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Portable Milling Machine from Micro to Macro Parts – Usability Review

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Abstract
This review paper shows various papers related to Portable Milling Machine. Modification in portable milling machine is required to easy machining of large as well as small parts. The modification in the portable milling machine can also save the machining time and enhance the production rate. Some time the large parts are difficult to transport from one place to another place, so in this situation Portable Milling Machine is helpful to machining in simple manner. So, first we carry the literature survey on same topic to understand work done so far in the same topic. This review paper included different types of portable milling machine, their parts and modifications. As well as construction, structural design, working setup, functioning and machining tests are observed in this survey of Portable Milling Machine. The possibility of designing the portable, versatile, in situ milling machine for macro parts is considered in this review paper.

Keywords: In Situ Machine Tools, Micro Machining, Portable Milling Machine, Desktop Milling Machine, Hybrid Milling Machine.

I. INTRODUCTION

At present, CNC machine plays vital role in manufacturing sector. CNC machine is very important because it is one of the best options to reduce the efforts of the man power. CNC milling machine technology is an important technology used in manufacturing industries. Presently, all the industries are using Milling machine. The main drawback of the milling machine is that, it is only used in large scale industries but not small industries. Portable milling machine is best alternate for small industries because it is easy to control and less space is required.

In recent years, the requirements of modern and modified machine tools has expanded considerably. Generally fabrication, repair and maintenance machining has been carried out using large conventional machine tools. Which is necessarily installed in dedicated machine shops. This type of machine is helpless in the situations like either repair or maintenance/machining of large parts or fabrication of small/micro parts due to the machine tool size constraint and limitation of work table flexibility. For the repair work on large parts and considerably complex systems such as aircraft, ships, power stations, metal fabrication mills, heavy machinery, etc. the conventional type of machining is not suitable. Here “Portable machines” are used during assembly and operation due to mobility, flexibility, time and energy constraints. The scaled down components which require machining work must be dismantled from the system and shipped to a machine shop for processing before they are returned and re-assembled into the system. This process is very time-consuming, complex, dangerous and expensive. For very large systems, this type of maintenance is impossible at all. Further, this conventional maintenance process can result in prolonged downtime of the system. For these reasons, in situ machine tools which can be shipped and attached to the component to be machined, while that component is still installed in the system, can offer great advantage. An approach to solve the problem is to discard the belief work piece inside machine instead replace it by the principle small machines on large work pieces.

Another recent area of research and development is that of specialized miniaturized or micro machine tools, which have overall dimensions measuring in hundreds of millimeters or less and use compact low-power spindles. These systems can be considered as special purpose machines as they mainly address high-precision machining of micro scale products. These machines can be divided into two broad categories:

– Those which are miniature versions of conventional machine tools and
– Those which are designed around the task to be performed without holding onto traditional machine architectures.

II. LITERATURE REVIEW

A. *Types of Portable milling machine*

1) *Three-axis meso milling machine*

John Allen et.al has reported a high-precision three-axis meso scale milling machine. The overall dimensions are (200×300×200 mm) and a working envelope 20 mm^3. This machine is equipped with a 60,000 rpm air spindle and it is arranged with the spindle which is horizontally mounted and the XY positioning system is vertically mounted in front of it. The force of gravity acting on it is counter by an air bearing fitted to it to counterweight to the Y axis; the machine is illustrated in Fig .[2]

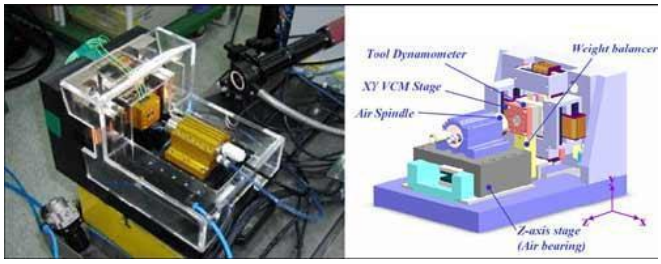


Fig. 1: Diagram and photograph of a three-axis meso milling machine [2]

