BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LX (LXIV), Fasc. 1, 2014
Secţia
CONSTRUCŢII DE MAŞINI

STUDY UPON MILLING COMPLEX SURFACE

PART I: MODELLING OF MILLING PROCESS

BY

BOGDAN-GABRIEL ANIȚĂ and CĂTĂLIN DUMITRAŞ*

"Gheorghe Asachi" Technical University of Iaşi,
Faculty of Machines Manufacturing and Industrial Management

Received: September 25, 2013
Accepted for publication: October 3, 2013

Abstract. Complex surface, called freeform used in industries engineering, aerospace industry dies / molds, plants high precision technical mechanisms aircraft / nuclear, robotics, etc. Complex surfaces is mainly produced by CNC center, in particular 3-5axe. Different methodologies application in the field of milling has been developed in the past to improve the efficiency of processing of complex surfaces milling process. This paper aims to provide a two-part study, recent research development on complex surfaces millings. In first part of this study mainly focuses on process modeling milling including: tool geometry, tool path and cutting forces.

Key words: milling, surface complex, cutting force, high speed.

1. Introduction

Mechanical engineering and aerospace they find widening extension with complex geometric, made from various materials.

Different terms are used to define complex surface such as: "free form" or "smooth portions" according to (Campbell & Flynn, 2001). Characterization of the most used "free-form" is a general characterization of the surface of an object which cannot easily be defined mathematically.

* Corresponding author; *email:* dumitrascata@yahoo.com

One believes (Rata, 1998); (Uliuliuc, 2011), that complex surfaces can be defined as those surfaces determined by a contour, high or low complexity, contour which can be found in a plan where orthogonal projections or different plans. One of the most important issues in system design and computer aided manufacturing is modeling surfaces. Models should provide flexibility in design, which are essentially a creative activity likely lead to simple implementations calculations surface properties and not least, to be described as various forms. A major concern in the field of cutting tools relates to the improvement of the design methodology for the purposes of increasing their generalization to a wide range of tool types, and to adapt them to the technical possibilities of automatic calculation. Being studies large scale in finding optimal trajectory generation methods, milling machine 5-axis have the advantage machining of complex forms but complications trajectory generation tool and large investments make machine tools with 3-axis machining remain a popular method.

The machining of complex surfaces, chip thickness and cutting force varies along complex surfaces and direction machining. Many of the designs of cutting forces have been developed and many methods have been introduced to compensate the cutting forces. The rest of the paper aims to provide a survey of recent research development millings complex surfaces. This study mainly focuses on three aspects of the modeling process of milling: the tool geometry, tool path and cutting forces.

2. Modeling Process of Milling

2.1 Tool Geometry

Great variety of cutters is available and used in the manufacture of molds and dies. Thus, each cutting edge of the tool is carefully designed to ensure maximum cutting performance and minimizes cutting forces results

One have developed (Alintas, 2001); (Youssef, 2004) patterns of each form of mechanical milling, therefore, individual models have been developed mechanical and dynamic for face mill, cylindrical mill, ball mill and conical mills (Altintas & Lee, 1998); (Yucesan a& Alintas, 1996).

The generalization of the parameterization tool and geometrical parameters (Fig.1), independently of each other, but relationships and boundaries are constrained to create reasonable mathematical form (Youssef, 2004). (Altintas & Lee, 1998) and (Ramaraj, 1994) considered the following aspects of cutting edge geometry: a) improving positive rake angle shearing, activity of cutting and decreased force, but being sensitive to wear and breaking; b) high angle helical smoothest and reduces the impact force during cutting entries. c) the presence of inclination of the processing surface reduces friction thus improving surface finish, but reduces the damping and increasing the likelihood of vibration.

Cutter geometry modeling methods are commonly used to describe simple mathematical models to increase the accuracy of the mechanical (Ozturk & Budak, 2007).

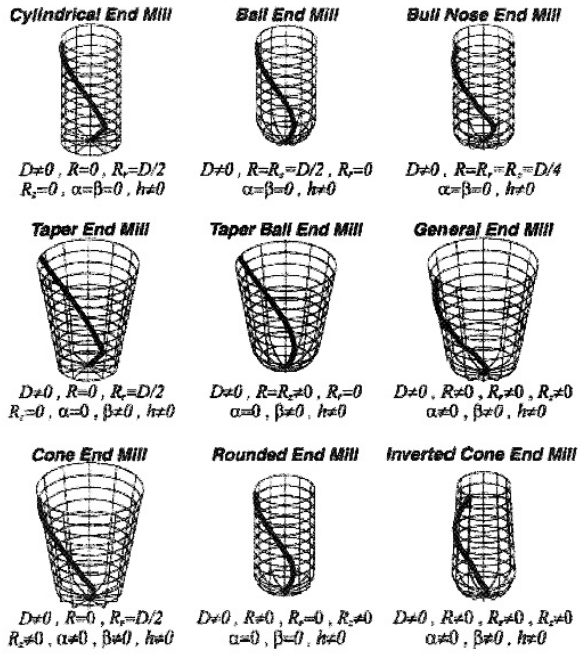

Fig. 1 − Geometric model of the helical cutting edge.

