5-Axis Milling Machine for Drilling Inclined Holes in Parts

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Abstract:
This present 5-axis milling machine which can be used an artifact-based identification is proposed and implemented based on drilling holes in various locations and orientations, and to produce a complex shape parts, and be easily operations done with high accuracy and reduced human effort and reduced manufacturing cycle time.

The 5-axis milling machine present in this paper is mainly composed by machine head and machine table. The machine head to rotate the machine head about a substantially vertical axis. The machine head include a tool spindle. Rotational movement of the machine head moves the tool spindle in an accurate path so that accurate shapes may be machined and drilling holes in various location and orientations, also with help of rotation of table at 3600 in vertical axis or horizontal axis.

Keywords: *5-axis machine, inclined holes, functional machine, Multi-axis, Tools*

1. Introduction

A.

Complex shaped parts such as dies, moulds, turbine blades, automobile and aerospace parts cannot efficiently be machined and also cannot effectively and accuracy be drilling holes in various locations and orientations by three-axis milling machine.

In pharmaceutical company, packaging of tablet, capsules, serine etc. using by blister packaging machine. These machine consist number of change parts, in one of the forming die, these die in number of inclined holes required for suck the air in cavities to formation of cavities shape on PVC foil. These holes diameter is 0.8 mm and inclination angle range is 5^0-35^0. (Shown in figure1)

These inclined holes are very difficult to drill on 3-axis milling and any types of radial drilling machine. These complex operations more difficult on cylindrical parts. Presently, this drilling operation performed by manually with help of drilling machine, but they required high skill worker and also required more manufacturing cycle times.

B.

Concluded on above problem (section 1.1), an inclined holes cannot possible drill on 3-axis milling machine therefore invention of 5-axis milling machine. In 5-axis milling machine is extended from 3-axis milling machine, the present 3-axis milling machine in add the two more axis's. First axis, the machine head to rotate the machine head about a substantially vertical axis with up to 450. Second axis, table is rotate at 3600.

