Proceedings of the 15th International Conference on Manufacturing Systems – ICMaS
Published by Editura Academiei Române, ISSN 1842-3183

"Politehnica" University of Bucharest, Machine and Manufacturing Systems Department
Bucharest, Romania, 26–27 October, 2006

DECOMPOSITION OF FORGING DIES FOR MACHINING PLANNING

Laurent TAPIE, Bernardin Kwamivi MAWUSSI, Bernard ANSELMETTI

Abstract: *In this paper we present a method of decomposition of forging dies during High Speed Machining (HSM) planning. The decoposition process lies on the creation of machining features. The decomposition phase, called Basic Machining Features Extraction is presented. The decomposition method integrates machining resources models and expert machining knowledge to provide an outstanding process planning.*

Key words: *forging die, high speed machining, feature modelling, shape decomposition.*

1. INTRODUCTION

Recent expands of High-Speed Machining (HSM) technology and Computer-Aided Machining (CAM) software, lead forging die makers to invest in these technologies. Indeed, several works underline the productivity and part quality gains involved by HSM [1]. Yet, the difficulty inherent in milling forging dies lies in developing an outstanding machining process by using HSM.

In this paper an original approach to develop die high speed milling process is provided during the finishing machining stage. This method lies on the die decomposition in machining feature. In the first section of the paper, a machining features definition model is provided in the case of three axis finishing HSM. Then, according to this model three levels of decomposition are highlighted: geometrical decomposition under topological constraints, machining resources integration and machining tool path arrangement. By the way of these three decomposition levels five typical basic machining features are defined from the analysis of several forging dies CAD model. After the presentation of the machining feature model the basic machining feature extraction method definition is detailed in section 3. Finally, the basic machining feature detailed in section 3 are extracting from an industrial application.

2. FEATURE MODELING APPROACH

The feature modelling approach offers the possibility to bring out more information by the way of CAD model surface. Indeed, a feature is generally composed by geometrical data associated with a semantic [2]. This semantic can carry out several information useful for part designer or manufacturer. Yet, few research works are developed in the field of machining feature modelling. Sun provided in [3] a decomposition in freeform features for die and mould. This decomposition is composed of two levels: multi-tool decomposition level and geometrical decomposition level. Nevertheless, in that approach the machining process is not really integrated in the machining feature semantic. So, in this section a generic machining feature model is provided and applied in the context of forging die machining.

2.1. Forging die machining feature model

The core of this model relies on a Unified Model Language (UML) [4] machining feature model (Fig. 1). Four main classes are defined. The surface class is represented by the CAD die model. Typical surfaces used to model die part are given in [5].

The topology class represents the relationship between machining feature. Interference topology and proximity topology are the two main topology types. Some types of interference topology are detailed in Fig. 2. For instance, the feature E2 leans on E1 with an opened island junction done by feature B1; E2 leans on E3 with a closed cavity junction done by B2; E4 leads into E2 with an opened flank junction done by B3; B3, B4 and B5 are interfere with each other, this interference topology is done by the blend feature B3-4-5. Some, proximity topology types are detailed in Fig. 3. For instance, E5 and E6 features belong to E2's domain in totality; E3 partially belongs to E2's domain; E3 stands higher than E1.

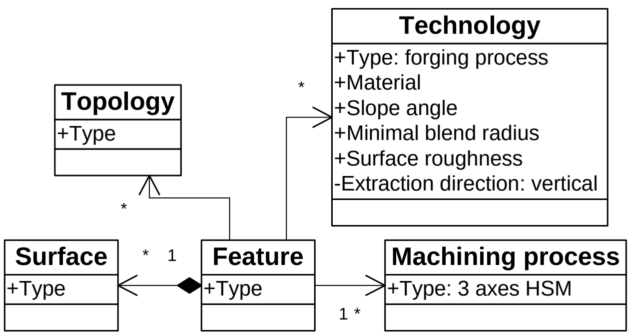

Fig. 1. UML machining feature model.

