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An Expert System of Moulding Working for Air Intake Hose Products using 3-Dimensional Parametric Modeling Technique

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ABSTRACT

This paper deals with an application on the mould machining of air intake hose product by using 3-dimensional parametric modeling techniques. The detailed domain is the 3-dimensional product with similar shapes and different sizes which needs too much working time for preparation of modeling or machining due to making a trial and errors repeatedly. Decision making rules for selection of modeling order and technique, and for calculation of cutting conditions, and for determination of sequence and method concerning machining operations are required by interview of expert engineers in the field. The developed expert system of modeling and machining is programmed by using a user programming language under the CAD/CAM software of the Personal Designer. The developed system that aids a mould engineer who is working in the modeling and machining section which deal with air intake hose product provides strong and useful capabilities.

Key words : 3-dimensional parametric modeling, Rule base, Knowledge base system

1. Introduction

The general survey for process design experts' system regarding injection mould was developed by Cho *et al.*[1] and recognizing peculiar character of the function of injection mould parts, the process table concerning working process, machine, cutting tools and working sequence required for working the recognized shape was presented. Sohn *et al.*[2] studied development of function to working site, working process of injected or rubber products with similar shape becomes different only in dimension of products but the same process is usually repeated for modeling technique and sequence.

In case of such work, it is considered that it is desirable to approach by the method of parametric - programming technique developed by Roller *et al.*[3] or of parametric-programming technique developed by Webber *et al.*[4] However, in the case of application of the parametric technique of two-dimensional shape or three-dimensional simple shape, there is no difficulty, but in application of programming the object including free curve or free curved surface of three-dimensional shape, the difficulty follows to reflect technical know-how or technical data in the field. M. Wieczorowski *et el.*[5] presented a comparative analysis of 3-dimensional surface characteristics evaluated by conventional procedures and by a newly proposed method that utilizes two dimensional autoregressive models. After that, a global system identification approach for the accurate parametric modeling of ultrasonic reflection and transmission experiments was studied by L. Peirlinckx *et el.*[6] in 1996. Recently, semiparametric bayesian analysis of survival data was studied by D. Sinha *et el.*[7] in 1997.

This study has developed the system creating working data by applying three-dimensional parametric modeling for cavity and core working for mould making of air intake hose, which is one of automobile parts shown in Fig. 1. The developed system offers an output of working data which is suitable for working condition in applying to the present working site by judging working condition,

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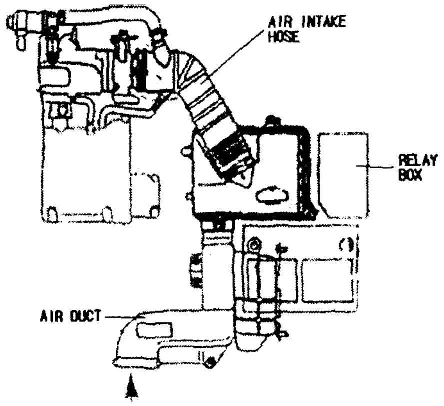


Fig. 1. Air intake system.

using machines, using tools, and cutting material, etc. by utilizing inference engine by knowledge base. This system is developed by utilizing User Programming Language (UPL) under the environment of Personal Designer CAD/CAM software.

2. Technique for Mould Working

2.1 Scope and object of study

In recent automobile engineering, the harmful exhaust gases being emitted through the automobile engine are classified into evaporating gas, blow-by gas and emission gas according to their exhaustion cause. And wider and deeper study is progressing for countermeasuring of emission reduction. Since this problem is related to the environment, it is prospected that the new emission control technique will be developed to reduce emissions in the future. This study made its scope to the automatic mould working for the connecting parts of air intake hose in order to reduce blow-by gas of such emission control techniques. The air passed through the air cleaner will pass through the intake hose and then is sucked into the engine. The object of this study is the connecting portion of the air intake hose where it is sucked into the engine. The object of this study is the connecting portion of the air intake hose connection between the air intake hose and the intake manifold, which is the formation of a combination of the main cylinder and the conical branch pipe.