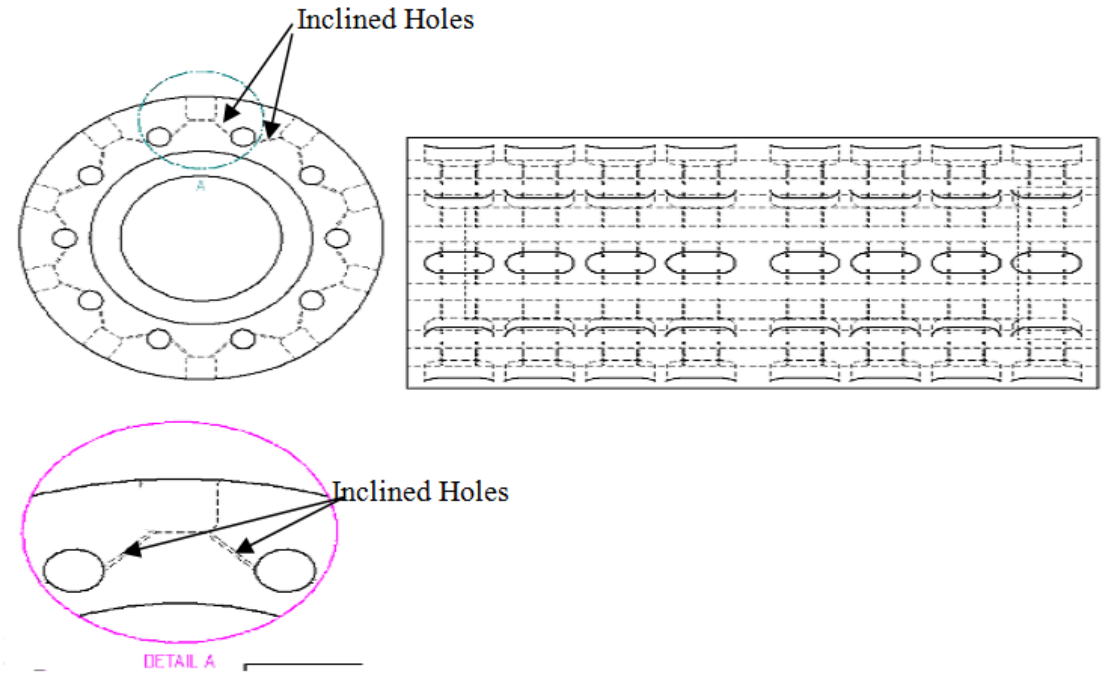

Fig. 1: Forming Die with inclined holes

2. Historical review of multi-functional machine tools

A. Multi-functional milling machines

The milling machine, which uses a rotary cutter with multiple edges, was developed by Elly Whitney in 1827 in USA [5]. It was initially mainly used to machine flat surfaces. The application of the milling machine was later expanded to 2D and 3D surfaces. The first NC machine tool developed by John T. Parsons in 1952 was a 3- axis milling machine. A noteworthy advancement of the NC milling machine was the development of the Machining Center (MC). The first MC named Milwaukee-Matic was developed by Kearney and Trecker in 1958 as shown in Fig. 2. One of the specific features of the MC is the automatic tool changer or ATC so that various kinds of milling as well as drilling operations can be performed once the work is fixed on the table. As the rotary table or index table was equipped on the MC, it became possible to machine five faces of a cubic workpiece. The attachment to change the direction of the main spindle from horizontal to vertical or from vertical to horizontal was also introduced to machine the five faces of the work. Most of the MC's at this stage contained simultaneously controlled three Cartesian axes (X, Y, and Z).

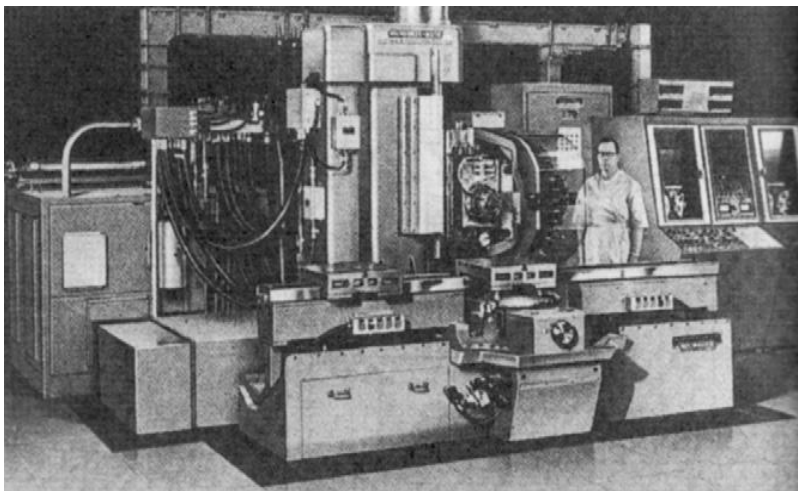

Fig.2: Milwaukee-Matic Model II developed by Kerney and Trecker in 1958.

3. Literature review

M. Boujelbane [1] discussed about 5-axis machine with Computer aided design (CAD) software systems give us the potential to model very complex shapes. The growing complexity of products has been pushing the development of new manufacturing technologies. Complex or organic geometries introduce different and more complex manufacturing problems. Dies and mould are usually machined using 5-axis ball end milling. Due to the increasing demand for higher accuracy, lower machining time, and higher surface integrity, several researchers have investigated the effect of cutter orientation on surface roughness and tool life. Based on a comparative study of milling at different inclination angles, they concluded that downward/reverse milling with a tool inclination in the range of 10-20 degrees represents the optimum machining strategy.

