Design and Simulation for Conjugate Cam Mechanism

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Abstract *Fuzzy synthetically appraising theory is put forward and to be used in the optimal selection of the law-of-cam motion. And its model is also established. An example has been given to illustrate the validity of this method. By compiling program about the optimal design and the simulation system, the motion and process simulation of the conjugate cams mechanism are realized. So the system can improve the efficiency, reduce the cost and solve the precision problem of high speed and over-loading about cam segmentation.*

Keywords *Conjugate cam mechanism Fuzzy evaluation Simulation Software*

1.Introduction

The conjugate cam mechanism has many excellences, including high speeding and over-loading, exact and effective control, steady capability and so on. It is a part of intermission and displacement mechanism, ATC equipment and walking equipment, which is widely used in wrapping machine, agricultural machine, printed machine and wiring assemble line and so on. Meanwhile, there exist a lot of faults. For example, there are complicated design processes, uneasy to ensure design quality, difficult to manufacture, to depend on import product for domestic need of high speeding and over-loading conjugate cam [1-4]. The cam's dynamic capability can be effectively improved by fuzzy synthetically appraising theory and optimal selection the cam's contour line. Some problems appeared during the process of design can be earlier solved by combining with advanced virtual design and manufacture technology which can shorten the cycle of design, improve the precision of design and effectively enhance the conjugate cam's design and the manufacture level.

2.Fuzzy synthetically selection of the-law-cam mation

It is important to select the-law-follower in the process of conjugate cam design. According to some fuzzy factors including the cam's working condition, economy, precision, and kinematics and dynamics characteristics of the motion law, meanwhile, synthetically considering a few relevant factors influenced the law-of-follower, the motion capability of conjugate cam can be effectively improved by fuzzy synthetically appraising theory. During the process of confirming the motion law, both loading and speed must be satisfied. So, we regard the two factors as sub-factors of the basic requirements[5-8]. Other factors include working conditions, economics, and precision and so on. Its secondary appraising rational tree, such as Fig. 1:

The process to choose the optimal motion law of the cam's followers by fuzzy synthetically appraising as follows:

A. The motion law-of-follower deduced by positive sequence is known as spare set. It can be denoted by the following set Fundatin of Shan Dong and SDUT (No Y2008F02、2005KJM04)

$$V_1 = \{v_{11}, v_{12}, \cdots, v_{1m}\}$$

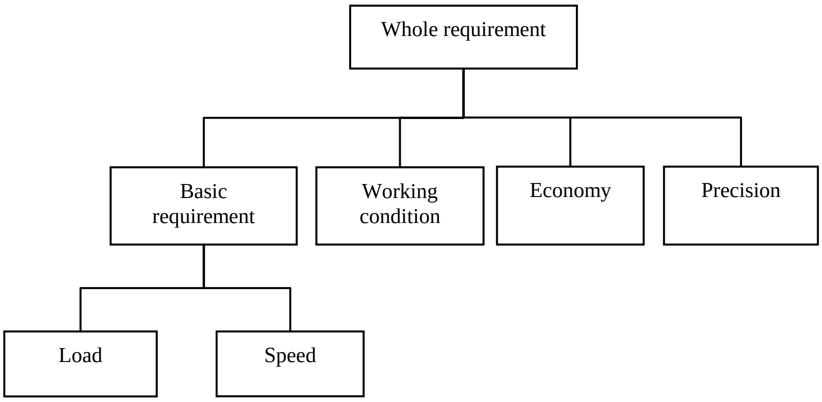


Fig.1. Secondary appraising tree of connection

B. The necessarily considered factors such as the maximum speed V_m, the maximum acceleration A_m, extracted the root-mean-square of speed A_{rms}, and move-loading torque characteristic value $(AV)_m$ and so on, are known as key factors, denoted by u_i

$$U_1 = \{u_{11}, u_{12}, \cdots, u_{1n}\}$$

C. As a result of different design requirement and the use spot, the importance of key factors is different. So, a fuzzy subset is established by analysing every key factor.

$$W_1 = \{w_{11}, w_{12}, w_{13}, \cdots w_{1n}\}, 0 \le w_{1i} \le 1, (i = 1, 2, \cdots, n)$$

In the set, w_{1i} is important degree coefficient of u_i, which is known as weight coefficient.