2.2 Structure and modeling of mould

For refilling the air intake hose parts which are the object of this study, the heat of blow-by gas collected from the engine and vibration of automobile should be considered, so a rubber with a high heat resistance must be used. The mould consists of two cavities, which determine the external shape of the part, the interior core, mould base, and accessary devices. Here, there are two kinds of working method of the part forming for the cavity in moulding technique. The one is the machining method using copy model and the other is a modeling for the object part by using the three-dimensional CAD/CAM software.

Copy machining requires great expense and time because it needs a working model. Recently, it is a general tendency to take the latter case in producing the mould.

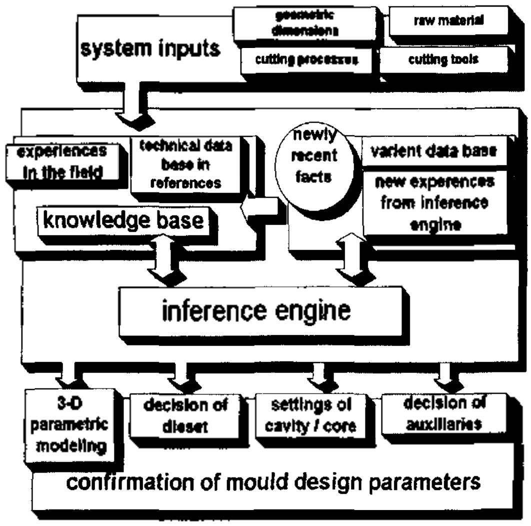
2.3 Practical application of knowledge base system

In the case of press die, the process design and die design system utilizing knowledge base, H. Gloeckl *et al.*[8] developed the optimum shape anticipating system of blank in the irregular deep drawing product, which has been studied wider and deeper. Recently, Park *et al.*[9] reported the CAD/CAM system of axisymmetrical deep drawing process. In the case of press process, since its object is mainly simple three-dimensional shape or two-dimensional shaped products, it has the advantage of handling easily. On the other hand, as most products have complicated three-dimensional shape in the injection or rubber mould working, it is not easy to apply to the system.

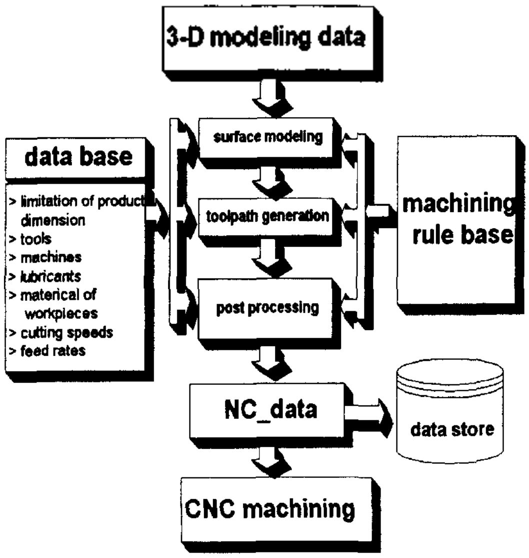
3. Construction of System and Working Rule Base

3.1 Construction of system

The construction of the system developed by this study is shown in Fig. 2. The system is constructed so that the element of mould is automatically modeling in order to generate NC data, after calculating the tool path by utilizing a modeling data. The geometrical dimensions, information of raw material, cutting conditions and cutting tools are used as system input.



(a) The relations between knowledge base and confirmation of design parameters



(b) The procedure of NC data generation

Fig. 2. The block diagram of expert system for air intake hose products.

Through inference engine, the confirmation of mould design parameters are outputted. Fig. 2(a) shows the relations between inference engine and knowledge base. The procedure of generating NC data is shown in Fig. 2(b). In this block diagram, system flow have organized relationship between data base and machining rule base.

At the 3-dimensional parametric modeling module, modeling for air intake hose of 3-dimensional shape is executed by utilizing the modeling rules built up on the input shape variable and knowledge base. At the surface modeling module, surface modeling is done in order to calculate the tool path. At the tool path generation module, the tool path is calculated. And, at the post processor module, NC data is generated to be suitable for the format of machine tool to be used. That is, by receiving the input information for the variable to decide the shape, working condition, and the material to be worked. The parting line is established to be able to work as a process. Parametric modeling is executed by using variables in accordance with the rules and sequences of modeling.