Y.-B. Bang [2], developed Micro cutting by precision machine tools is an effective method for producing 3D micro parts. Therefore, research related to micro cutting is being performed. In this researcher constructed a precision 5-axis milling machine of compact size (about 300 mm in height) and at a low cost (about 1/10 of the cost of precision milling machines on the market), which is available for machining micro parts. This machine is composed of three precision linear stages (X, Y and Z-axis) and two precision rotary stages (A and C-axis).

Werner Babel [3], the invention concerns a milling head for machine tool, which has housing and in it a working spindle mounted so it can move axially, and the workhead, which can move horizontal on the face, is mounted so it can pivot on a horizontal axis of rotation.

Leslie P. Stickney [4], invention of a milling machine is provided with a substantially vertical support on which a machine head is mounted. The machine head includes a mounting portion which is rotatably attached to the vertical support for rotational movement about a substantially vertical axis. The machine head is provide with tool spindle in which a milling tool may be mounted for milling a workpiece supported on bed of the machine.

N.Mishim [6] has developed various types of conceptual design of supports of machine tool for multi-axis machine tools. In this research the author tried to develop a new design tool to support decision making at the conceptual design stage of machine tools. The proposed design evaluation method based on robust design methodology was effective in determining suitable structure of machine tools.

4. Multi Axis milling

Multi-axis machining is a technology which underwent important innovation; it allows the realization of complex shape pieces for aeronautical and automotive industries, and for dies and moulds. Milling surfaces dies and moulds often requires the utilization of two supplementary rotary axes, (fourth and fifth axes) of the machine-tool, to improve the precision of machining, with respect to geometry of the workpiece and surface quality, to increase tool life and avoid collision between cutter and the part (see figure 3). Drilling inclined holes in dies and moulds, crankshaft and others automobile and aerospace part also often requires rotary axes (4th & 5th axes) of the machine tool. The machine have a 3 axis Cartesian structure (X, Y, Z) with the addition of two rotators axis of the table (C) and the second rotation axis of the spindle (B).

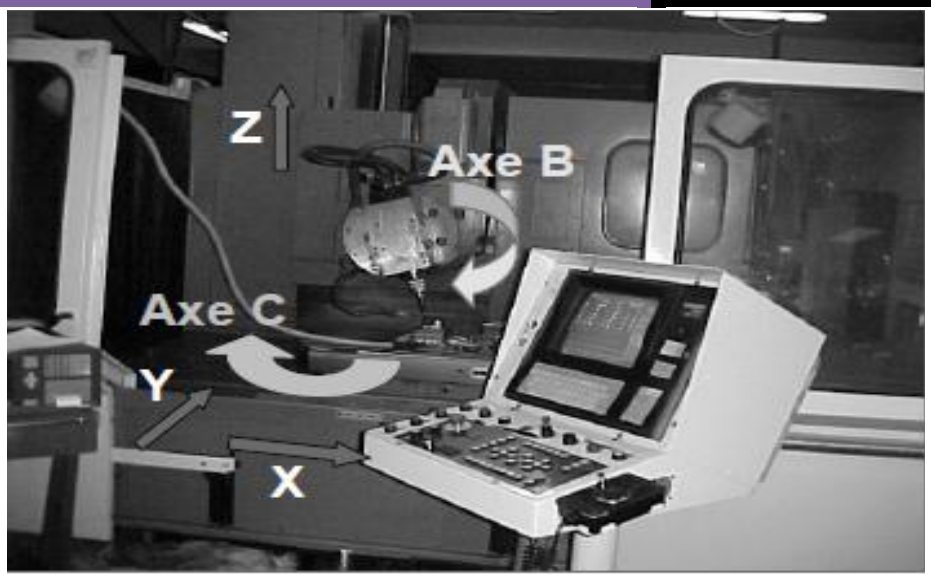

Fig.3: 5-Axis milling Machine

4.1 5-axis milling machine

Five axis machining is carried out on machine tools which have two rotation axes (A; B or A; C or B; C) allowing the tool to be oriented relatively to the part in addition to the usual axes of translation X; Y; Z: In the present work, we are only interested in continuous 5- axis machining, the most generally used for aeronautics parts. Continuous 5-axis machining is used for the surface milling with ball end cutter, and flank milling with cylindrical or conical cutter.