2.2. Tool Path

Tool path generation is to create a surface that closely approximates the surface machined by CAD design to some prescribed tolerance. Being extensively studied trajectory for machine tools with 3-axis (Zhang, 2008) and 5-axis (Francis, 2012), with significant progress achieved for processing complex surfaces. Milling machine 5-axis have the advantage machining of complex forms but complications trajectory generation tool and large investments make machine tools with 3-axis machining remain a popular method.

In processing CNC 3 axis (Fig. 2), tool path is usually defined as the movement path of the tool center. In the case of application of a ball cutter head, the center refers to the center of the sphere of the cutter. Geometric place of the center is called the cutter location (CL) tool path and the geometric place the points of contact between the cutter and the desired surface is called the cutter contact (CC).

The correct choice of tool path strategy is essential to achieving the desired machined surface. Without considering the impact of tool path selection with consideration of processing parameters such as cutting forces, vibration analysis, tool life, cutting and surface temperature of the work piece, leading to negative cutting .

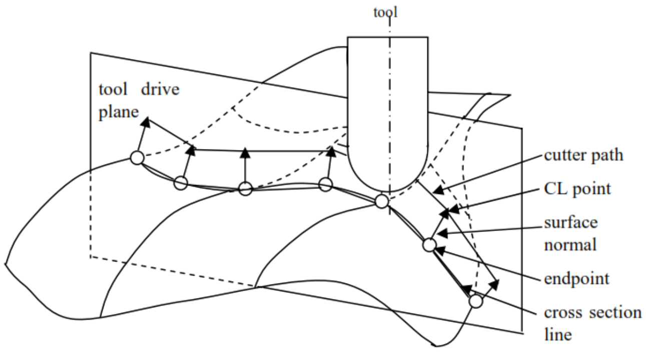

Fig. 2 − Generation of tool path.

(Toh, 2006) and (Zhang *et. Al.,* 2008) investigated the best tool path strategy and the optimal angle relative to the work piece and curved surfaces. Tool path generation is based on three methods: isoparametric, isoplan and iso-scallop. Isoparametric method (Fig. 3) are widely used for trajectory generation as a mathematical tool effectively, however, may be poor processing efficiency and smooth surface due to the occurrence of additional processing or unpredictable scallop, if parameter increment is small or large.

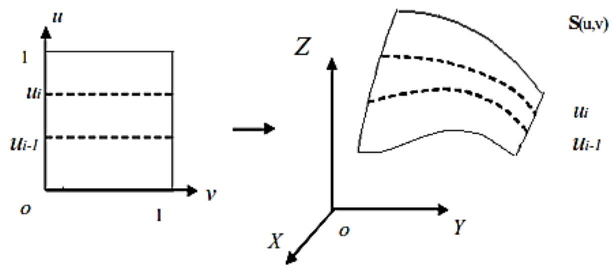

Fig. 3 − Iso parametric curves in the parametric.

In this method, isoparametric curves are used directly as contact path of cutter. The side steps of tool path are calculated by scallop constraint between two successive trajectories. Calculation algorithm is valid only for parametric surfaces; they cannot be used in the analytical surface. Tool path produced by this model are curved space rather than plane, so it is difficult to control speed feed for the volume variable cutting along curved trajectory.

Iso-plane method (Fig.4) is one of the methods most widely used in CAD/CAM systems. Due to its simplicity and robustness, the advantage of this method is the use of the language APT.

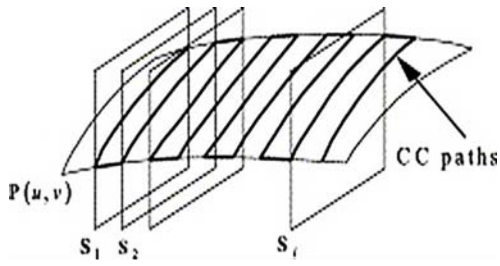

Fig. 4 − Iso-plane method.