The number of rotation of spindle of the machine tool, S, and feeding speed, F, in the made-up F are major data which directly influence working, of which decision is calculated from the relations of the kind of material to be worked and cutting tool, and the data base is built up on the basis of data obtained at the work in the field. The M code of NC data which is related to supply and suspension of cutting oil is provided to decide whether the cutting oil shall be supplied or not in accordance with the working material. The made-up NC data is to be stored by hard disk or floppy disk of the computer so that connecting to DNC can be done easily.

3.2 Rule base

In the developed expert system in this study, the rule base for three-dimensional modeling and the rule base related to working are adjusted in order to generate working data. Such rule bases are formalized rules without inconsistency in theory and reasonable logic through references, the data book at the working site, technical data and interview with engineers. In this thesis, the following working rules were used. The rule base concerning modeling were omitted. Some major working rule base used to develop this system are as follows:

Rule 1) The cutting speed is according to the following formula:

$$V = \frac{\pi \cdot D \cdot N}{1000} \quad (m/\text{min}) \tag{1}$$

Where, N is the number of rotation (rpm), V is the cutting speed (m/min) and D is the outer diameter of the cutting material (mm).

Rule 2) Feeding in milling working is according to the following formula:

$$f_Z = \frac{F}{Z \cdot N} \qquad (mm/blade) \tag{2}$$

Where, f_Z is feeding per blade(mm/blade) F is table feeding(mm/min), Z is the number of blade and N is the number of rotations (rpm).

Rule 3) The cutting depth shall be calculated with the variable to the diameter of tool and is according to the following formula:

$$C_d = \alpha \cdot T_d \tag{3}$$

Where, C_d: Cutting depth (mm)

α: Constant following cutting condition

T_d: Diameter of tool (mm)

Rule 4) Decision of cutting step is according to the following formula:

$$C_S = 2 \cdot \sqrt{2 \cdot T_R \cdot C_d - C_d^2} \tag{4}$$

Where, C_s: Cutting step (mm)

T_R: Radius of tool (mm)

C_d: Cutting depth (mm)

Rule 5) The angle of inclination influences greatly to cutting resistance, chip exhaustion and the life of the tool. In the case that the strength of the cutting line requires solid material to be cut, black surface and intermittent cutting, the angle inclination is made small, and in the case of soft material to be cut and with poor rigidity of machine, the angle of inclination is made large.

Rule 6) The relief angle has the function to avoid friction between relief face of tool and material to be cut, and to feed the cutting line to the object to be worked. when cutting rigid material a strong cutting line is required and the relief angle is made small. When cutting soft material apt to be hardened by working, the relief angle is made larger.

Rule 7) The side cutting angle influences greatly upon chip exhaustion and cutting resistance, selecting a proper angle is required. Considering rigidity of the tools to be used, and in the case of finishing cutting of small cutting depth, thin and long material to be cut and small rigidity of machine, the side cutting is to be small. And, in the case of rigid, or cutting material of large calorific value, side cut working for material to be cut of large diameter or a machine of large rigidity of toughness of a side cutting angle should be larger.

Rule 8) The end cutting angle prevents friction between cutting face and tool, and influences density of the working surface, in the case of small cutting volume, finishing cutting, or when cutting thin and long material, the radius of the nose is to be small, and when a strong cutting line is required for black surface or intermittent cutting, it requires side cut working for material to be cut with a large diameter, and in the case of a high rigidity machine, the radius of the nose should be larger.

Rule 9) As far as the shape of the working object allows, select a tool with a large approaching angle.

Rule 10) As far as the shape of the working object allows, select an insert shape with a high strength cutting line.

Rule 11) As far as the shape of the working object allows, select a large insert of a larger nose radius.

Rule 12) For light and finish cutting, select an insert of many applying corner numbers.

Rule 13) As far as cutting conditions and cutting in volume allows, select a small insert.

Rule 14) Select the largest cutting in volume within the scope of allowable working conditions.

Rule 15) Select the largest feeding volume within the scope of allowable working conditions.