D. According to $u_i \ (i = 1, 2, \cdots, n)$, satisfactory subject degree of every element in the spare set is confirmed., forming the following matrix:

$$\underset{\sim}{R_1} = \begin{bmatrix} r_{111} & r_{112} & \cdots \\ r_{121} & r_{122} & \cdots \\ \cdots & \cdots & \cdots \\ r_{1n1} & r_{1n2} & r_{1nm} \end{bmatrix}, 0 \le r_{1ij} \le 1$$

It denotes the subject degree from element v_j to factor u_{ij} in the spare set.

E. The choice of motion law

$$\begin{aligned} B_1 &= W_1 \cdot R \\ &= (w_{11}, w_{12}, ..., w_{1n}) \cdot \begin{bmatrix} \mathrm{r}_{111} & \mathrm{r}_{112} & \cdots & \mathrm{r}_{11m} \\ \mathrm{r}_{121} & \mathrm{r}_{122} & \cdots & \mathrm{r}_{12m} \\ \cdots & \cdots & \cdots & \cdots \\ \mathrm{r}_{1n1} & \mathrm{r}_{1n2} & \cdots & \mathrm{r}_{1nm} \end{bmatrix} \\ &= (\mathrm{b}_{11}, \mathrm{b}_{12}, ..., \mathrm{b}_{1m}) \end{aligned}$$

Hereinto, $b_{1k} = \sum_{j=1}^{n} w_{1j} \cdot r_{1jk} \ (k = 1, 2, ..., m),$

v_j corresponding to $\max b_{1k}$, v_j is the best choice.The flow chart of synthetically choice is denoted as Fig. 2.

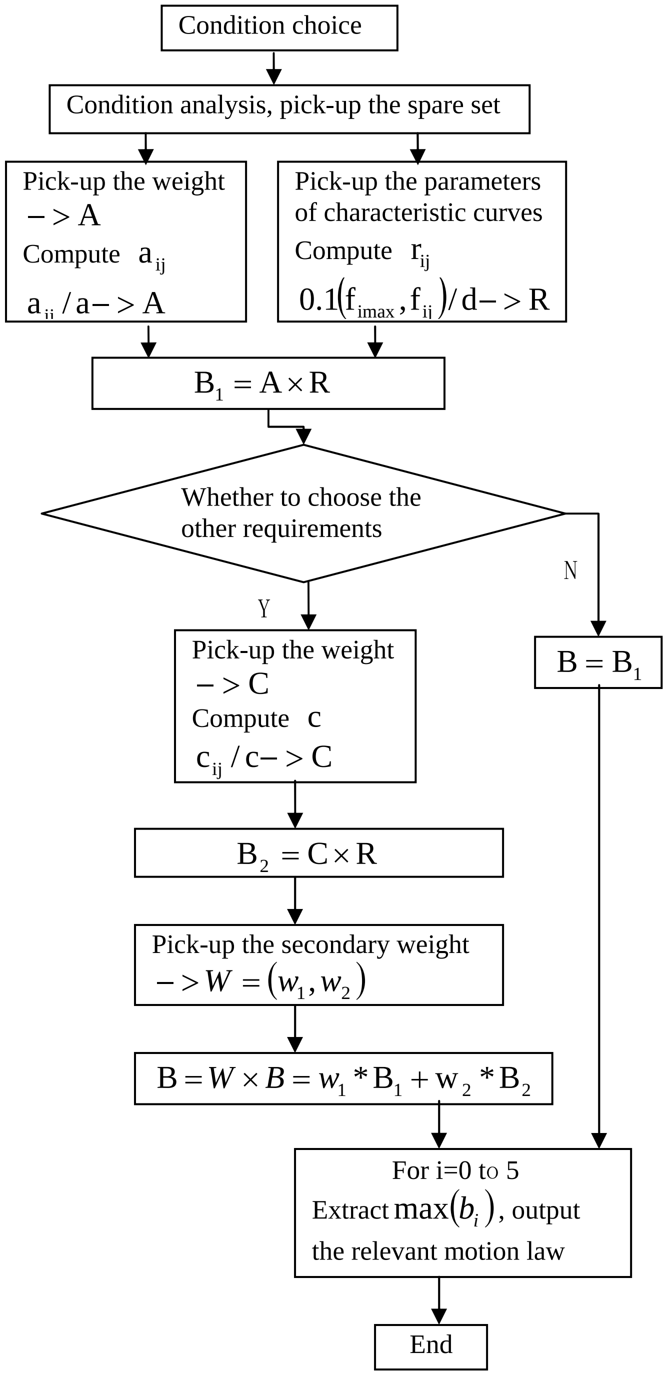


Fig.2 The flow chart of the cam's followers' motion law confirmed by fuzzy synthetically theory

F. Example

①Requirement of use: middle speed, light-load, low noise.