Industrially, most of the existing milling and engraving machines are three-axis machines. Only the relative displacement is to be controlled in these cases. The relative orientation is no controlled. A five-axis machine allows the tool to reach five-faces of the work-piece. This is realized through the two additional relative rotations between the work-piece and the tool.

4.2 Why 5-axis milling machine

4.2.1 Reaching tilted/side planes

That is, tilted with respect to the X-Y plane. This is another way of saying 5-face machining.

4.2.2 Maintaining better cutting quality

This is because the optimum orientation from point of view cutting angles can be maintained. That is, certain cutting process can be realized just by varying the z-value. However, as the cutting process precedes new planes that neither parallel nor normal to the X-Y plane are created. Tilting the cutter will allow maintaining the desired relative orientation between these new planes and the cutter.

4.2.3 Realizing more intricate details

A cutter with conic shape can allow realizing more cutting depth of an intricate contour. In the figure below, if the width of the contour is 1mm, then a cylindrical tool will be able to go may be only 3 or 4 mm deep and the shank of the tool in this case would be 0.8 mm. On the other hand a conic tool that is tilted as shown in Figure 4 below can have a larger shank for the same depth of cut and contour width.

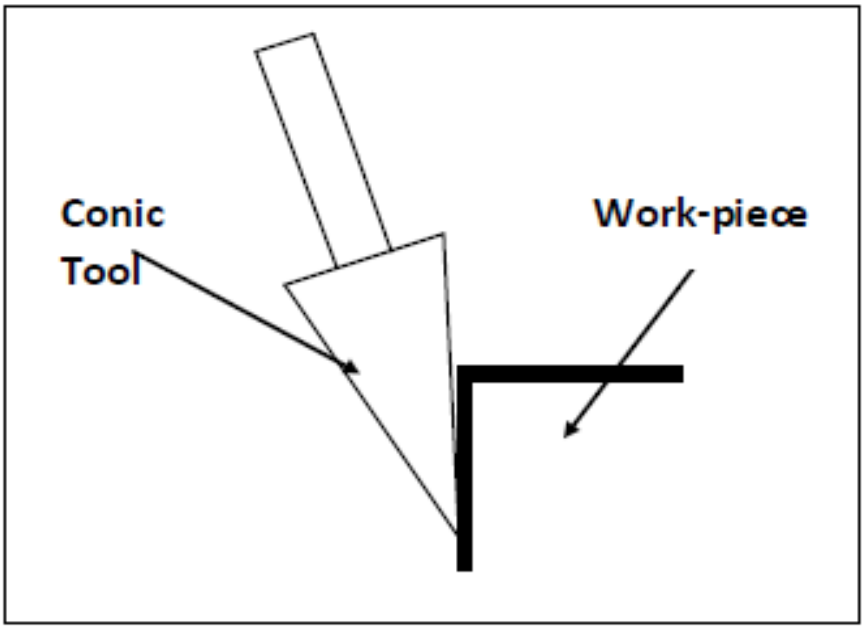

Fig.4: Conic Tool and 5-axis to realize finer details

4.3 Milling Head

In 5-axis milling machine, the machine head is rotate in substantial vertical axis. This rotation of machine head is add in the 3-axis (X,Y,Z) conventional milling machine, the machine head rotate rang is 00-450 with both side (i.e. +A or -A). This rotation is one of the main axes in 5-axis milling machine (shown in figure 5). When we want inclined holes, achieving the complex shape, then, these machine head rotate in required angle from 00 to 450; it may be in left side or right side. Therefore, it's easy for performing the operation on the parts.