4. Application and Consideration of System

The possibility of application of the system to the present working site is examined to apply the developed system to the practical working. The variables concerning quality of mould elements, the number of cutting processes, the diameter of tool, the number of tool blade, etc. and 8 shapes variables concerning air intake hose such as diameter, length, length of branch pipe, angle of branch pipe etc. The parameters of air intake hose product are inputted by utilizing the developed system.

For the mould material, STD11 with hardness of H_RC 55-H_RC 60 was selected, the number of cutting processes was 4, and for tools, ϕ20 mm of ball

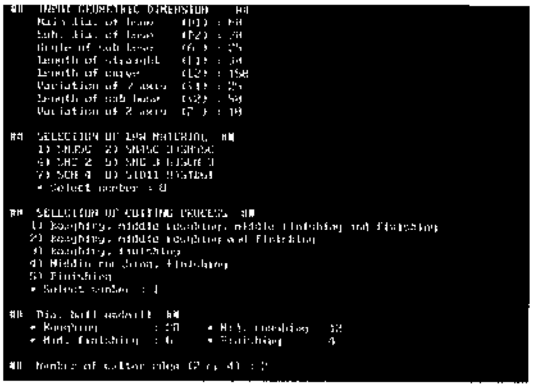


Fig. 3. Display of input data.

endmill for rough cutting, ϕ12 mm for middle cutting, ϕ6 mm for middle and fine cutting, and ϕ4 mm for fine cutting were used respectively. Fig. 3 shows the condition of screen on which the completed input is shown.

From the input data given by the user at the input module, the cutting condition such as cutting speed, feeding speed, cutting depth, cutting distance, the number of rotation of the main axis, etc. are calculated.

At the 3-dimensional parametric modeling module, 3-dimensional modeling for the shape to work is completed. At this time, 3-dimensional model for the mould element of the air intake hose is automatically generated in accordance with procedure and method by modeling rules.

At the surface modeling module, the parting line is decided in order to working core and cavity and surface model, in order to obtain a complete tool path.

At the tool path generation module, the tool path for the related cutting process following information on tool received from input module is calculated. The tool path generated by utilizing surface model is shown in Fig. 4.

In accordance with the shown tool path generated by utilizing surface model to cutting working condition variables, the tool path reflected cutting conditions such as cutting speed, feeding speed, cutting depth, cutting distance, and number of rotation of main axis is calculated, and is stored as the directory and name of file designated by the user.

The post processor is built in the system to be suitable for the format of the machine tool to be used for working. The built-up post processor is structured with the NCBASIC computer language. The tool path is calculated as NC data suitable for the format of CNC machine tool to be worked by the built up post processor and is stored as the directory and file name stored by the user. By inputting working condition variables and modeling shape variables of Fig. 3, a portion of NC data generated through the whole model of the developed system is shown in Fig. 5.

When NC data generated by this system is analyzed, it is calculated as the four processes of rough cutting, middle cutting, middle and fine cutting, and fine cutting and the ball endmill of 20 mm in diameter is used for the first process and it is worked under the cutting condition of 21.99 m/min. cutting speed, 40 mm/min. feeding speed, 350 rpm is the number of rotations of the main axis, 6 mm cutting depth, and 18.33 mm cutting distance. In the second

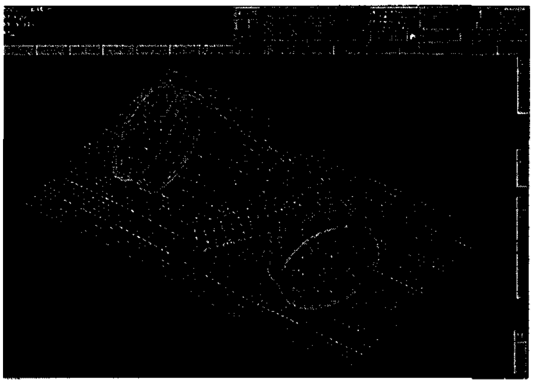


Fig. 4. A generation of tool path.

