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Key technologies of "zero die trial" design system for aluminum profile extrusion①

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Abstract: Aluminum alloy profile parts are widely used in the fields of aviation, equipment, automobile and ornamental industries. The construction method for "zero die trial" intelligent design system of aluminum extrusion die was studied based on KBE idea. An object-oriented knowledge language AEKL(Aluminum Extrusion Knowledge Language) was developed to construct intelligent knowledge model with three methods, frame, parameters and rules. On the aspect of knowledge reasoning, case-based reasoning was employed in addition to traditional rule-based reasoning method. API provided by CAD platform was used in geometry disposal. Finally, the corresponding prototyping system was established and an design example was shown.

Key words: aluminum profile extrusion; zero die trial; knowledge based engineering; simulation
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1 INTRODUCTION

Due to the excellent properties such as low density, high strength, good machinability performance and erode resistance, aluminum alloy profile parts are widely used in the fields of aviation, equipment, automobile and ornamental industries.

In the 21st century, it is crucial for an aluminum factory to develop new products with high quality, low cost and short time, because of fierce competition. In recent years, the advances in the technology of CAD, CAE, CAM and AI, together with Knowledge based engineering(KBE) have provided the powerful tools for designing high-quality die more efficiently. To enhance the level of extrusion die design, realize the digital, intelligent, knowledge-based design, all above technologies must be integrated and utilized efficiently. Then the mold-trial times can be decreased, even the "zero mold-test" can be attained.

KBE is a computer integration technology that can provide the best solution for the engineering problem through knowledge driving and multiplying. KBE is the integration of CAX and AI technology[1-6]. In this paper, the construction method for "zero die trial" intelligent design system of aluminum extrusion die is developed based on KBE idea. The key technologies of the system are discussed.

2 FRAMEWORK OF "ZERO DIE TRIAL" SYSTEM

Based on the idea of KBE, the prototype of "zero die trial" intelligent system was established. The framework of this prototype system is shown in Fig. 1.

The frame consists of graphic interface, knowledge tool, knowledge base, CAD system and CAE system. In "zero die trial" system, design rules and knowledge can be obtained from existed knowledge bases and used to develop a new design scheme. Then the new scheme is verified with CAE system, whose results also can be taken as a new knowledge source through data mining. It should be pointed out that each part of the system is not an isolated one. All parts are organized integratedly to fulfill design task.

3 KEY TECHNOLOGIES OF "ZERO DIE TRIAL" INTELLIGENT DESIGN SYSTEM

3.1 Knowledge modeling

In "zero die trial" system, knowledge modeling involves extrusion product modeling, extrusion die modeling and extrusion processing modeling.

Since traditional geometric model of product can not realize reasoning and judgment, it can not provide the required information of intelligent system[7-9]. Hence, the feature technology is employed in present system. A feature, which has certain engineering meaning, is taken as the basic element of information model of a product. It can integrate geometric model, technique information, material information, precision information, etc. effectively. The feature model of aluminum profile is shown in Fig. 2.

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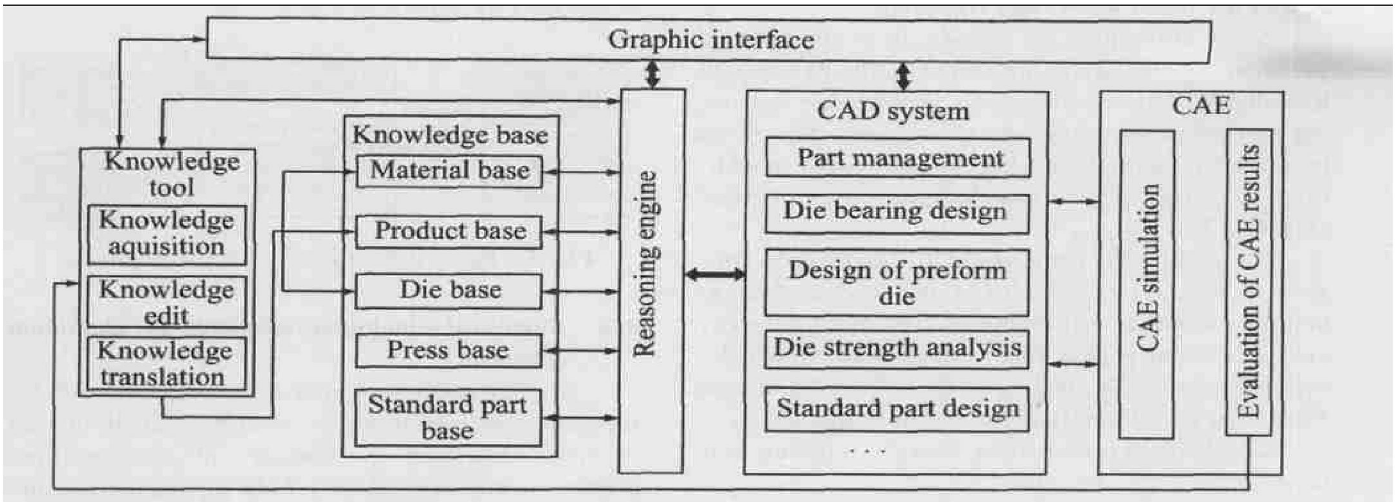