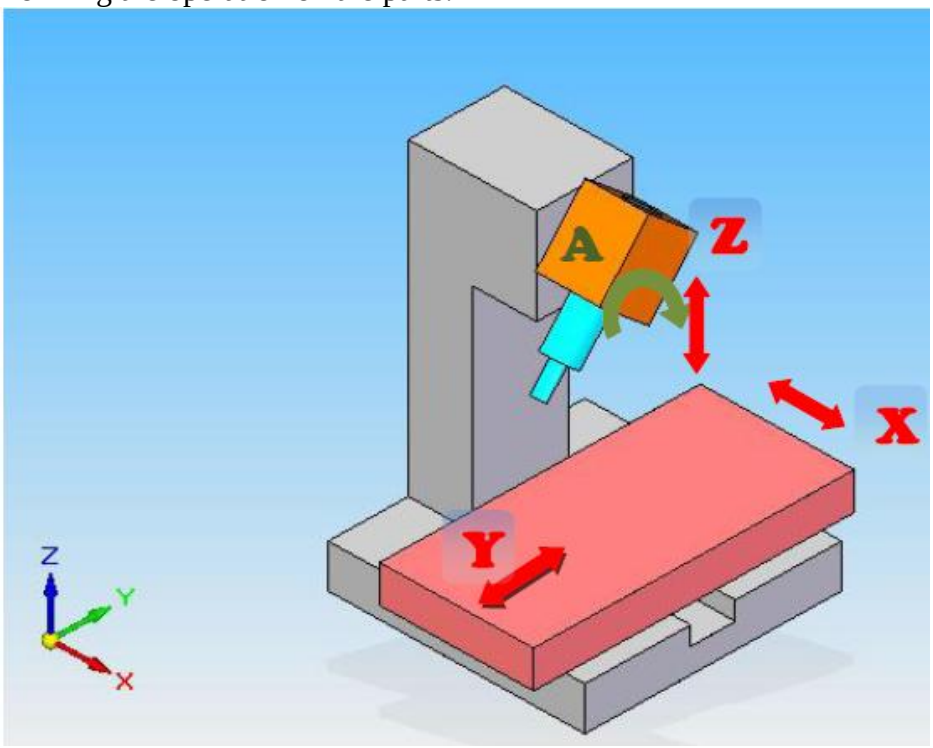

Fig. 5(a): Isometric View of Machine head Rotate in 5-axis milling Machine.