②Spare set: $V_1 = \{v_{11}, v_{12}, v_{13}, v_{14}, v_{15}\}$

= {sine, amending constant speed, amending trapezoid, amending sine, equal addition and minus}

③Characteristic values of every curve are regarded as key factors:

$$U_1 = \{V_m, A_m, (AV)_m, A_{rms}, \tau_m, J_m\}$$

Because of the higher speed, A_m and J_m should be lower. So, its weight coefficient should be a little bigger; because of the light-load, weight coefficient of V_m and $(AV)_m$ can be a little lower; because of the lower noise, weight coefficient of τ_m should be proper bigger. Synthetically considering various requirements, the right weight modulus can be taken as:

$$W_1 = \{w_{11}, w_{12}, w_{13}, w_{14}, w_{15}, w_{16}\}$$
$$= \{0.2, 1, 0.1, 0.5, 0.6, 0.8\}$$

After computing every percentage of their weights:

$$W = \{0.0625, 0.3125, 0.03125, 0.15625, 0.1875, 0.25\}$$

④Characteristic values of various motion law, such as Tab.1:

Tab.1 Characteristic values of various motion law

Sequence number	Curve's name	V_m	A_m	$(AM)_m$	A_{rms}	J_m	T_m
1	amending equal speed	1.275	8.013	5.671	4.001	201.4	63.3
2	equal addition and minus	2.0	4.0	8.0	4.0	∞	—
3	amending trapezoid	2.0	4.888	8.048	4.232	61.43	26.71
4	sine	2.0	6.238	8.126	4.443	39.48	44.14
5	the mending sine	1.76	5.528	5.435	3.908	69.47	34.17

Subject degree can be formed with $r_{ij} = 0.1 + (f_{i\max} - f_{ij})/d$

$$d = (f_{i\max} - f_{i\min})/(1 - 0.1).$$

The matrix can be formed:

$$R_1 = \begin{bmatrix} 0.1 & 1 & 0.1 & 0.4 & 0.1 \\ 0.5 & 0.1 & 0.8 & 0.66 & 1 \\ 0.1 & 0.92 & 0.13 & 1 & 0.15 \\ 0.1 & 0.84 & 0.45 & 1 & 0.85 \\ 1 & 0.1 & 0.88 & 0.83 & 0 \\ 0.57 & 0.1 & 1 & 0.82 & 0 \end{bmatrix}$$

⑤Adopting synthetic appraise model of weighted average, namely:

$$b_j = \sum_{j=1}^{m} w_j \cdot r_{ij}, i = 1, 2, ..., m$$

That: $B_1 = W \cdot R = (0.511, 0.298, 0.746, 0.779, 0.456)$

Hereinto, the amending sine curve is the best choice which is corresponding to $\max b_j = 0.779$, the following curve is amending trapezoid curve (corresponding to $b_j = 0.746$), sine, equal addition and minus, amending constant speed. Known by experience, amending sine curve among several curves has the strongest use, the better capability/performance. The method's accuracy and feasibility are validated. The amending trapezoid is in the second place.

3.Motion simulation for conjugate cam

Because contour curve of cam is formed by multiple curves, the correct contour curve of cam will not be gained if the input cam's parameters and motion law aren't proper (Fig. 3).

In order to avoid manufacturing the unqualified cam, the cam's rationality and accuracy must be detected by motion simulation after gaining the relevant datum of designing cam model. We pick up the above data of the design model and change them into date format which can be recognized by graph software AutoCAD and UG. The cam's accurate contour graph and three-dimensional dynamic simulation model can be automatically built in the graph environment. In the whole process of design, No only the relevant datum can be disposed of; but the visualization of designing results can be achieved by motion simulation. The designer can amend design parameters at any moment. So, the optimal design scheme can be gained, the ratio of waster during the practical process can be reduced, meanwhile, the cost can be reduced too.