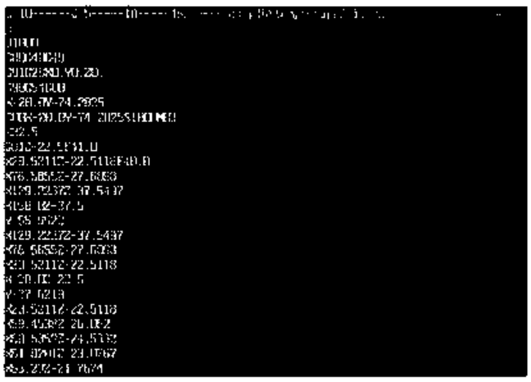


Fig. 5. Display of output data.

process, with the ball endmill phi 12 mm in diameter, it is worked under the cutting condition of 22.6 m/min. of cutting speed, 40 mm/min. feeding speed, 600 rpm is the number of rotations of the main axis, 3.6 mm cutting depth and 11 mm cutting distance. For the third process, with the ball endmill of ϕ6 mm, it is worked under the cutting condition of 22.61 m/min. cutting speed, 40 mm/min. feeding speed, 1200 rpm is the number of rotations of the main axis, 1.8 mm cutting depth and 5.5 mm cutting distance. And for the fourth process, with the ball endmill of ϕ4 mm, it is worked under the cutting condition of 22.61 m/min. cutting speed, 35 mm/min. feeding speed, 1800 rpm is the number of rotations of the main axis, 1.2 mm of cutting depth and 3.6 mm of cutting distance, data possible to working is generated.

The above result confirmed that the generated NC data calculated and generated a suitable number of rotations of the main axis, feeding speed, cutting distance and cutting depth which can be used at the actual working site[10].

In the case of a changing shape dimension variable and working condition, by working the air intake hose product which is changed its shape and size in accordance with the input shape dimension and working condition, the shape change by parametric technique was examined. Input data for examination of parametric shape modeling is shown in Table 1. For input condition, by inputting working conditions and shape variable differently with each other with three different specimens. Work was executed with the CNC machining center using generated NC data for each specimen. For processing condition, chemical wood was used for the specimen, for rough cutting, the ball endmill of ϕ20 mm in diameter was used, and it was worked under the cutting condition of 100 rpm rotation of the main axis, 25 mm cutting depth, and 18.33 mm cutting distance, and for middle cutting working, with the ball endmill of ϕ12 mm in diameter, it was worked under the cutting condition of 250 mm/min feeding speed, 1200 rpm main axis' rotation number, 12 mm cutting depth, and 11 mm cutting distance, and for middle cutting working, with the ball endmill of ϕ6 mm, it is worked under the cutting condition of 600 mm/min feeding speed, 1400 rpm the number of rotation of main axis, 6 mm cutting depth, and 5.5 mm cutting distance. And, for fine working, with the ball endmill of ϕ4 mm in diameter, it was worked under the cutting condition of 850 mm/min feeding speed, 1800 rpm the number of rotations of the main axis, 3 mm cutting depth and 2.8 mm cutting distance. The worked result for three specimens is shown in Figs. 6 to 8. Fig. 6 is the shape of air intake hose part worked by NC data

Table 1. Input data of each specimen

Dim. of shape (mm)	Specimens		
	A	B	C
Main dia. of hose	65	60	45
Sub dia. of hose	35	20	20
Angle of sub hose	25	30	15
Length of straight	30	30	40
Length of curve	170	150	100
Variation of Y axis	20	25	15
Length of sub hose	50	40	55
Variation of Z axis	20	10	10

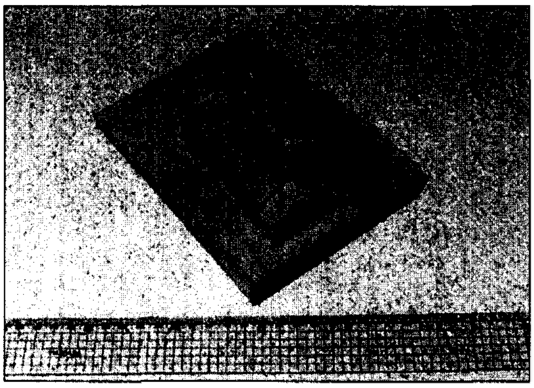


Fig. 6. Finished shape of specimen "A".