Fig. 1 Framework of "zero die-trial" system

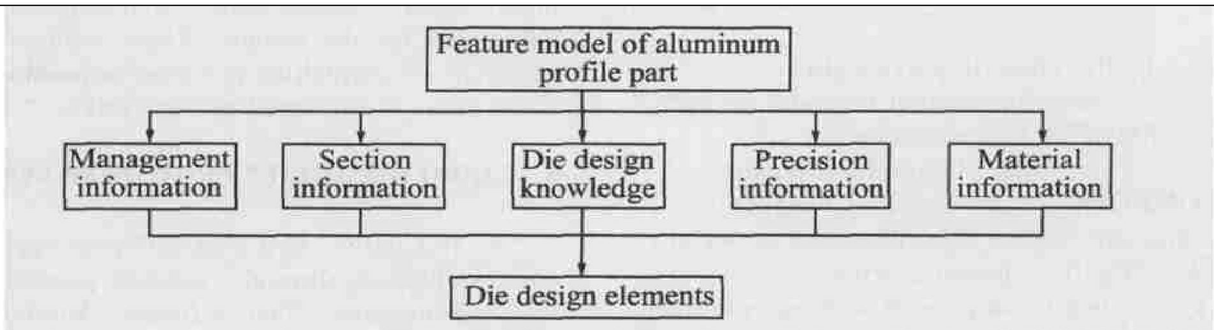

Fig. 2 Feature model of profile

An object-oriented knowledge language AEKL (Aluminum Extrusion Knowledge Language) is developed to describe frame, parameters and rules.

1) Frame representation(UNITS/UNIT)

UNITS: ⟨name of whole frame⟩ define whole frame

UNITNUM: ⟨numeric⟩ define frame numbers

UNIT: ⟨frame name⟩ begin defining

DISPLAY: ⟨characters⟩ define prompt information

PARMSETNAME: ⟨name of parameters group⟩ define parameters group

RULESETNAME: ⟨name of rule group⟩ define rules group

SUBUNITSETNAME: ⟨name of sub-frame⟩ define sub-frame

SUBUNITNUM: ⟨sub-frame number⟩ define sub-frame number

ENDUNIT end of frame definition

...

ENDUNITS end of whole frame definition

2) Parameters representation(PARMS/ PARM)

PARMS: ⟨name of parameters group⟩ define parameter group

PARM: ⟨parameter name⟩ define parameter

DISPLAY: ⟨characters⟩ define prompt information

VALUETYPE: define type of parameter value

VALUE: ⟨characters⟩ define parameter value

ENDPARM end of parameter definition

...

ENDPARMS end of parameter definition

3) Rules representation(RULES/ RULE)

RULES: ⟨name of rules group⟩ define rule group

RULENUM: ⟨numeric⟩ define rule number

RULE ⟨numeric⟩: define rule order

IF{precondition} describe precondition

THEN{conclusion or action} describe conclusion or action

...

ENDRULES end of rule groups definition

3.2 Case based knowledge reasoning

Since aluminum die design is a complicated problem, involving application of different types of knowledge. Different types of knowledge reasoning methods are needed in the system. The cased base reasoning method(CBR) is introduced in addition to the rule based reasoning method(RBR)[10-12].

