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Prototype Development of Milling Machine Using CAD/CAM: A Review

Ms. Prajakta H. Dahake[1]; Ms. Nikita R. Saharkar[2]

Asst Professor, Mechanical Engineering Department, Dr. Babasaheb Ambedkar College of Engineering & Research, Nagpur, India[1];

Student, MTech, CADMA, Mechanical Engineering Department, Dr. Babasaheb Ambedkar College of Engineering & Research, Nagpur, India[2].

praju_dahake1@yahoo.co.in[1]; nikita.saharkar@gmail.com[2]

ABSTRACT

The development of unmanned machining systems has been a recent focus of manufacturing research. The conventional milling machine removes metal with a revolving cutting tool called a milling cutter. For this, CNC machines are in use. CNC machine operates on part program. This program includes several G-codes and M-codes. This program is generated by skilled operators. This may cause error in geometry. Also increases labor cost. Thus new technology of milling operation is conceptualized to reduce these problems using CAD/CAM. In this, firstly part design is created in CAD software like CATIA, ProE etc. This part design is fed in CAM software. Accordingly, coordinates forms. Also program is generated. According to that program, cutting tool operates to produce required part.

Keywords: *Milling machine, CAD/CAM, CNC machine, Interfacing*

1. INTRODUCTION

1.1 Milling machines

Milling machines were first invented and developed by Eli Whitney to mass produce interchangeable musket parts. The milling machine removes metal with a revolving cutting tool called a milling cutter. With various attachments, milling machines can be used for boring, slotting, circular milling dividing, and drilling. This machine can also be used for cutting keyways, racks and gears and for fluting taps and reamers.

Milling machines are basically classified as being horizontal or vertical to indicate the axis of the milling machine spindle. These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type milling machines. Most machines have self-contained electric drive motors, coolant systems, variable spindle speeds, and power operated table feeds.

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1.2 CNC milling machine

Computer Numerical Control (CNC) Milling is the most common form of CNC. CNC mills can perform the functions of drilling and often turning. CNC Mills are classified according to the number of axes that they possess. Axes are labeled as x and y for horizontal movement, and z for vertical movement. CNC milling machines are traditionally programmed using a set of commands known as G-codes and M-codes. G-codes and M-codes represent specific CNC functions in alphanumeric format.

1.3 New technology

A table top mini milling machine is produced. This milling machine is interfaced with the CNC machine. Use of traditional manufacturing system using CNC requires part program to be fed by skilled operators. But sometimes there may be error and inaccuracy in manual part program. So as to reduce this error, new technology is conceptualized. In this technology, firstly part is designed in CAD tool. This part is transferred to the CAM tool. From geometry coordinates are generated and using these coordinates program is generated. According to program, cutting tool and workpiece moves to produce required part.

2. LITERATURE REVIEW

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2.1 C. Doukas et al has given multisensory data for milling operations on the estimation of tool-wear**.** A cutting depth of 0.5mm has been used along with a feedrate of 1000mm/min. The experiment has been repeated at the spindle speed of 1350rpm and 2700rpm, to investigate the effect of cutting speed on the wear level. Every 15 min the process is paused and the inserts are removed and inspected under an optical microscope for the measurement of the tool wear level.

This paper shows the results of a preliminary experimental investigation on tool-wear in end milling. Spindle torque and vibration signals were recorded during the process. A correlation between measured signals and tool-wear was attempted. Power consumption, as depicted from the current draw signal, can be associated with the sustainability evaluation of the milling operation, due to their directly correlation to the toolwear level.

Table1. Setup variables:

Variable	S=1350	S=2700
Cutting Speed	210m/min	420m/min
Feed Rate	1000mm/min	
Depth of cut	0.5mm	
Feed per tooth	0.15	0.5

A 3axis CNC knee mill, operating a spindle of 5Hp is being used for machining and it is capable of reaching approximately 3800 RPM. In order for the workpiece to be securely positioned on the machine table, an adaptor plate has been designed and manufactured, while also allowing the positioning of the acceleration sensor as close to the machining area as possible. Straight cutting passes have been performed, alongside the Y-axis of the machine, to minimize effects of feed direction changes. A cutting depth of 0.5mm has been used along with a feed rate of 1000mm/min. The experiment has been repeated at the spindle speed of 1350rpm and 2700rpm, to investigate the effect of cutting speed on the wear level. Every 15, 5 min the process is paused and the inserts are removed and inspected under an optical microscope for the measurement of the tool wears level.

2.2 Adam Hansela et al, has given idea for improving CNC machine tool geometric precision using manufacturing process analysis techniques. With the ever increasing demands for higher and higher accuracy on modern CNC equipment, the manufacturing processes for machining and assembling the structural components are an increasingly important factor in establishing a geometrically correct machine tool. Specifically, flatness, perpendicularity, parallelism, and straightness of interfacing surfaces determine whether the machine tool's basic accuracy. Exhibiting less geometric error allows other errors such as thermal growth, ballscrew pitch error, and control error to be isolated and more easily corrected.