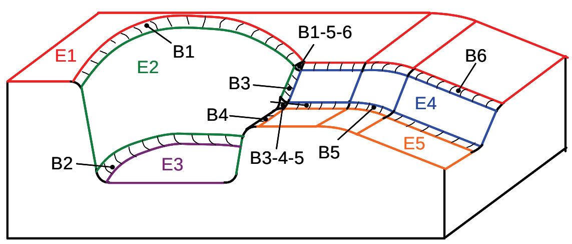

Fig. 2. Interference relationship examples.

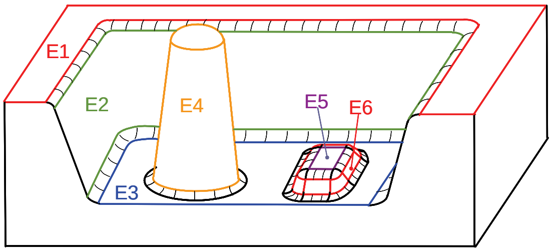

Fig. 3. Proximity relationship examples.

The technology class gives the needed requirements for forging process. In the method this three classes are considered as data given to machining expert.

The last class, called “machining process”, represents themachining expert point of view. In the case of die machining this class is detailed according to the model represented in Fig. 5. Thus, the machining process represents the aggregation of three classes. The tool angular position class represents the tool axis direction which can be reached according to die shape without any global interference. This class can be added with a direction map as detailed in [6]. In forging production the forging part must be extracted in one direction. Consequently, an extraction direction is associated to the die. This specificity is integrated in the technology class (Fig. 1). So, in the case of forging die machining each machining feature can be machined with the same direction. Besides, three axes HSM technology is commonly used in die makers industry. Thus, the model provides a machining direction similar to the spindle axis.

The machining strategy class represents the CAM model associated to the CAD model. Thus, this class is composed of tool trajectory during cutting phase and tool trajectory during approach or clearance motions.

Machining resources constraints are also integrated in our model. The machine tool skills have an important impact in the feed rate, consequently in part quality and machining time [7]. Thus, two sub-classes are associated to the machine tool. The structure class group the machine tool data: axis stroke, maximum feed rate, maximum acceleration, jerk; spindle maximum speed, power. The NCU class groups the HSM close loop control parameters. A cinematic model of our machine tool, called “performance viewer” was implemented in Esprit CAM software [7] to model these classes. The cutting tools class model is divided in the tool cutting part and the tool body & attachment. These classes are commonly used in CAM software in machining simulation to analyse local and global interference of the tools with the part shape.

3. BASIC MACHINING FEATURE EXTRACTION

3.1. Extraction Method

The extraction method is composed of four main steps (Fig. 6): (1) CAM basic tool paths were generated in several forging die CAD models. These tool paths are associated to common machining strategies used in three axis milling: along planar curves in the case of plan containing tool axis (parallel plane sweeping) or in the case of plane perpendicular to tool axis (Z-contouring milling), along planar curves in a inclined plan (contouring milling), along 3D curves (curve following). In step (2) cinematic tool paths analysis was performed with CAM simulation and performance viewer model. This analysis is based on feed rate slowing down areas and machining time deduced from the performance viewer cinematic model. In step (3), these areas tool paths’ are analysed by the way of expert knowledge. This knowledge is based on some machining tests and

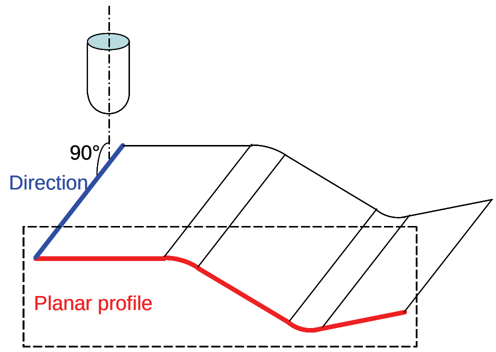

Fig. 4. Complex bottom feature.