2) *Three-axis desktop milling machine*

Q. Y. Wang et.al has developed machine tool miniaturization technology and micro machining mechanism, by designing a three-axis desktop milling machine tool (Fig 2). This three-axis desktop milling machine tool is having dimensions in width x length x height of 500 mm x 800 mm x 710 mm, and it can be mounted on a desk due to its small volume. The strokes of X, Y, and Z axes are 100, 50, and 50 mm, respectively. The base board is made of the cast iron, which has a good ability of vibration isolation. The Y axis is orthogonally stacked on the X axis as shown in (Fig. 2). The Z axis is perpendicular to the other two axes, which is also supported by a cast iron bracket. The close-looped motion control theory has been introduced for the purpose of developing the three-axis desktop milling machine(Fig 3). [3]

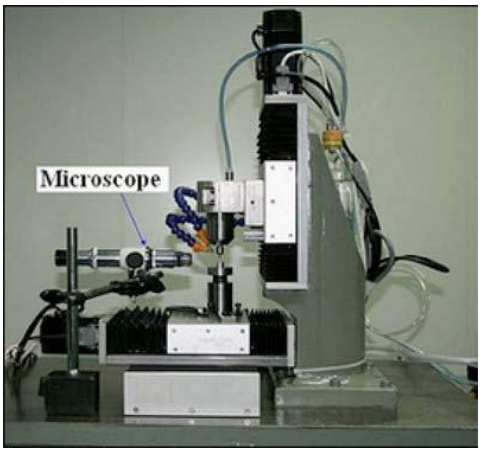


Fig. 2: Outlook of the three-axis desktop milling machine tool [3].

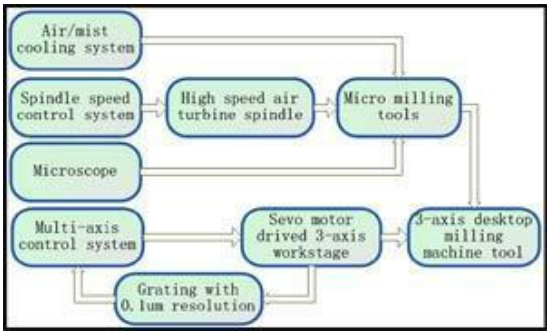
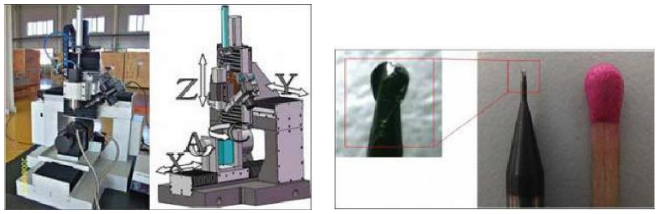


Fig 3: Structure of the machine tool [3].

3) *Five-Axis micro milling machine for machining complex 3-D meso parts*

Xiang Zhang et.al has reported five axis micro milling machine. The dimension of base body of the machine tool is 715mmx739mmx919mm. The spindle system, feed system, and monitoring system compose mainly base body of the machine tool which is installed in the marble platform as shown in Fig. 4. The feed system is composed of three precise linear stages (X-axis, Y-axis and Z-axis) and

a precise turn table which includes two precise rotary stages (A-axis and C-axis). The motion controller used is UMAC (Universal Motion and Automation Controller). An industrial video microscopy system of magnification of 300 times can be used to observe the processing. Video microscopy system compose of the lens of the microscope, high brightness cold light source and video processing software [4].



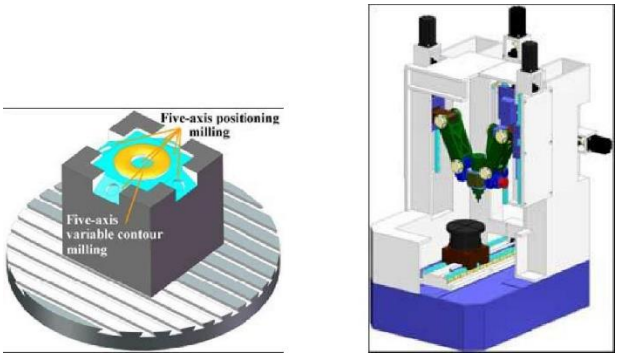
(a) Five-axis micro-milling machine tool
(b) Micro-ball-end cutter