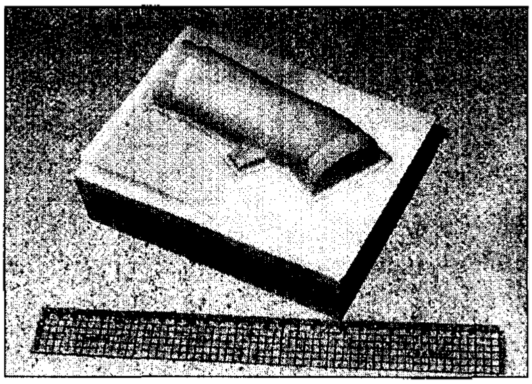


Fig. 7. Finished shape of specimen "B".

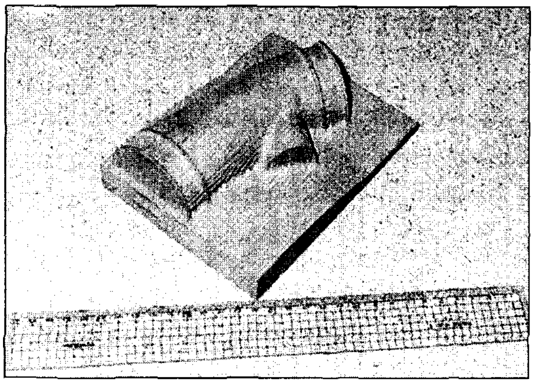


Fig. 8. Finished shape of specimen "C".

generated by inputting shape variable to specimen A of Table 1. Fig. 7 is the shape of air intake hose part worked with NC data generated by inputting shape variable to specimen B in Table 1.

Fig. 8 is the shape of air intake hose part worked with generated NC data by inputting shape variable to specimen C in Table 1. Fig. 9 shows the working of the specimen shown in Fig. 6 with the

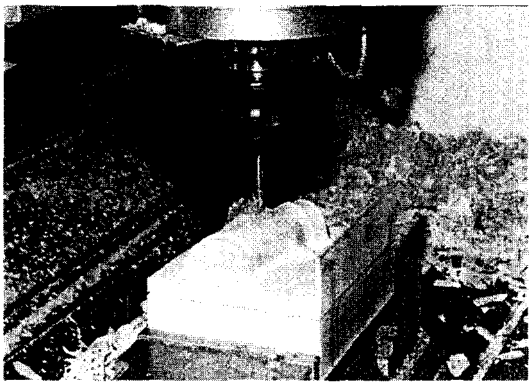
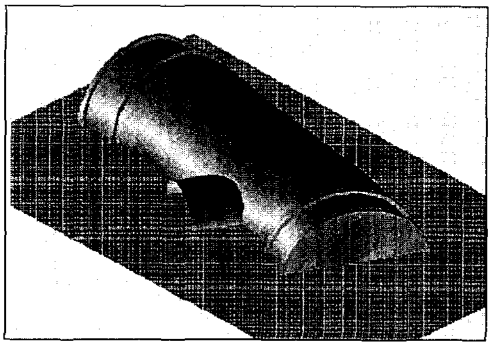


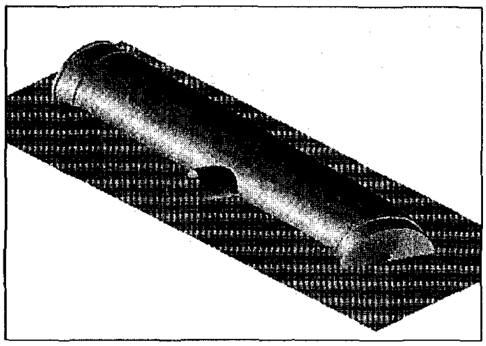
Fig. 9. Cutting of specimen "A".