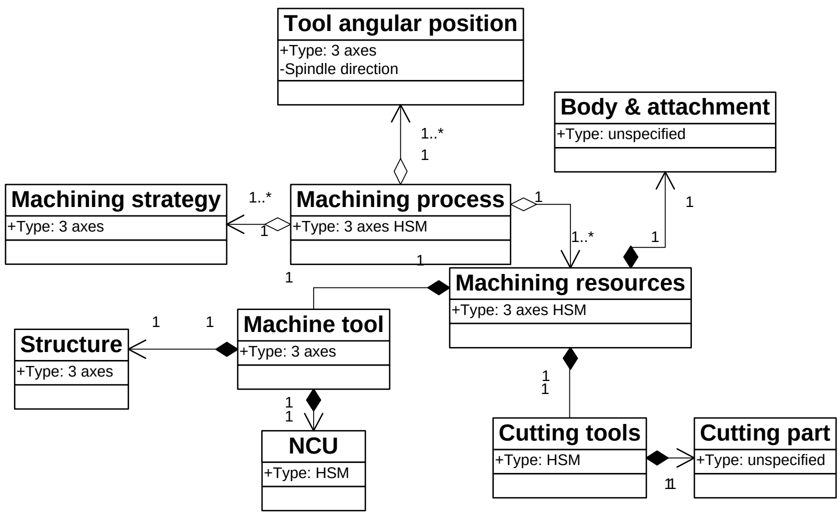

Fig. 5. Machining process model.

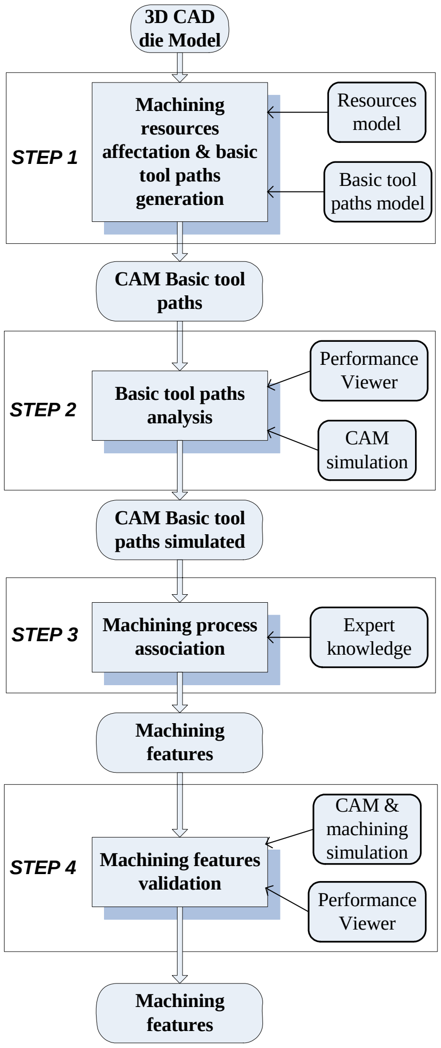

Fig. 6. Extraction method.

simulation performed on our machine tool with quality and productivity criterions. Then, machining features identified are validated in step (4) and basic machining features are extracted.

3.2. Basic machining features models

Five typical forging die basic machining features are obtained according to extraction method.

The "simple bottom" (SB) feature is composed of one plane perpendicular to the tool axis. By the way of expert knowledge, to avoid machining with a null effective cutting speed, this feature is machined with end mill tool. Thus, a surfacing machining strategy is associated to this feature. The sweeping mode is chosen according to topological relationship and productivity criterion.

The "complex bottom" (CB) feature is composed of one to several surfaces. These surfaces can be represented by generated cylindrical surfaces with a direction perpendicular to spindle axis and a planar profile defined in a plan containing spindle axis direction (Fig. 4). The machining strategy associated to this feature should be parallel plane machining. Yet, topological relationship influence can induce machining strategy adaptation; this is illustrated in the following section.