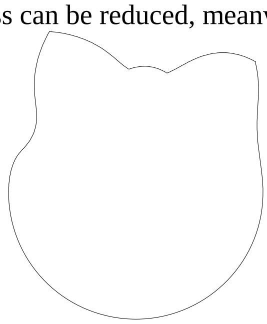


Fig.3. The error cam's contour curve

The flow of simulation analysis and numerical controllable programming module is mainly divided into two parts:

First, implement graph simulation in AutoCAD2006 by compiling data interface files (Camshape.scr) on the platform of VC++6.0, we can extremely intuitively judge whether contour is distortion or comes to a point. Meanwhile, we can compile the interface files that numerical controllable line incision machine tool needs by AutoLISP language.

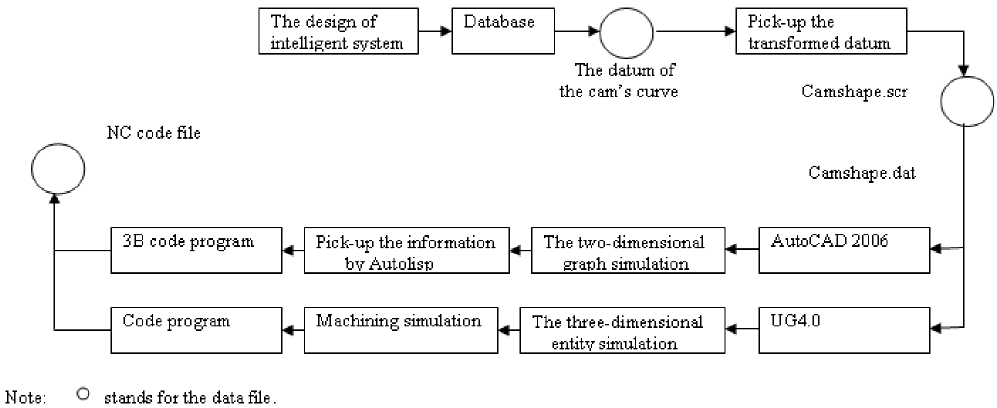


Fig.4. The flow chart of simulation and program model

Second, implement three-dimensional graph simulation and numerical controllable programming in UG NX3.0 by compiling data interface files (Camshape.scr) on the platform of

VC++6.0, simulate the processing movement of the cutting tool and cutting situation of the workpieces by using the UG's formidable processing module.

Examine whether there occurs over-cutting or interference collision in order to validate the accuracy and the rationality of the procedure in front of the post-processing and make the prompt revision, thus guarantee accuracy of numerical controllable programming of cam's contour.

Its flow chart of simulation and program model is denoted as Fig. 4.

The motion simulation is denoted as Fig. 5.

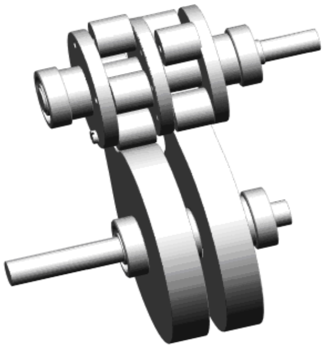
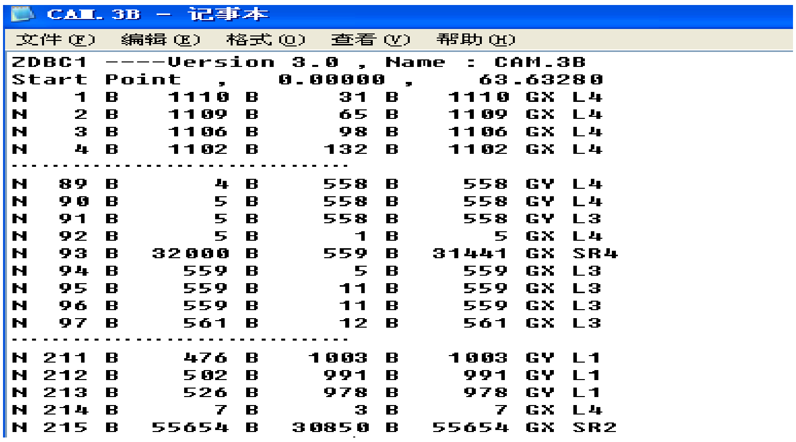


Fig.5 The three-dimensional motion simulation of conjugate cam

4.Machining simulation for conjugate cam

For the regular cam tested by motion simulation model, we pick up the data which program needs from the graphics software and send data files to the automatic program model, and meanwhile, we choose the type of program, then, the numerical control line incision 3B or machining G programming can be realized according to practical needs. And the accuracy can be detected by machining simulation. If there were some problems, the program would be compiled over again.