Tool paths are generated by intersecting the surface with a series of parallel planes in Cartesian space. And surface intersection curves of the plan are CC tool path. These intersecting parallel planes are usually vertical or horizontal. The separation between the planes of intersection provides better control than the remaining sections isoparametric method because it is controlled by the distance separating the two points (Cartesian) between plans, instead of using parametric curves. The scallop (Duroobi, 2012) based on the amount left attached between two or more passes of the tool path established (Fig. 5).

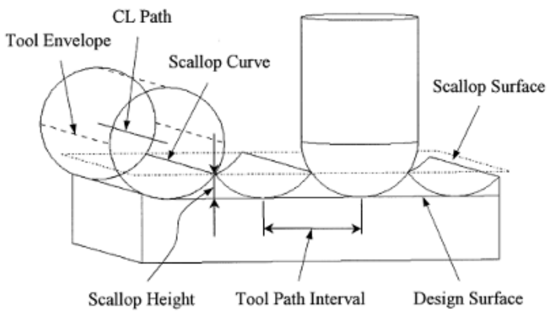

Fig. 5 − Tool path generation of the iso scallop.

The scallop is determined by two adjacent parallel planes. The main path of the tool is selected by selecting a limit curve and each point on the main path and a parallel point is formed in accordance with the requirements of the scallop. This point parallel is defined as a point on the surface along the path perpendicular to the previous path. The curve adjustment on parallel point is performed and is determined by the previous steps. The result is continuous curve that connects all points of the first parallel tool paths. This path is the path adjacent to the main path tool, serving as a trajectory starting repeated. In most cases, this method is effective, but like all other methods, there are some limitations in its application. The main disadvantages are self-intersecting and accumulation of calculation errors. As a new generation of tool paths based on the previous, numerical errors can be carried over to the next path, and errors are thus accumulated. However, due to the variety of application objects, each method of application has its own limitations. It is impossible to apply an effective method for processing any type of surface. Different ways leading to different topographic cutting machined surface and the relationship between topography and unidirectional pattern cutting being a positive condition. The difference caused by cutting both ways is lower when the feed rate is slow but becomes large with increasing feed rate. When cutting speed is zero in the tip cutter in vertical milling, this condition lead to negative quality machined surface and cutter wear. For this reason is why the cutter axis is often inclined at an angle γ and η to get a good quality surface finish. Tilt the cutter / surface is usually a constant milling machine with 3 axes, but fluctuates with many degrees of freedom available. During processing on an inclined plane chip thickness and chip distribution are different from flat surfaces. With the improvement of machine tool efficiency, frequent use the down milling in order to improve the quality of the tool. However, the work piece in different conditions of 15^0 - 75^0 inclination has different characteristics according to the change of processing path or direction of the cutting tool. Different strategies for milling, contouring and ramping, available to produce a new surface depends on the direction of the tool path trajectory and range was expressed by (Fontaine *et. al.,* 2007). Based on machining the tool path and cutting edge trajectory equation in relation to the work piece, the algorithm developed by (Zhang *et. al.,* 2008) for the numerical simulation of convex and concave surfaces (Fig. 6), is effective in saving calculation time.

2.3. Cutting Forces

Despite the progress, many models have been developed and many of them were introduced to compensate for reduced cutting forces error processing. Cutting force models have been developed in the past decades for different tool geometry, work piece and processing conditions. Dynamic models and the mechanical (Alintas & Lee, 1998), (Sun *et. al.,* 2009), (Liu *et. al*., 2005) improved the model element tangential radial and axial cutting forces are calculated using coefficients of shear and edges. Have been studied the various curvatures of the surface resulting in different magnitudes of cutting forces in ball-end milling. Since the areas of contact between the cutter and the work piece in convex and concave surface machining being used to contact proximate regions to improve the accuracy in the estimation models of cutting forces (Smaoui *et. al*. 2008).

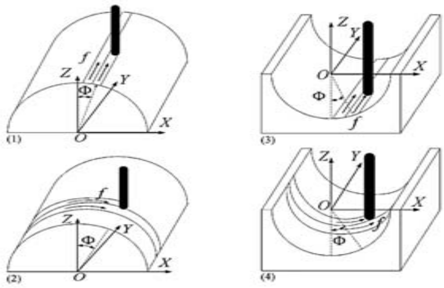

Fig. 6 − Unidirectional cutting mode: *1*. convex contouring, *2*. convex ramping, *3.* concave contouring, and *4.* concave ramping.

3. Conclusions.

The conducted bibliographic study revealed a series of concerns related to the milling complex surfaces: Considering the geometry of cutting aspects such as being: positive rake angle improving shearing, cutting and decreased activity forces, but being sensitive to wear and break; high helical angle smoothest and reduces the impact force when cutting entries; presence inclination, reduces the friction on the surface machined thus improving surface finish, but reduces the damping and increasing the probability of the vibration. As a consequence of complexity, chip thickness and cutting parameters are changing during processing. Therefore, it is necessary to have complete control of the process to get the best accuracy and surface roughness.