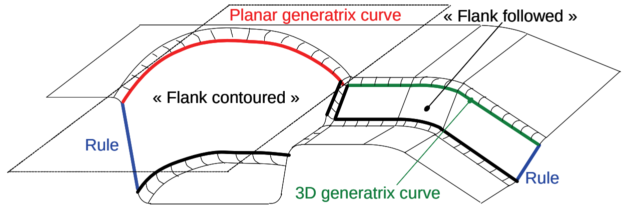

Fig. 7. Flank contoured and followed feature.

Table 1

Blend machining feature process

	ComplexBottom	Flank Contoured	Flank Followed
Simple Bottom	No existence	Contoured	3D curve
Complex Bottom		Contoured or 3D curve	3D curve
Flank Contoured			Contoured or 3D curve

The "flank contoured" (FC) feature is composed of 1 to several ruled surfaces with a planar generatrix curve (Fig. 7). The machining strategy associated to this feature is contouring machining along curves defined in generatrix plan.

The "flank followed" (FF) feature is composed of 1 to several ruled surfaces with a non planar generatrix curve (Fig. 7). The machining strategy associated feature is machined along 3D surface generatrix curves.

The "blend" (B) feature is composed of blend surface. This surface assured the topological relationship between the last four features. This feature model is based on the model provided in [5]. This feature is machined along 3D curves or contoured according to the basic features in topological relation (Table 1).

4. INDUSTRIAL APPLICATION

Our method is applied to the generation of the machining process of the industrial die shown in Fig. 8. First, the die decomposition in basic machining feature is given. Then, topological relationship is deduced from the model associated to the topology class. For instance, FF1 "leans on" CB1 with an opened cavity junction and "leads into" FC2 with an opened flank junction. By the

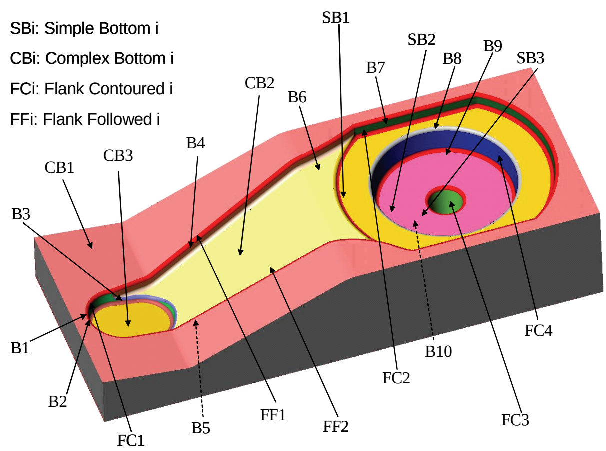

Fig. 8. Basic machining features identification.

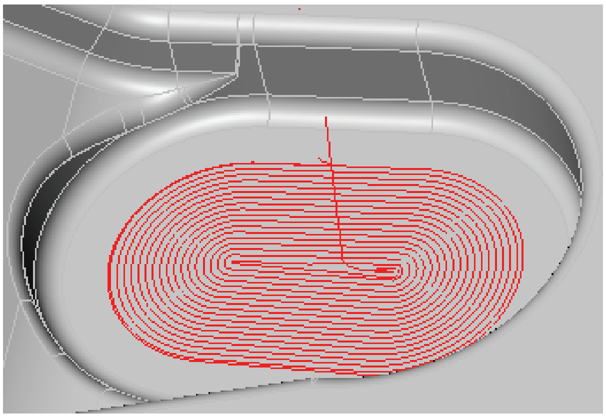

Fig. 9. Complex Bottom machining feature adaptation.

way of this decomposition each basic tool path is generated. CB1, CB2, CB3 are swept with up milling (one way) in parallel plane containing tool axis and perpendicular to the generatrix of CBi. FC1, B2 are contoured with up milling in plane parallel to CB3. FF1, FF2, B4, B5 are swept with up milling (one way) along generatrix of ruled surfaces defining FF1 or FF2. FC2, FC3, FC4, B6, B7, B8, B9, B10 are contoured with Z-level up milling (one way). HP1, HP2, HP3 are surfaced with a morph out spiral and up milling (one way). B1 is swept along is generatrix curve with up milling.