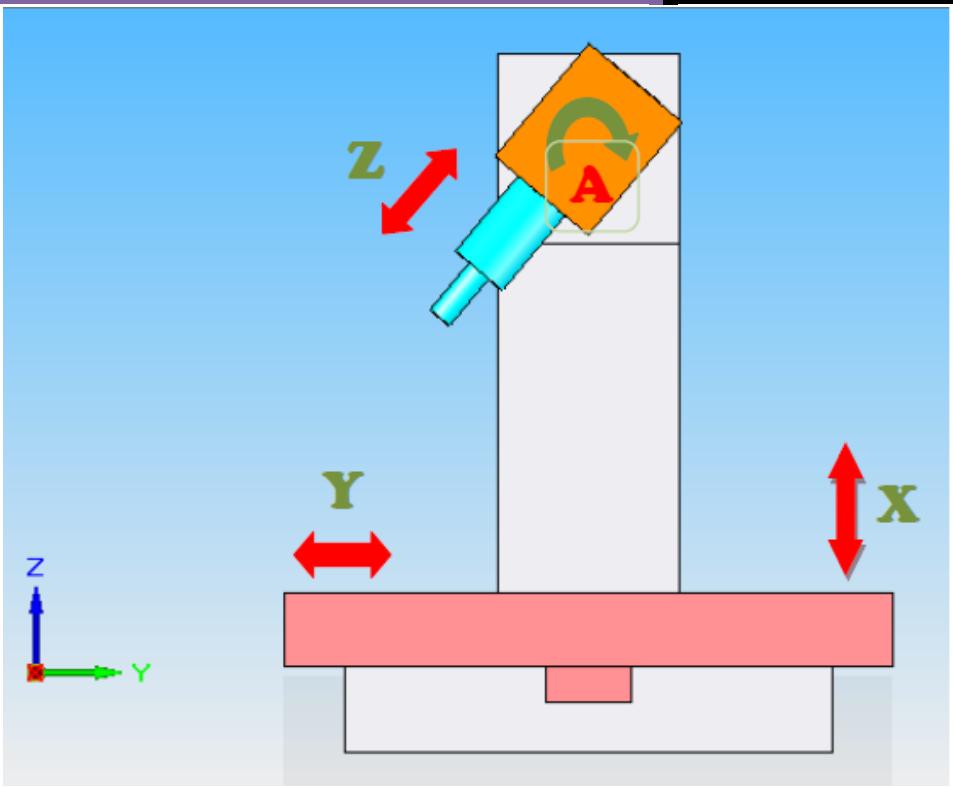

Fig. 5(b): Front View of Machine head Rotate in 5-axis milling Machine.

4.4 Rotating Table

Rotating table is a second axis of 5-axis milling machine; table may be rotate in vertical axis or horizontal axis (shown in figure 6(a)).This is another mail axis in 5-axis milling machine. If cylindrical part is hold in work-piece holding device the table rotate in axis of cylindrical part (shown in figure 6(b)), in certain degree of rotation for the cylindrical parts hold in particular position. other axis is rotate in vertical axis, if part is fix on the table, we have to rotate the table at 3600 in vertical axis (shown in figure 6(c)) because of that it eliminates the repetitive task for loading and unloading of parts, which ultimately reduces the cycle time, and also helping to produce the complex part or components.

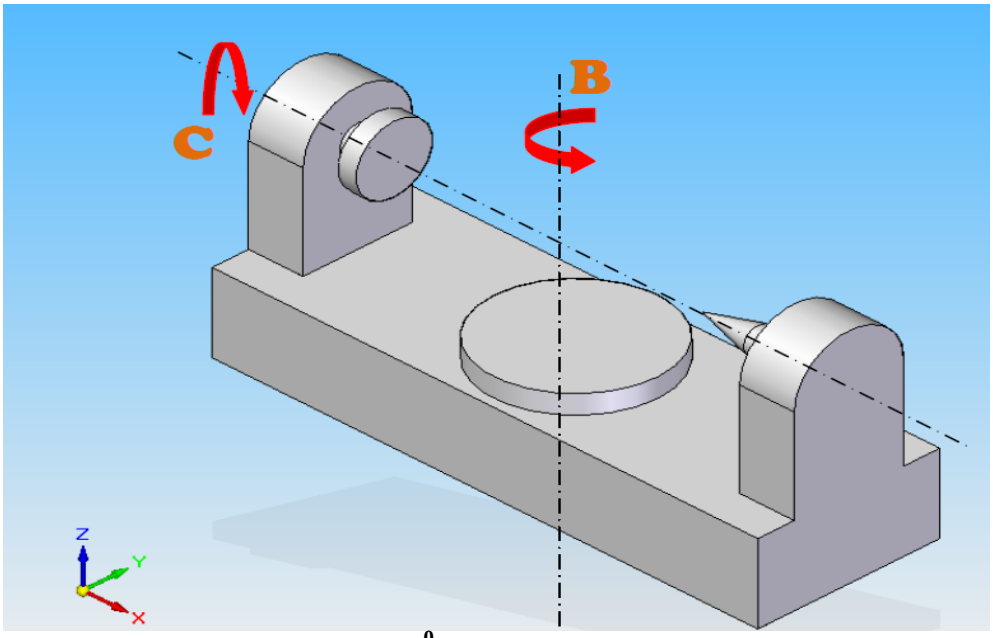

Fig.6 (a): Table rotates at 360^0 in Vertical (B) and Horizontal (C) axis.

