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Robotic Milling: A New Era of Machining

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Abstract:
Robotic milling is considered as an alternative solution of CNC milling, however there are significant difference between these two processes. CNC milling technologies enabled new possibilities in constructing complex digitally generates architectural shapes but have restricted working area and produce shape limitation. Industrial robot are an appropriate technology for developing flexible and reconfigurable, manufacturing systems. Which contribute to perform various automated operation such as milling, cutting, drilling , grinding, surface finishing etc. the work presented in this paper tackles some specific aspects regarding the cam techniques used for robotic milling to overcome the shape and size limitation of CNC In this paper we provide some comparative study about how changing the various parameter leads to change in functioning of robot to obtain good surface finish and to enhance the accuracy and repeatability of robotic milling. This document is designed to provide nowadays technology, future potential and technical constraints about the robotic milling and its advantages.

Keywords: robot, milling, cad/cam.

I. Introduction

In 1954 George Devol invented the first digitally operated and a programmable robot called the Unimate. In 1956, Devol and his partner Joseph Engelberger formed the world's first robot company. In 1961, the first industrial robot, Unimate, went online in a General Motors automobile factory in New Jersey.

Introduction of robot into the production process becomes important, particularly, wherever the technological requirements are higher. Robot had made the working process easier, but it is also important in view of increase of quality and continuity of the manufacture of products, leading to operating cost reduction. The application of industrial robots in high-precision contact applications such as machining operations has received significant interest in recent year. One example of development in this area has been the automatic generation of 3 and 5-axis tool paths from CAD/CAM software to robot programs.

The applications in industry, where robots have proved to be the best solution, include palletisation, installation, machine operation, grinding, Polishing, laser and plasma cutting. Using robots for production with increased complexity of products calls for new forms of integration of robots in the manufacturing processes or systems.

The drilling and milling operations were already handled by an automated gantry-based system but could not support the Additional workload. Robotic milling has four distinct advantages:

1. Flexibility: - The large range of motion inherent to an articulated arm enables the system to be applied to various Products. Should the rate requirement decrease in the future or change significantly from its initial application, it can continue to be adapted and utilized on other assemblies, including those with complex geometries.
2. Lower cost: - Because industrial robots are produced in high Volume their cost is low and reliability is high compared to Customized positioners.
3. Minimal installation disruption: - As with most automation, the robotic system had to be installed into an active factory and disruption to production was to be minimized. The Robotic system is modular and can be easily broken down into smaller, manageable components, such as the 6-axis positioned, linear track sections, control cabinet, etc.
4. Large working volume (dual zone):- The first axis of the robot provides a huge advantage as far as working volume. When mounted to a linear axis, the robotic system can be configured to perform assembly operations on either side of the bed ways, effectively doubling the system's working volume.
Machining through robots has lot of advantages as well as several disadvantages

1. Accuracy Issues:
Most industrial robots are constructed as a cantilever, in which each of the arms is supported by motors, brakes and reduction gears, they struggle to achieve high positioning accuracy level, being limited to 0.5-2mm (Vergeest & Tangelder, 1996) and at the same time are more prone to disturbances from the process forces [1].
2. Vibrations – Chattering:
Another main issue of robot machining is the effect of vibrations to the produced surface quality. Due to the low natural frequency of articulated robot body, resonance can occur due to machining process vibrations [2]. Oki et Al., focusing in the cutting of work pieces from an extruded aluminium alloy, assessed the effect of vibrations on the characteristics of end milling operation. Their experiments proved that during high-speed cutting, the generated process frequency is high enough without resonance issues, ensuring stable and normal end milling with restrained chatter and vibration of the articulated robot [3].
3. Programming:
As far as the programming side of machining with industrial robots is concerned, it is still a major disadvantage against the conventional CNC machines. Robots are mainly programmed using the traditional “teach and repeat” method of programming. The user manually moves the robot in predefined positions and the robot save the coordinates. As a result, the accuracy is not of great importance for this method and is generally regarded as being poor.