Then, basic tool paths are adapted according to topological relationship and the productivity criterion given by the "performance viewer". For instance, FC1 "leans on" CB3 with a closed cavity junction. Consequently, to minimise tool retractions and approaches, CB3 is machined with a spiral from the centre to the outside limit of CB3 (Fig. 9).

For CB2 basic machining process, the "performance viewer" reveals areas where the feed rate is not reached. CB3 interference topological relationship with FF1 and FF2 induces these feed rate loss. So, feed rate loss areas detected are machined with FF1 or FF2. This adaptation is validated by the "performance viewer", machine tool cinematic behaviour is better.

5. CONCLUSION

In this paper, a method of decomposition with a feature modelling approach is presented. This method lies on a machining feature model including geometry, topology, technology of forging die and high speed machining resources. Class object UML language is used to design machining feature. Five typical machining features are extracted from our method.

Our future works will be focused on defining topological rules by the way of the importance of the linkage between basic machining feature topology and machining process.

REFERENCES

[1] Fallböhmer, P., Rodriguez, C. A., Özel, T., Altan, T., (2000). *High-speed machining of cast iron and alloy steels for die and mold manufacturing*, Journal of Materials Processing, vol. 98, pp. 104–115.

[2] Van den Berg, E., Bronsvoort, W. F., Vergeest, J. S. M., (2002). *Freeform feature modelling: concepts and prospects*, Computers in Industry, vol. 49, pp. 217–233.

[3] Sun, G., Sequin, C. H., (2001). *Operation decomposition for freeform surface features in process planning*, Computer-Aided Design, vol. 33, pp. 621–636.

[4] Booch, G., Rumbaugh, J., Jacobson, I., (1999). *The UML reference manual*, Addison-Wesley, ISBN 0-201-57168-4, USA.

[5] Mawussi, K., Bernard, A., (1996). *Complex dies representation and definition with complex feature-based model*, Proc. of the 15th International Computers in Engineering Conference (ASME), September 17–21, Boston (USA).

[6] Zirmi, O., Paris, H., (2005). *Modélisation de l'usinabilité des pieces aéronautiques dans un contexte de conception de gamme d'usinage*, 9ème colloque AIP PRIMECA, La Plagne, 5–8 Avril 2005.

[7] Tapie, L., Mawussi, B. K., Anselmetti, B., (2006). *Machining strategy choice: performance viewer*, accepted for publication at IDMME 2006, 17–19 May, Grenoble, France.

Authors:

Laurent TAPIE, Ph.D. student, Laboratoire Universitiare de Recherche en Production Automatisée ENS-Cachan, 61, Avenue du Président Wilson, 94235 Cachan, Cedex, France, E-mail: tapie@lurpa.ens-cachan.fr

Dr. Bernardin Kwamivi MAWUSSI, Associated Professor, LURPA ENS-Cachan, 61, Avenue du Président Wilson, 94235 Cachan Cedex, France ; IUT de Saint Denis – Université Paris 13, Place du 8 Mai 1945, 93206 Saint-Denis, Cedex, France, E-mail: mawussi@lurpa.ens-cachan.fr

Pr. Bernard ANSELMETTI, Professor, LURPA ENS-Cachan, 61, Avenue du Président Wilson, 94235 Cachan, Cedex, France, IUT de Cachan – Université Paris 11, 9 avenue de la division LECLER 94234 Cachan, Cedex, France, E-mail: anselmetti@lurpa.ens-cachan.fr