Generally, the content in CBR expression consists of part type, complexity degree, product amount, technique requirement, design knowledge, etc. In present paper, case is expressed by self-developed expression language, AEPCRL(Aluminum Extrusion Part Case Representation Language):

CASEBASE: 〈case base name〉 define case base

CASE 〈numeric〉: define case number

NAME: 〈character〉 define product name

TYPE: 〈description, weight〉

describe product type and weight

FUNCTION: 〈character〉

describe product function

COMPLEXITY: 〈description, weight〉

complexity degree of product and its weight

FEATTYPE: 〈character array〉

typical feature in present product case model

FEATWEIGHT: 〈numeric array〉

weight of typical feature

CHARACTER: 〈character〉

characteristics of case, corresponding design and technique knowledge

ENDCASE

…

ENDCASEBASE end of case base definition

The case retrieving process can be described as Fig. 3.

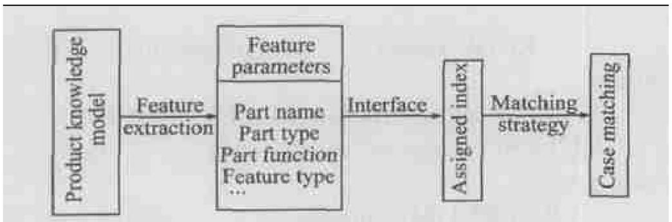

Fig. 3 Procedure of case retrieval

3.3 Basic principle of geometry disposal

Aluminum extrusion die designing is a geometry-related process. Two geometry-related knowledge proposal methods are available. One is utilizing knowledge tools with reasoning and geometric function; the other is API provided directly by CAD. In present system, the second method is employed, as shown in Fig. 4.

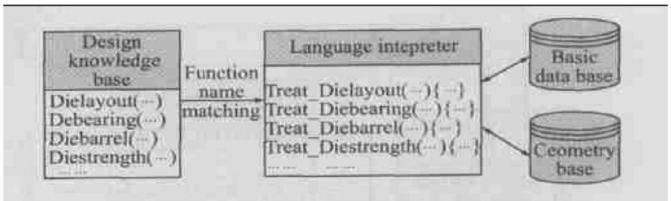

Fig. 4 Basic principle of geometry disposal

3.4 Numerical simulation technology for aluminum extrusion

Aluminum extrusion is a temperature and deformation coupled process, so numerical simulation is very important to analyze the temperature, stress, strain and velocity field during extrusion. Furthermore, technique parameters can be optimized based on simulation, which can provide a reliable tool for die design. Finite volume method (FVM)[13-15], which do not need remeshing during simulation, is employed in this system.

4 "ZERO DIE TRIAL" PROTOTYPE SYSTEM

In this part, "zero die trial" prototype system was established through realizing partially above key technologies. The software AutoCAD was chosen as platform, while Autodesk objectARX API as developing tool. The system mainly consists of aluminum extrusion product knowledge modeling, extrusion die design, case retrieving, etc.

A practical aluminum part is shown in Fig. 5 and its section feature model is shown in Fig. 6. The flat die is selected. The die-bearing designing model and press selection based on concentric circle method and the results are shown in Fig. 7. Based on case based reasoning principle, retrieved case is obtained and shown in Fig. 8. CAE modeling is established and numerical simulation is conducted for design verification. Because of symmetry, half of the model is used, as shown in Fig. 9. From the simulation result, it can be seen that the product can be manufactured successfully.

