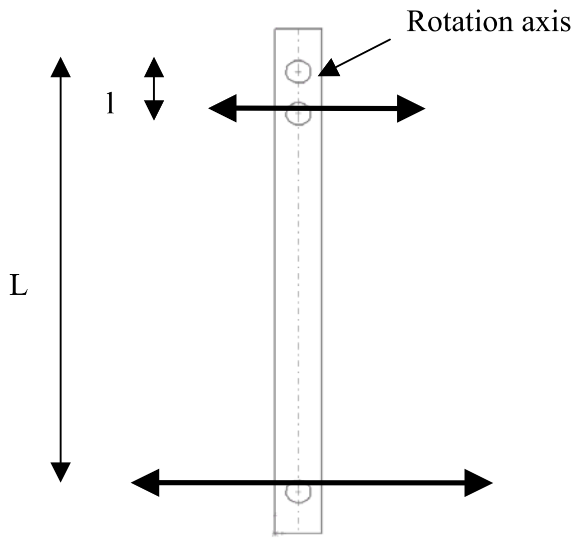

Fig 3. New power bar mechanism.

The new proposal system, consider common elements, (motors and power screws), but the operation is very different. Our new design include three bars parallelogram mechanism, to operate the three new axis (X, Y, Z). That's because this design allow us to have smooth movements. In figure 4 we show a general schema of the new axis displacement.

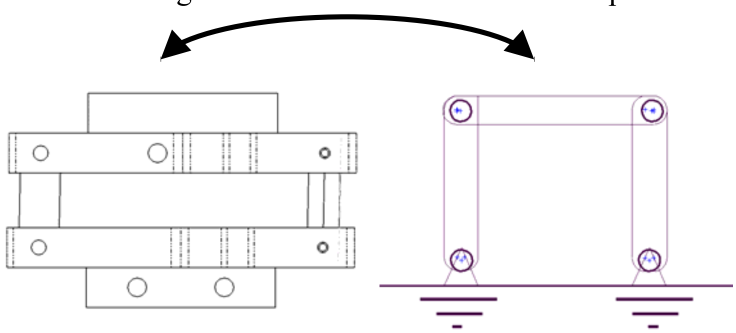

Figure 4. New axis displacement.

The new design for MMT, showed in fig 5), represents a new configuration to obtain low cost microdevices. The MMT has 180×210×135mm, and will be controlled by PC. The MMT will have three translation axes (X, Y, and Z), and one rotational. The axis X, Y and Z, have 20 mm of displacement. All of them have the same configuration. The theoretical resolution is less than 1.00µm per step of the motor. With this new mechanism, the mayor problem consist in control problem, but this new machine permit us to increase the rigidity and reduce the problems of assembly, discovered in the previous one. Actually we are manufacturing the parts to report in future their characteristics.

CONCLUSIONS

We presented a new MMT design that will reduce problems of rigidity and assembly. In order to improve these factors, we increase the size of the machine tool and the same time we increase the theoretical resolution. This new machine tool will require a new control system that includes new adjustment technique and bimodal motors. The new machine tool includes more parts, but most of all are similar. That reduces the manufacturing time.

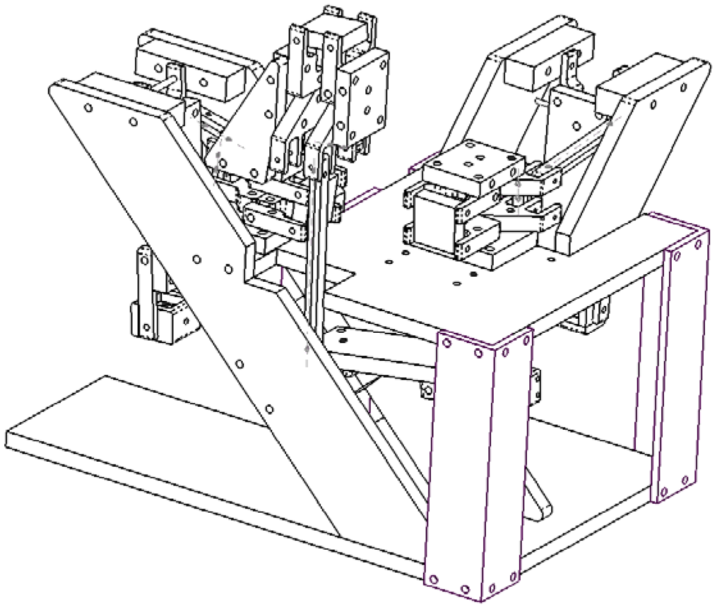

Figure 5 General Design of Machine.

ACKNOWLEDGEMENTS

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REFERENCES:

[1] Ishikawa Yu., Kitahara T. Present and Future of Micromechatronics. *1997 International Symposium on Micromechatronics and Human Science*, pp.13-20.
[2] Naotake Ooyama, Shigeru Kokaji, Makoto Tanaka and others. Desktop Machining Microfactory. *Proceedings of the 2-nd International Workshop on Microfactories*, Switzerland, Oct.9-10, 2000, pp.14-17.
[3] Bleuler H., Clavel R., Breguet J-M., Langen H., Pernette E. Issues in Precision Motion Control and Microhandling. *Proceedings of the 2000 IEEE International Conference On Robotics & Automation*, San Francisco, pp.959-964.
[4] Okazaki Yuichi, Kitahara Tokio. Micro-Lathe Equipped with Closed-Loop Numerical Control. *Proceedings of the 2-nd International Workshop on Microfactories*, Switzerland, Oct.9-10, 2000, pp.87- 90.
[5] Kussul E., Ruiz L., Caballero A., Kasatkina l., Baydyk T. CNC Machine Tools for Low Cost Micro Devices Manufacturing. *The First International Conference on Mechatronics and Robotics*; St.-Petesburg, Russia; 2000, Vol.1, pp.98-103
[6] Maekawa H., Komoriya K. Development of a Micro Transfer Arm for a Microfactory. *Proceedings of the 2001 IEEE International Conference on Robotics & Automat*ion, Seoul, Korea, May 2001, pp. 1444-1451.
[7] Mishima N., Ashida K., Tanaka M. Development of Machine Tools for the Microfactory. *Proceedings of International Workshop on Microfactories*, 2000, pp.137-140.
[8] Kussul E., Rachkovski D., Baidyk T. and Talayev S.. Micromechanical Engineering: a Basis for the Low Cost Manufacturing of Mechanical Microdevices Using Microequipment, *J. Micromech. Microeng.,* 1996, 6, pp. 410-425.