Proper selection of tool path strategy is essential to achieving the desired machined surface. Without considering the impact of tool path selection with consideration of processing parameters such as cutting forces, vibration analysis, tool life, cutting and surface temperature of the work piece, leading to negative cutting

REFERENCES

Altintas Y., Lee P., *Mechanics and Dynamics of Ball End Milling*, Transaction of ASME, J. of Manuf. Science and Eng., **120**, 684-692. (1998).

Altintas Y., Engin S., *Generalized Modeling of Milling Mechanics and Dynamics: Part I – Helical End Mills*. Int. J. of Machine Tools and Manuf., **41**, 2195–2212, (2001).

Campbell R. J., Flynn P. J., *A Survey of Free-Form Object Representation and Recognition Techniques*. Computer Vision and Image Understanding. **81**, 166–210, (2001).

Duroobi A. A., Zhong H. X., Wenliang C., *Fedd-Interval Scallop Height Estimation Using Multi Axis CNC Milling Machine*. Anbar J. for Eng. Science, **5**, *1*. (2012).

Fontaine M., Mofki A., Devillez A., Dudzinski D. *Modelling of Cutting Forces in Ball-End Milling with Tool–Surface Inclination: Part I: Predictive Force Model and Experimental Validation,*. J. of Materials Proc. Technology, **189**, *1–3*, 73–84, (2007).

Francis J. *5-Axis Tool Path Generation with Collision Detection for Finish Machining of Freeform Surfaces.* Thesis Master of Science in Manufacturing Engineering Missouri University of Science and Technology, 2012.

Liu X.-W., Cheng K., Longstaff A.P., Widiyarto M.H.·Ford D. *Improved dynamic cutting force model in ball-end milling.Part I: Theoretical modelling and experimental calibration*. Int J Adv Manuf Technol **26**, 457–465, (2005).

Ozturk E., Budak E., *Modeling of 5-Axis Milling Processes.* Machining Science and Technology, **11**:287-311, (2007).

Ramaraj T. C., Eleftheriou E., *Analysis of the Mechanics of Machining with Tapered End Milling Cutters,* Trans. of the ASME, **116**, 398-404, (1994).

Smaoui M.; Bouaziz Z., Zghal A. *Simulation of Cutting Forces for Complex Surfaces in Ball-End Milling*. Int. J. of Simulation Modelling, **7**, *2*, 93-105 (2008).

Sun Y., Ren F., Guo D., Jia Z., *Estimation and Experimental Validation of Cutting Forces in Ball-End Milling of Sculptured Surfaces.* Int. J. of Machine Tools & Manuf. **49**; 1238–1244; (2009).

Uliuliuc D., *Contribuții teorectice si experimentale la studiul procesului de prelucrare prin electroziune a suprafețelor profilate*. Ed. Politehnium, Iasi, 2011.

Rata V., *Cercetari privind utilizarea si caracteristicile tehnologice ale prelucrarii electrochimice la obtinirea sufetelor complexe de revolutie,* Bucuresti, 1998.

Youssef Amro M., *Optimization of machining strategy and process planning of complex geometry.* McMaster University Hamilton, Ontario, 2004.

Yucesan G., Altintas Y., *Prediction of Ball End Milling Force*, Trans. of ASME, J. of Eng. for Ind., **1**, *1*, 95-103, (1996).

Zhang W. H., Tan G., Wan M., Gao T. Bassir D. H., *A New Algorithm for the Numerical Simulation of Machined Surface Topography in Multiaxis Ball-End Milling.* J. of Manuf. Science and Eng. **130**, *1*, (2008).

STUDIU ASUPRA FREZĂRII SUPRAFEȚELOR COMPLEXE

I. Modelarea procesului de frezare

(Rezumat)

Suprafețele complexe se întâlnesc în industria de automobile, industria aerospatiala (în special atunci când se utilizează matrițe), robotică etc. Suprafețele complexe sunt obținute în principal pe mașini cu comandă numerică care au 3-5 axe. Au fost dezvoltate diferite metodologii de frezare care au scopul de a îmbunătăți eficiența procesului complex de prelucrare. Această lucrare își propune să prezinte un studiu privind dezvoltarea recentă a direcțiilor de cercetare în domeniul frezării suprafețelor complexe. A doua parte a acestui studiu se concentrează în principal pe două aspecte: prelucrarea cu viteze mari de prelucrare și erorile de prelucrare.