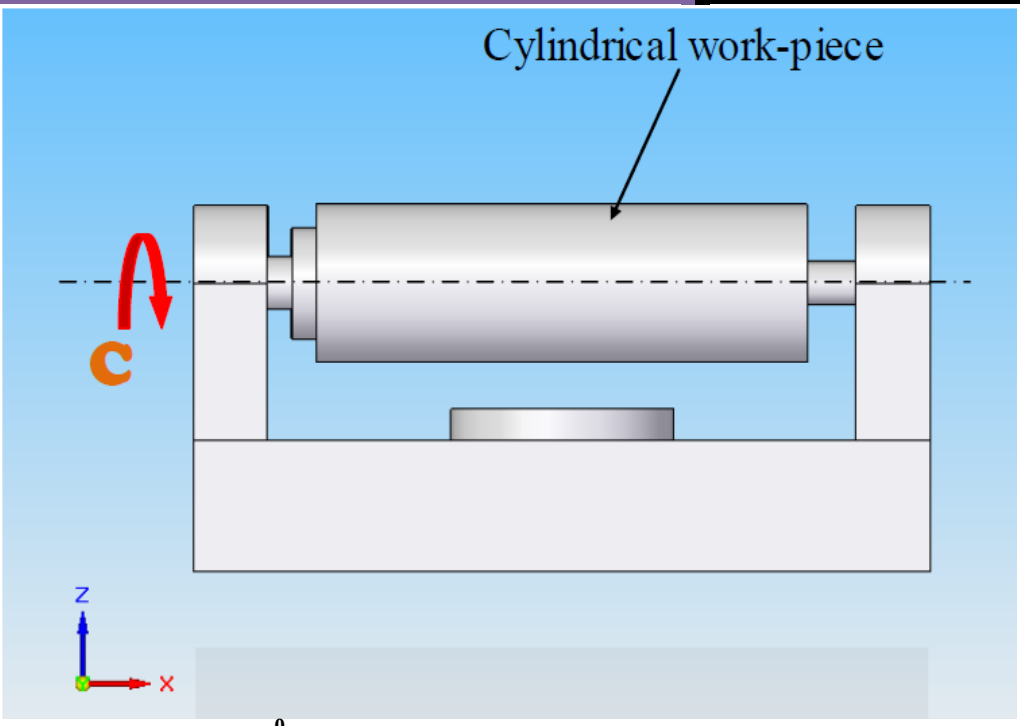

Fig.6 (b): Table rotates at 360^0 in Horizontal axis (C-axis) with cylindrical component holding.