Table 2. Input data of shape parameters for expandability and feasibility

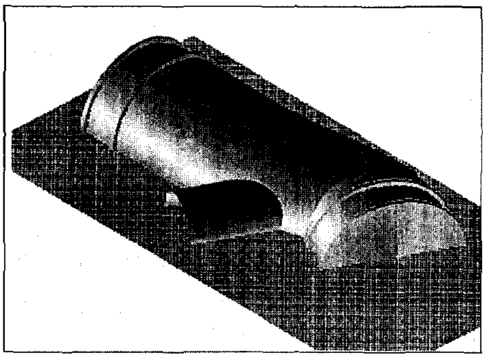
Dim. of shape (mm)	Specimens			
	AA	BB	CC	DD
Main dia. of hose	65	60	45	50
Sub dia. of hose	35	20	25	30
Angle of sub hose	20	30	25	35
Length of straight	30	30	40	25
Length of curve	140	260	120	130
Variation of Y axis	25	25	15	30
Length of sub hose	35	25	50	30
Variation of Z axis	20	15	10	30



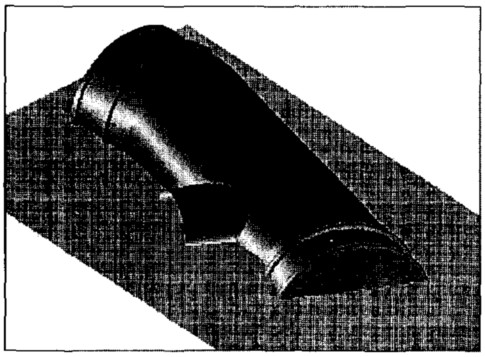
(a) Modeling output of specimen "AA"



(b) Modeling output of specimen "BB"



(c) Modeling output of specimen "CC"



(d) Modeling output of specimen "DD"

Fig. 10. Examination of expandability and feasibility

vertical milling machining center by utilizing NC data.

In order to check the feasibility and the expandability of this system, several input parameters shown in Table 2 should be adapted. Fig. 10(a-c) and (d) show the shaded output results obtained from the system. It found that this system could be possible to obtain the machining data of air intake hose with the various shapes and size rapidly. According to the input variable as the cutting result of three working specimens, the result was obtained that it is possible to cut the working specimens having calculated shape and size. In the case of injection mould which changing shape occurs frequently following dimensions having similar shape, we can easily experience a number of trial and error on modeling work and repeating work in order to generate design and NC data. The result of generating automatic modeling and NC data by the developed system can minimize inefficiency of such trial and error and repeated designing work. However, in the cutting work to be able to obtain suitable working data and its result relating to various moulds, tools, and machine tools, systematic and standardized theory and adjustment of data of the working size are required, and continuous study is required in the future for automatic modeling, and building up working data base and rule base.

5. Conclusion

The mould working system of air intake hose developed in this study is the expert system which calculates and outputs NC data so that working is possible at modeling process and NC machine for mould working for air intake hose of three-dimensional shape of which dimension changes partially or generally, though it has similar shape. In order to build up knowledge base for modeling and working, the method of interview with experts in the mould designing and working field was applied, and knowledge was obtained through the existing data on the working site which was standardized, and the expert system was developed by using UPL language to express knowledge. The air intake hose modeling and working data generation system developed by this study, outputs NC data so that working can be done by machine tool by automatically calculating working data following characteristic of automatic modeling and working of air intake hose of three-dimensional shape including free curve and free curved surface by inputting minimum information deciding the shape of injection product. The working data at this time calculates the working data reflecting suitable for working by judging characteristics such as quality of material and characteristics of working machine and tools, and material to be cut. Such general process was reasoned from the knowledge base by the reasoning organization of expert system and its result was offered an output.

The working data for each result was generated by inputting the shape variable group of three kinds by utilizing the developed system, and the shape change by three-dimensional parametric through working by CNC machine was confirmed, and the possibility of application to the working site was examined. However, considering relationship of various mould materials, cutting tools and cutting machine tools by expanding this developed system, in the cutting working to be able to most suitable working data and working result, the standardized theory and establishment of data at the working site are required, and continuous study is required in the future to build up automatic modeling, working data base and rule base for various shapes. The advantages expected by developing this system are to be able to minimize time and expense in the working and producing moulds, and especially, many trial and error following modeling can be reduced. Also, since it calculates suitable working data by judging various cases following the working conditions, the life of tools can be extended and more clean working surface can be obtained.

However, this study will be requiring the more knowledge level in order to adapt the various types and condition in the working field. This system would be developing reinforcement of machining rule base for various mould materials, the structure and location of cavity and core, decision of dieset and auxiliary in the future.

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