Fig. 4: Base body of the machine tool [4]

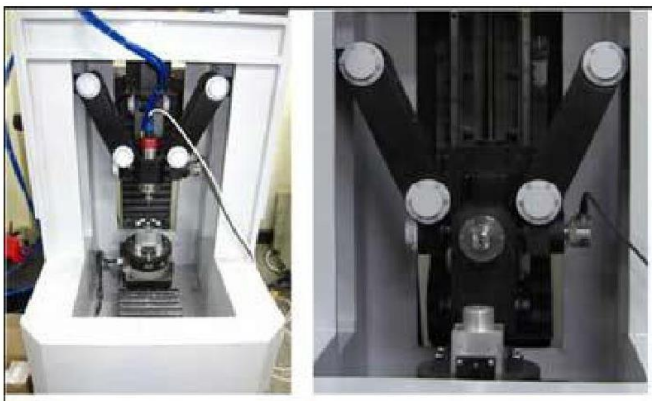
4) *Hybrid five face milling machine in one setup*

Fugui Xie et.al has reported a hybrid five face milling machine. The work piece presented in Fig. 5(a) has a free form surface, several flat surfaces, and holes under different tilting angles. This application is both five-axis positioning milling and five-axis variable contour milling. The mechanism of the prototype is based on a 3-DoF parallel module and a 2-DoF serial table, and the parallel module has two translational DoFs and a rotational DoF. The mobile platform of the module can rotate from a configuration of -25° to one of 90°. The serial table has a translational DoF and a rotational DoF. With this combination, the SPKM165 is capable of five-face milling in one setup [5].

An example of work piece manufactured from hybrid five face milling machine is shown in fig 5(a).



(a) A classic five-axis milling application (b) CAD model of the hybrid milling machine with actuation redundancy.



(c) Overview of the RASPET150

Fig. 5: Hybrid five face milling machine [5]

B. Performance And Machining Tests

In the machining test of three-axis desktop milling machine, three micro components such as micro gears, micro thin walls and micro electrodes made from copper alloy or aluminum alloy have been machined by end milling tools in diameter of 0.1, 0.2, and 0.4 mm. The machining ability of this three-axis desktop milling machine tool in aspect of three-dimensional complex micro structures is verified by the machining tests [3].

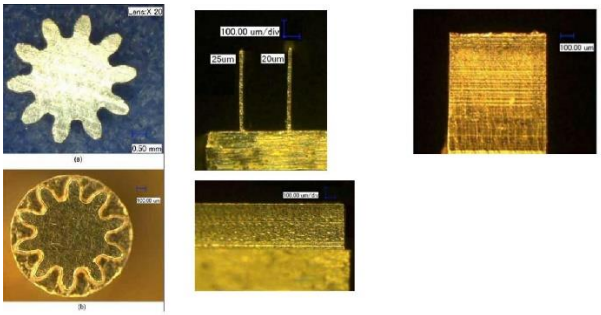
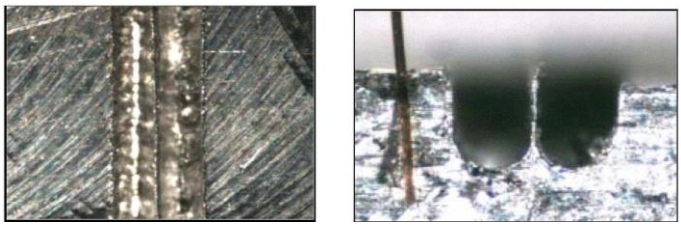


Fig. 6: Micro parts made from 3-axis desktop milling machine [3]

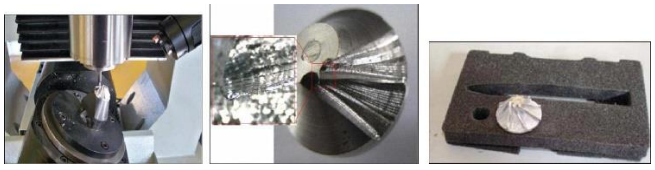
In machining test of 5-axis micro milling machine, the machining test used a ball-end milling cutter of O.5mm diameter, and processed a 2D straight thin-wall structure with the size of 500micro-m X 30micro-m in LY12 duralumin.