II. Types of milling

1) **3-axis milling**: -
An axis is a direction of motion controlled by the CNC machine control. It can be linear (motion along a straight line) or circular (a rotary motion). ... For machining centres, a three axis machine will have three linear axes. An axis is a direction of motion controlled by the CNC machine control. It can be linear (motion along a straight line) or circular (a rotary motion). ... For machining centres, a three axis machine will have three linear axes.

Advantages

- 3 axis milling is capable to generate 3d surface.
- 3 axis has more flexibility than CNC machining

Disadvantages

- 3 axis milling require highly skilled labour intensive.
- 3 axis milling has very low surface finish.

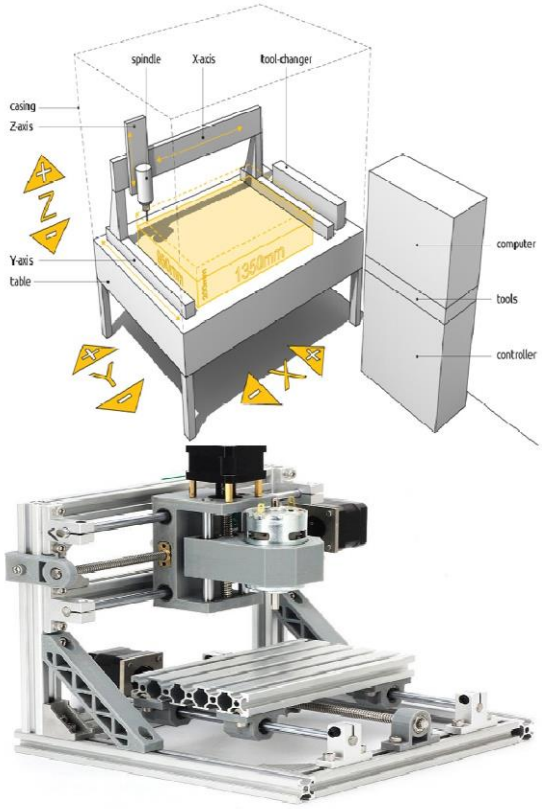

Fig.1 Linear robot or 3 axis robot

2) 4-axis milling:

4-axis milling involves the same processes involved in 3-axis machining, where a cutting tool is used to remove material from a piece to create the desired shape and profile. However, in the case of 4-axes machining, milling is performed on an additional axis. A 4-axis CNC machine operates on the X,Y and Z axes like a 3-axis machine, but it also includes rotation around the X-axis, which is called the A-axis. This is the 4th axis that's added to our machining process. In most cases, the work piece will be rotated to allow for cutting to occur around the B-axis.

4-axis milling is useful when holes and cut-outs need to be made in the side of a piece or around a cylinder. They can provide quick and efficient work based off computer numerical inputs for precise results. The 4 axis scara (supervisory control articulated robotic arm) robots shown in fig.2.

Fig.2SCARA robot (supervisory control articulated robotic arm)

2) 5-axis milling :-

As its name indicates, 5-axis machining uses a tool which moves in five different directions corresponding to the 3 linear X, Y and Z axes, to which are added two axes, A and B, around which the tool rotates. With such a configuration, the part can be approached from all directions and can be worked from five sides in a single operation.

Unlike 3-axis machining, this technique is extremely suitable for deeper parts made from harder materials, and it guarantees a high degree of precision due to using shorter machining tools. The machining speed is also faster, while tool vibration is reduced.

In addition, whereas operating 3-axis machining is simpler 5-axis machining requires longer preparation time but less material handling. The

5 axis robot shown in fig.3.

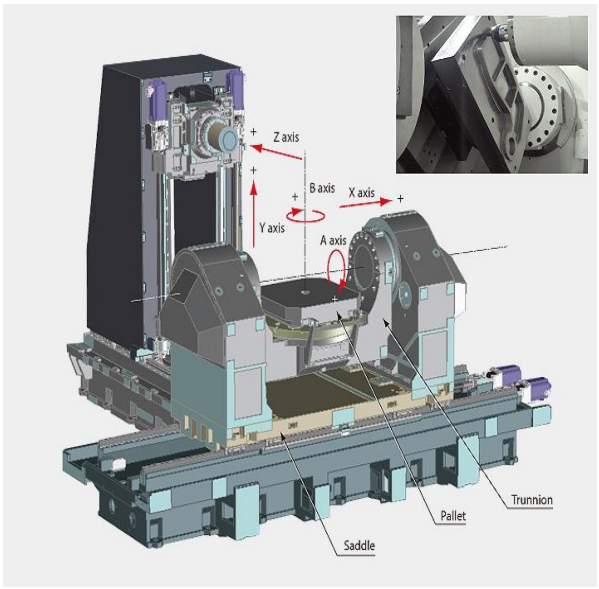

Fig.3. Articulated 5 axis robot.