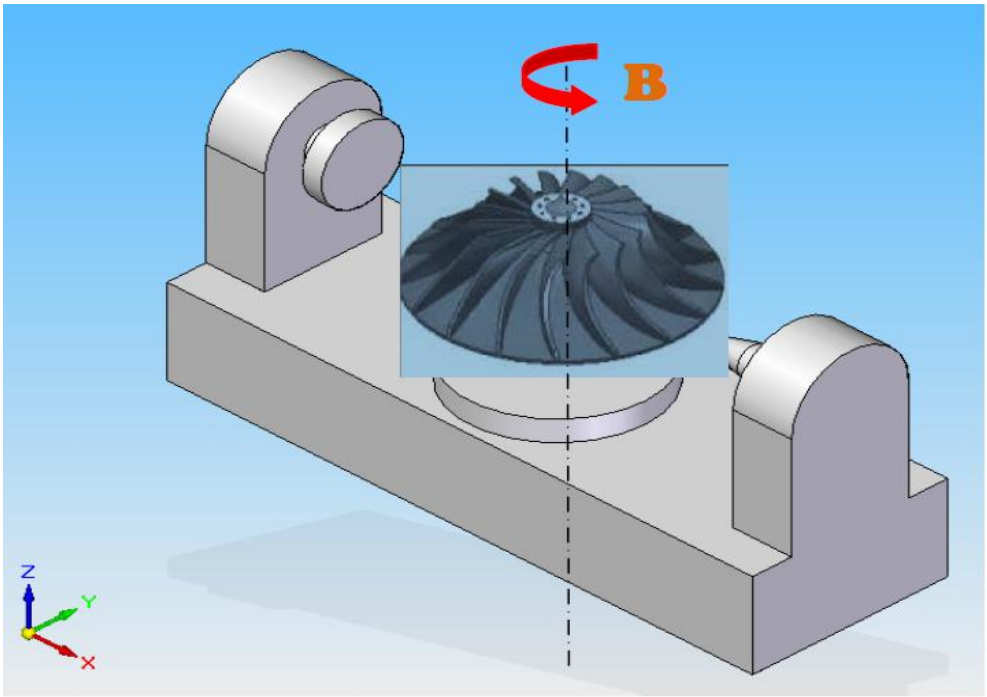

Fig.6(c): Table rotates at 360^0 in Vertical axis (B-axis) with complex component.

5. Advantages of 5-axis milling machine

- Simplifies fixturing = saving on Fixture and Tooling Costs.
- Reduces the Number of Machines Needed = Less Investment/Space Saving.
- Reduces Cycle Time = Increases Profit.
- Elimination of Human Error = Increases Part Accuracies.
- Shorter Cutting Tools Can be Used = Less Vibration, Eliminates the Need for Special Cutters and Reduces Cutting Load.
- Reduction in Machining Process = Improvement of Production Schedule.

- Some 3D parts with curved surfaces simply cannot be machined without using a 5-axis milling machine.
- The error caused by the re-clamping can be eliminated: once the workpiece is clamped, there is no need for re-clamping in a different direction.
- In case of machining cylindrical shapes, *A*-axis rotation can be used without *X* and *Y*-axis interpolation; therefore, precise machining can be easily performed.
- The 5-axis machine has a fast material removal rate and improved surface finish.

Increased Part Accuracy – Improved Surface Finish – Higher Cutting Speeds

6. Limitations of 5-axis milling machine

- Reduced Rigidity.
- Reduced working envelope.
- Reduced federate.
- Hard to implement automatic tool changer.
- For compact heads- no taper, collets are used.
- Total accuracy depends heavily on the rotary axes accuracy and setup.
- Accuracy depends on accurate tool length data.
- This machine is costlier than 3-axis machine.

7. Application of 5-axis milling machine

7.1 Parts for Aeronautics and Space Industry

High strength and low weight are essential for the aeronautics and space industry. Integral construction has established itself as the way to minimize the weight of "airborne" parts: components with complex structure are manufactured completely from a single blank. Metal removal levels can be as high as 95 %. This high "buy-to-fly" rate leads to high costs for the raw material of the blanks.
In the area of structural components, 5-axis machining opens new opportunities for reducing weight without loss of component strength.

7.2 5-axis machining in automobile manufacturing

Uncounted molds and dies are needed in automobile manufacturing for sheet metal and plastic processing. Dies for sheet metal forming can be up to 6 m long and need to be milled at the very high accuracy of ± 0.02 mm so that the upper and bottom dies can work together with the correct gap. Moreover, a very high surface quality of all functional surfaces is necessary in order to ensure that the forming tools have a long service life.

7.3 Five-axis machining in the field of medical technology

In the field of medical technology, demand is high for devices that are adapted to special examinations or therapies. This can make treatments considerably more precise and reduce aftereffects on the patients. The devices are often characterized by very complex geometries that make 5-axis machining of single parts on milling machines attractive.

8. Conclusion

This paper has discuss about inclination holes produce in forming die is difficult by 3-axis machine. So, concluded on that problem, we want adding of two more axes in 3-axis machine i.e. call 5-axis machine. 5-axis machine is very beneficial for producing the inclinations holes as well as to produce complex shape components such as aerospace parts and automobile parts.

5-axis machine is reduces the manufacturing cycle time, the re-clamping can be eliminated: once the workpiece is clamped, there is no need for re-clamping in a different direction, reduces the number of machines needed, elimination of human error.

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