{a} Side view of2D thin-wall {b} Top view of2D thin-wall

Fig 7: Structure of 2D straight thin-wall[4]

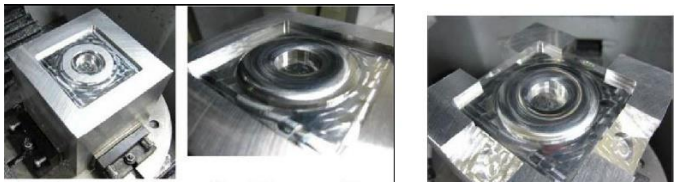
In the same material a 3D curved surface thin-wall structure was processed, and the thinnest of top thin-wall was l00 micro-m.Fig 8(a). To check the machine tool processing capability for complex 3D parts, the parts of a mini impeller applying to process 5-axis machining was designed. The diameter of bottom of the impeller is 20mm, and diameter of top is 4.4mm. It is composed of 8 blades, and the thinnest department of blade is only 0.22mm. In machining first, use a ball-end cutter with diameter 2.5mm to do the 3-axis rough machining for removing the most material. Secondly expansion of the channel by using a ball-end cutter of 1mm diameter processed 8 channels [4].



(a) Structure of 3D curved surface (b) Semi-finish machining of mini impeller (c) Processed impeller thin-wall

Fig 8: Meso-Scale parts made from 5-axis micro milling machine [4]

The work piece shown in Fig. 5(a) is machined in three steps. The material of the work piece is aluminum alloy (LY12). Step one consist - Cavity contour milling: this is the application of three-axis positioning milling. The finished work piece is shown in Fig 9(a). Step 2 consist variable contour milling: this is the application of five-axis milling. In this procedure, the rotational angle of the mobile platform is within the range of [-16°, 23°], i.e., θ∈[-16°, 23°]. As shown in Fig. 9(b), the finished surface is very smooth and slightly shiny. Step 3 consist five-axis positioning milling: the finished work piece presented in Fig. 9(c) has several tilting surfaces and holes under different angles. Thus, five-axis positioning milling capability is required. If the tilting angle reaches 90°, five-face milling capability is necessary. [5]



(a) Cavity contour milling (b) variable contour milling (c)Five-axis positioning milling result

Fig. 9: Machining experiment results [5]

From the literature survey, the following points are observed:

- With five axis micro milling machine, 2D thin wall, 3D curved surface and a mini impeller is machined with precision.
- With three-axis desktop milling machine, micro gears, up to 20 micron thin wall, and a microelectrode is machined with accuracy and precision.
- With the hybrid five face milling machine in one set up have precisely made a work piece with flat surfaces and free form surfaces with cavity contour milling and variable contour milling operations.

In recent years the demand for manufacturing large parts is increasing, most of the advances in the field of machine tools for large parts have been achieved by solutions proposed by the industry. For the machining of large parts transport, handling, clamping and measuring have the great impact in machining time cycle. By the use of in situ repair operations we can save so mach of machining time and maintenance time

There are much less researches done on versatile miniature machine tools for machining macro scaled down parts. Though there are large scaled special purposes machines exist for machining macro sized parts, such as aerospace industry, naval industry, power plants, rail roads. The research can be done

on the area of the development of versatile, miniature machine tools for machining large complex industrial systems. When the machining of components have an uncommon high ratio of overall dimension the machining in conventional type milling machine is not possible. In such cases the portable, in situ machining is the best solution. The portable milling machine has the following advantages:

- Robustness
- Mobility
- Miniaturization
- Adaptivity
- Mutability
- Multi Functionality
- Specialization
- Energetic Networking

Conclusion

With all the above mentioned benefits of portable milling machine there is the ease of transportation and fitting the miniature sized machine inside/on the huge geometry. This will be very comfortable work environment for the future trend of machining. So, the future work can be done on the idea of bridging the gap between machining micro to macro sized parts.

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