Advantages-

- Five-axis machining enables can work using shorter tool because we can lower the tool mounted using the axis robot reaching the surface to be milled so it offer flexibility to increase speed and reduces vibrations of tool.
- Five axis milling is able to machine complex design easily in less time period which improve process efficiency.
- Five axis machine can design the complex part easily so we can improve accuracy so it solve our problem to cast complex parts.
- With a five-axis machine, we can perform the drilling operation with high degree of accuracy, in very less time period.

Disadvantages-

- Need for Expensive and special machine tools with spindle and controllers.
- 5axis milling is milling leads to machining the parts from several orientations so it makes high tool wear.

3) 6-axis milling:

6-axis machining uses a tool which moves in six different directions corresponding to the 3 linear X, Y and Z axes, to which are added three axes, A, B and C around which the tool rotates. With such a configuration, the part can be approached from all directions and can be worked from six sides in a single operation.

This technique is extremely suitable for deeper parts made from harder materials, and it guarantees a high degree of precision due to using shorter machining tools. The machining speed is also faster, while tool vibration is reduced.

6-axis machining requires longer setting up time but less material handling.

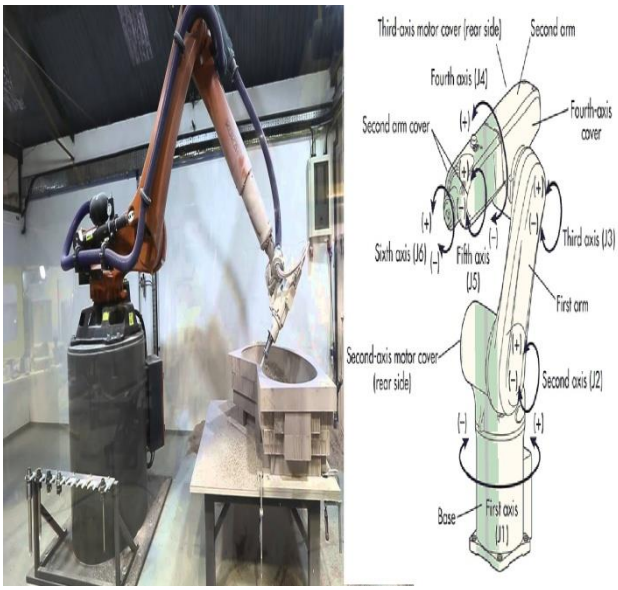

Fig.4. Articulated 6 axis robot.

Advantages-

- 6 axis robot are Easy to handle and flexible enough to machine difficult part easily [4].
- Lead time is reduced for machining complex part due to high degree of freedom and also easy to learn programming methodology.
- High repeatability is one of the key selling point of any robot in order of their working capacity.

Disadvantages-

- Need for Expensive and special machine tools with spindle and controllers.
- It require large setup time which require a skilled professional to fix the parts properly in order to achieve high surface finish.
- The tool is consumed at a very high rate.

4) **7-axis milling:**

7-axis machining uses a tool which moves in six different directions corresponding to the 3 linear X, Y and Z axes, to which are added three axes, A, B and C around which the tool rotates. The additional 7th axis is generated by moving the work-piece.

With such a configuration, the part can be approached from all directions and can be worked from six sides in a single operation, as well as moving the work-piece gives the extra edge to machine the required part smoothly and efficiently with very high degree of accuracy.

This technique is extremely suitable for deeper and shallow parts made from harder materials, and it guarantees a high degree of precision due to using shorter machining tools.

The machining speed is bit slower due to the calibration of 7th axis, while tool vibration is reduced. With the help of seven axis machining we can machine the complex design such as sculpture, antiques, and other mechanical equipment efficiently.