2.3.1 Jig and fixture design

Parts of the machine tool are assembled in separate units as much as possible for optimal efficiency. X and Z rails are installed directly onto the bed, but the Y-axis rails are installed to the column in an independent station. For assembly workers to efficiently place and measure the rails during installation and adjustment, the column must be placed in the horizontal orientation on a jig with the rails facing upward. For stability and safety, a four point fixture was originally designed The geometric errors are predominately a factor of the machine tool machining and assembly process. Multiple orientations during fixturing in both assembly and machining result in significant distortions to the final assembled product. These are a result of cutting forces, fixturing deformations, gravity deformations, and bolt force deformation. By analyzing each process in detail using virtual simulation techniques, a high-fidelity model of the corresponding error at each manufacturing step can be achieved that is not physically measurable due to constraints of measurement equipment. Using simulated data as offset data in the machining process as well as in the jig and fixture design ensures a geometrically accurate final product.

2.3 Masakazu Soshia et al, has given the concept of Spindle rotational speed effect on milling process at low cutting speed**.** The spindle rotational speed fluctuates during milling due to intermittent cutting forces applied to the spindle, but the speed effect when machining with a relatively large cutter at low cutting speeds is still not clear. Table 1 shows the basic specifications for the motor. The maximum rotational speed and torque of the servomotor is 5,500 min-1, and 700 Nm respectively.

Table 2 PMSM specification:

Rotor size (O.D. × length),	160	300
Stator size (O.D. ×	240	410

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Torque, Nm (@500min-1)	400 (Cont.)	700 (Max)
Maximum rotational speed, min-1	5,500	
Power supply voltage, V	AC200V	
Cut-off frequency, Hz	200	

The focus of this paper is to investigate the effect of spindle servomotor dynamic characteristics on milling processes at various rotational speeds. Based on the simulation and experimental studies, it was found that the cutting speed fluctuation is not negligible at low operation speeds and that the spindle servomotor dynamics affect the machining process and tool life. Thus, it was concluded that the spindle dynamics have to be carefully evaluated and chosen when testing machinability of metals, especially low rotational milling applications typically required for machining of difficult-to-cut materials.

A physical cutting test was conducted on a highly rigid 3-axis milling machine equipped with the high performance PMSM. A milling tool with a single insert was used to cut C55 carbon steel, and the results were compared to the simulation in order to verify model. The commanded rotational speed was set to 260 min-1 with required cutting torque of approximately 270 Nm. By adjusting the gain of the servomotor controller the high performance PMSM bandwidth was reduced to 100 Hz. The simulated motor response against the same torque at the same commanded rotational speed of 260 min-1. The predicted reduction in spindle speed and overshoot were relatively accurate, although there are differences while the cutter was engaging the material. This is mainly due to the torque disturbance being molded as a continuous input compared to the more complex physical torque profile, however this detail was not critical for the study.

2.4 Xiaoyan Zuo et al, revealed integrated geometric error compensation of machining processes on CNC machine tool". This paper presents an integrated geometric error model of machining system and compensation method on machine tools. Regarding a machine tool, fixtures, workpiece and tool as an assembly, an integrated geometric error model has been established.
The integrated error is modeled by the propagation and the accumulation of errors based on Jacobian-Torsor theory. It is different with previous model, in this model; all the geometric errors of machining system are converted into the machine tool instead of the workpiece machining surface. As is well known in the machine tool, there are 21 geometric error of a 3-axis milling machine tool, which can be measured by laser interferometer. Based on this integrated model and machine tool error, the combination of geometric errors of machining system reflect on the machine tool can be predicted. Finally, a new compensation method is proposed to realize the error compensation, NC program is corrected corresponding NC codes according to the predicted errors during virtual machining before it is fed to the actual machining.

2.5 B. Denkenaa et al, has suggested adaptive cutting force control on a milling machine with hybrid axis configuration. In the re-contouring process of aircraft engine components, the unknown geometry and inhomogeneous material properties of the workpiece are major challenges. For this reason a new repair process chain is supposed which consists of noncontact geometry identification, process simulation and NC-path planning, followed by a force controlled milling process. A new milling machine prototype is employed to ensure an effective force control loop. By use of a magnetic guided spindle slide, higher dynamics and precise tracking are enabled. Since variation of the process forces result in variable control plant characteristics, an indirect adaptive controller has been designed. Consequently, models of actuator and process are presented and the estimation of the present parameters by a recursive least square algorithm is outlined. Once the parameters are known, the control polynomials are calculated on the basis of a pole placement control approach. First experimental results of a force controlled milling process are put forward.