By the procedure of drawing data in AutoCAD, the cam's counter data can be gained and changed into 3 B line cutting codes such as Fig. 6. And the knife track codes such as Fig. 7; the machining simulation is denoted as Fig. 8.



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N    2 B    1109 B      65 B    1109 GX L4
N    3 B    1106 B      98 B    1106 GX L4
N    4 B    1102 B     132 B    1102 GX L4
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N   89 B       4 B     558 B     558 GY L4
N   90 B       5 B     558 B     558 GY L4
N   91 B       5 B     558 B     558 GY L3
N   92 B       5 B       1 B       5 GX L4
N   93 B   32000 B     559 B   31441 GX SR4
N   94 B     559 B       5 B     559 GX L3
N   95 B     559 B      11 B     559 GX L3
N   96 B     559 B      11 B     559 GX L3
N   97 B     561 B      12 B     561 GX L3
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N  211 B     476 B    1003 B    1003 GY L1
N  212 B     502 B     991 B     991 GY L1
N  213 B     526 B     978 B     978 GY L1
N  214 B       7 B       3 B       7 GX L4
N  215 B   55654 B   30850 B   55654 GX SR2
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Fig.6. The 3 B line cutting codes

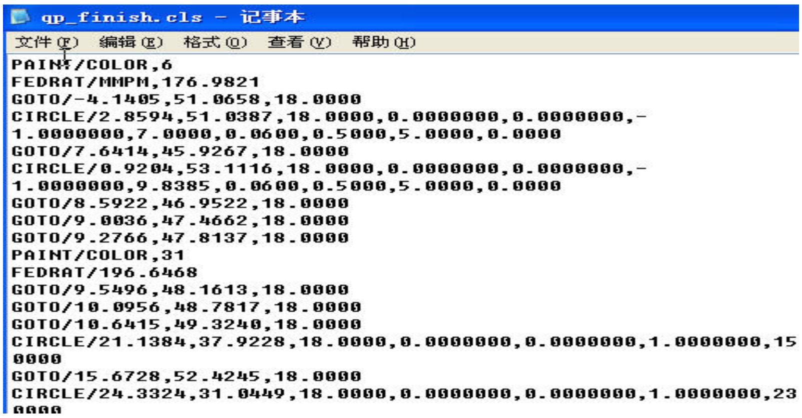
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Fig.7. The knife track codes

At last, by the program's transferring model, send the correct program to the cam machining tool and complete the cam's machining. To do so, the design, simulation and manufacture are integrated; it can share the datum and enhance the work efficiency.

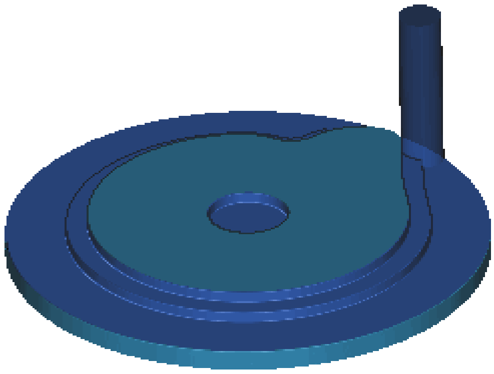

Fig.8. The machining simulation of conjugate cam

5.Conclusions

According to some fuzzy factors including the cam's working condition, economy, precision, and kinematics and dynamics characteristics of the motion law, the fuzzy optimal design for the conjugate cam is realised by applying the fuzzy synthetically appraising theory. And its model is also established. Meanwhile, program the procedure of the fuzzy optimal design and simulation system. By combining existing advanced graphic simulation software, the design, simulation and manufacture are integrated. Therefore, integration work of design and manufacture is completed. So, the system can share the datum, improve the efficiency, reduce the cost and solve the design precision problem of the high-speed, over-loading conjugate cam.

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