7 axis milling is a technology which enhances surface finish as well as increases the quality of the product and also enhance the surface finish of the product.

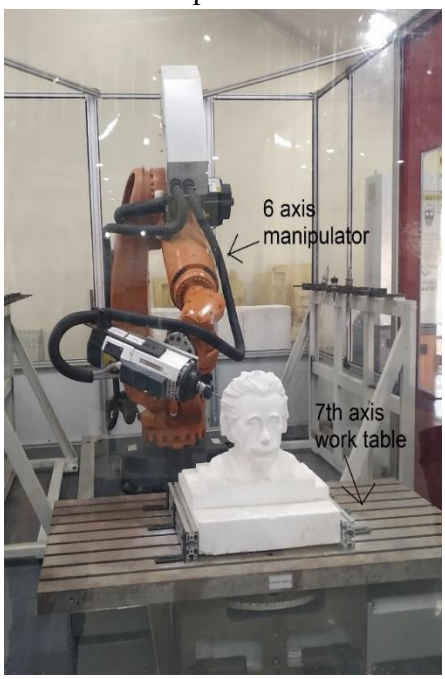

Fig.5 Articulated 7 axis robot milling

Working: - it consist of three parts

1. Designing/modelling the design using software.
2. Converting the Cad file into .Stl file [5] and feeding the design into KCP of manipulator.
3. Calibrating the manipulator as well as work-table as per design to complete the calibration.

Advantages:

1. The ability to machine complex shapes in a single setup, which saves time, cost and operator error.
2. Seven-axis machining enables shorter cutting tools to be used since the head can be lowered towards the job and the cutter oriented towards the surface
3. Seven-axis machining also offers the ability to machine extremely complex parts from solid that would otherwise have to be cast.
4. With a Seven-axis machine, the head can be oriented along the correct axis for each hole automatically, allowing drilling to be completed much more quickly.
5. It has very high degree of freedom which gives it an upper hand to machine complex parts easily.
6. High repeatability, it can machine part repeatedly with high endurance.
7. Able to generate 3d surface, so we are able to generate 3d figures easily which reduces the cycle time.
8. High flexibility, it is flexible to machine the object at any angle.
9. High accuracy.
10. Cost effective as per product, it can generate 3d surfaces easily

Disadvantages:

1. Need for Expensive and special machine tools with spindle and controllers.
2. Excessive tool wear, due to continuous the tool get wear and tear easily at very high rate.
3. Complex designing, it required very skilled professional to design a 7 axis milling system
4. Large setup time, it required very large setup as well as expertise to setup.
5. Expert vision required, a trained as well as skilled operator is required to perform the robotic milling operation.
6. Complex process, so it requires large time for setup as well as to train the operator.

Scope: -7 axis milling are useful for producing complex designs easily and efficiently with very high surface finish.

7 axes give us a unique advantage to machine the object with 360 by rotating the work piece.

It is also useful in designing various automating parts so it has applications in various industries like,

1. **Aeronautical:-**Aeronautical engineering we require high accuracy and precision, along with much sharp edges and steep curves that can be easily obtained from seven axis milling.
2. **Automobile:-** in automobile engineering the design and surface finish is of very high importance for both metal and polymer parts seven axis provide flexibility to machine both metal and polymer part with very high surface finish.
3. **Aerospace engineering: -** From design point of view aerospace industry has very low tolerance and requires precise part design that can be achieved by 7 axis milling.
4. **Automatic guided vehicle: -** AGV work on the basis of coordinates points or instruction provided to it, so it requires very reliable machine design that can be achieved using 7 axis milling.

5. **Design and development process:** - 7 axis milling provide us an ample opportunity to study an object using reverse engineering which helps in design and development process.
6. **Applied research technology:** -7 axis gives us opportunity to test our design feasibility using software provided in milling process.

III. Conclusion

In this paper, the milling and its types are explained and how milling evolve over the period of time,along with the advantages of 7 axis milling its working so, that one can easily understand how robotic milling is more advantages than other method of milling along with their method to improve accuracy, and the issues regarding limitation of robotic milling.

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