2.6 Matti Rantatalo et al, has given idea for milling machine spindle analysis using FEM and non-contact spindle excitation and response measurement. In this paper a method for analyzing lateral vibrations in a milling machine spindle is presented including finite-element modeling (FEM), magnetic excitation and inductive displacement measurements of the spindle response. The measurements can be conducted repeatedly without compromising safety procedures regarding human interaction with rotating high speed spindles. The measurements were analyzed and compared with the FEM simulations which incorporated a spindle speed sensitive bearing stiffness, a separate mass

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and stiffness radius and a stiffness radius sensitive shear deformation factor. The effect of the gyroscopic moment and the speed dependent bearing stiffness on the system dynamics were studied for different spindle speeds. Simulated mode shapes were experimentally verified by a scanning laser Doppler vibrometer. With increased spindle speed, a substantial change of the Eigen frequencies of the bearing-related Eigen modes was detected both in the simulations and in the measurements. The centrifugal force that acted on the bearing balls resulted in a softening of the bearing stiffness. This softening was shown to be more influential on the system dynamics than the gyroscopic moment of the rotor. The study performed indicates that predictions of high speed milling stability based on 0 rpm tap test can be inadequate.

2.7 Mohsen Soori et al, has given concept of virtual machining considering dimensional, geometrical and tool deflection errors in three-axis CNC milling machines. Virtual manufacturing systems can provide useful means for products to be manufactured without the need of physical testing on the shop floor. As a result, the time and cost of part production can be decreased. There are different error sources in machine tools such as tool deflection, geometrical deviations of moving axis and thermal distortions of machine tool structures. Some of these errors can be decreased by controlling the machining process and environmental parameters. However other errors like tool deflection and geometrical errors which have a big portion of the total error, need more attention.

This paper presents a virtual machining system in order to enforce dimensional, geometrical and tool deflection errors in three-axis milling operations. The system receives 21 dimensional and geometrical errors of a machine tool and machining codes of a specific part as input. The output of the system is the modified codes which will produce actual machined part in the virtual environment.

2.8 Chana Raksiri et. al, has revealed geometric and force errors compensation in a 3-axis cnc milling machine. This paper proposes a new off line error compensation model by taking into accounting of geometric and cutting force induced errors in a 3-axis CNC milling machine. Geometric error of a 3-axis milling machine composes of 21 components, which can be measured by laser interferometer within the working volume. Geometric error estimation determined by back-propagation neural network is proposed and used separately in the geometric error compensation model. Likewise, cutting force induced error estimation by back-propagation neural network determined based on a flat end mill behavior observation is proposed and used separately in the cutting force induced error compensation model. Various experiments over a wide range of cutting conditions are carried out to investigate cutting force and machine error relation. Finally, the combination of geometric and cutting force induced errors is modeled by the combined back-propagation neural network. This unique model is used to compensate both geometric and cutting force induced errors simultaneously by a single model. Experimental tests have been carried out in order to validate the performance of geometric and cutting force induced errors compensation model.

2.9 B. Lauwers, et. al, introduced efficient NC-programming of multi-axes milling machines through the integration of tool path generation and NC-simulation. This paper describes the development of an "extended CAM system" for multi-axes milling, integrating tool path generation, axes transformation (post processing) and NC-simulation. The system performs an immediate verification of each generated cutter location and in case a collision occurs (e.g. between machine and part), it takes the appropriate action by applying a collision avoidance algorithm. Different collision avoidance algorithms have been implemented: change of tool orientation, selection of other machine axes configurations and simple tool retract. The effect of a tool orientation change on the quality of the machined surface has been studied in order to define the range of tool orientations that may be used for collision avoidance.

The off-line generation of collision free NC-programs for multi-axes milling operations mostly proceeds in two sequential steps. In a first step, the CAM module (tool path generation) calculates the trajectory of the milling cutter. Each tool posture is described by its tool tip (x,y,z) and tool orientation (i,j,k), both expressed in a workpiece co-ordinate system. Advanced CAM systems allow checking the tool path for micro (gauging) and macro collisions. Research and development on the avoidance of micro collisions is reported. Collisions between the tool (+ tool holder) and non-cutting areas of the part are classified as macro collisions. Most CAM systems retract the tool in case macro collisions occur, while only a few propose a collision avoidance

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algorithm by changing the tool orientation. In a second step, the tool path, output as a CLDATA-file, is converted by a NC-postprocessor to a machine specific NC-program.

3. CONCLUSION

This paper provides the details of the research work which has been carried out in the milling operation under various conditions. This milling machine is a very crucial element of any operation. The proposed mechanism uses CAD/CAM software for milling operation.

Traditional CNC milling machine uses manually generated NC part program. This may cause manual error in part program. Thus to avoid this error, new technology is conceptualized. CAD/CAM software makes it easier to generate NC part program directly from given geometry. So it reduces error, increases efficiency and improves accuracy.

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