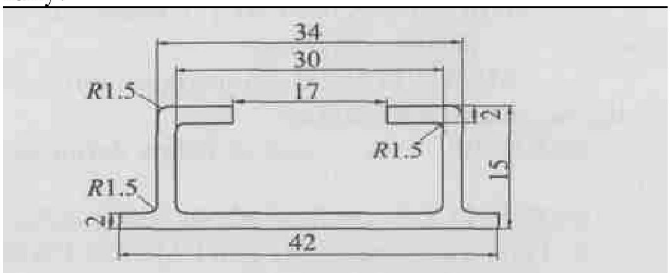

Fig. 5 Practical part

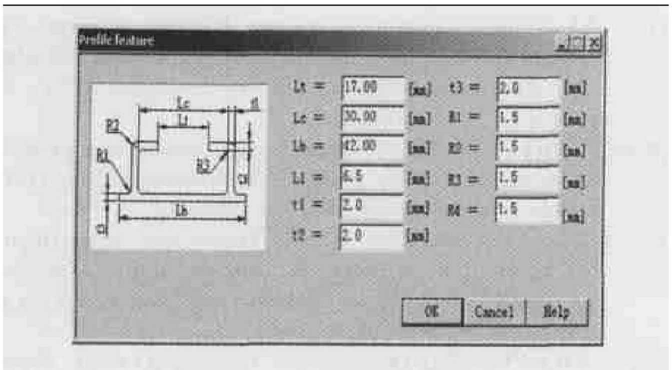

Fig. 6 Section feature modeling

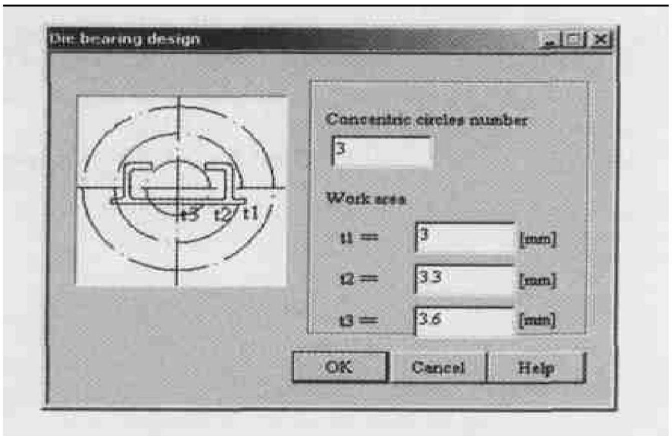

Fig. 7 Die bearing design

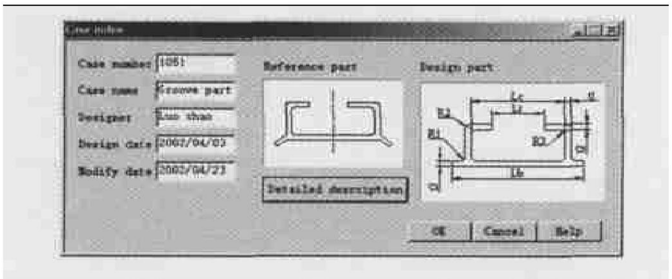

Fig. 8 Design case retrieval

5 CONCLUSIONS

The framework of "zero die trial" intelligent die design system for aluminum extrusion was proposed based on KBE idea. The corresponding prototype system was also established. It should be pointed out that "zero die trial" is a technology concept as well as an ideal manufacturing mode. To make it practical in factories, updates should be made in the aspect of design, manufacturing, management and information exchange. Various advanced technologies should be integrated and the consistence between practice and virtual system should be kept in the preparation of original material, manufacturing conditions, etc. In this way, "zero die trial" manufacturing mode can be attained.

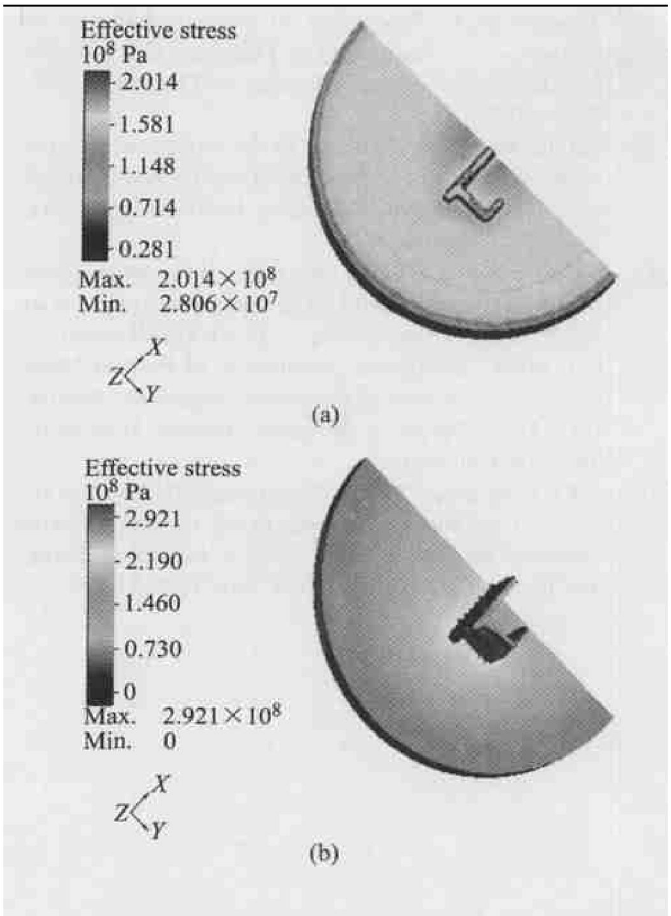

Fig. 9 Simulation of extrusion process

REFERENCES

[1] PENG Ying-hong, ZHAO Zhen, RUAN Xue-yu. KBE technology in engineering design[A]. JIAN Song. Proceedings of International Conference on Engineering and Technological Science 2000[C]. Session 1. Beijing: New World Press, 2000. 94 - 100.

[2] Oldham K, Kneebone S, Callot M, et al. MOKA —A methodology and tools oriented to knowledge-based engineering applications[A]. Martensson N, Mackay R, Bjorgvinsson S. Proceedings of the Conference on Integration in Manufacturing[C]. Goteborg, Sweden, 1998. 198 - 207.

[3] Penoyer J A, Burnett G, Fawcett D J, et al. Knowledge based product life cycle systems: principles of integration of KBE and C3P[J]. Computer-Aided Design, 2000, 32: 311 - 320.

[4] PENG Y H, ZHAO Z, LI D Y, et al. Key technologies of knowledge based metal forming system[A]. Kiuchi M, Nishimura H, Yanagimoto J. Proceeding of the 7th International Conference on Technology of Plasticity[C]. Yokohama: Japan Society for Technology of Plasticity, 2002. 1363 - 1368.

[5] Kneebone S. The knowledge enterprise. Coventry: KBE conference'98[EB/OL]. http://www.kbe.coventry.ac.uk

[6] ZHAO Z, LUE S, PENG Y, et al. Development of knowledge-based process planning system for stamping die design[A]. Kiuchi M, Nishimura H, Yanagimoto J. Proceeding of the 7th International Conference on Tech-

nology of Plasticity[C]. Yokohama: Japan Society for Technology of Plasticity, 2002. 1363－1368.

[7] ZHOU Xiong-hui. Research of the Computer Integrated Manufactory of Die and Mold and Its Key Technology [D]. Shanghai: Shanghai Jiaotong University, 1994. (in Chinese)

[8] GU Zheng-chao, YING Dao-ning. Information molding of mechanical product[J]. Computer Aided Design and Manufacturing, 1995, 3: 3－14. (in Chinese)

[9] NIE Ming. Theory and Application of Product Molding Software Facing to Computer Integrated Manufactory [D]. Shanghai: Shanghai Jiaotong University, 1995. (in Chinese)

[10] LEI Yong-gang, PENG Ying-hong, RUAN Xue-yu, et al. Case-based reasoning based process planning model of similar structure dies[J]. Journal of Shanghai Jiaotong University, 2000, 34(3): 303－305. (in Chinese)

[11] LI Xiang, YUAN Guo-hua, RUAN Xue-yu. On CBR-based conflict resolution in cooperative design[J]. Mechanical Science and Technology, 2001, 20(1): 22－23. (in Chinese)

[12] ZHAO Zhen, PENG Ying-hong. Application of KBE in stamping process design[J]. Mould & Die Technology, 2001(4): 59－61. (in Chinese)

[13] ZHOU Fei, SU Dan, PENG Ying-hong. Basic theory for simulation of metal forming with finite volume method[J]. Journal of Shanghai Jiaotong University, 2002, 36(7): 915－919. (in Chinese)

[14] ZHOU Fei, SU Dan, PENG Ying-hong, et al. Simulation of aluminum material extrusion process with finite volume method[J]. The Chinese Journal of Nonferrous Metals, 2003, 13(1): 65－70. (in Chinese)

[15] ZHOU Fei, SU Dan, PENG Ying-hong. Contrast simulation of aluminum extrusion process with FEM and FVM[J]. Journal of Shanghai Jiaotong University, 2003, 37(7): 1072－1076. (in Chinese)

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