Building multi-objective optimization function of NC cutting parameter for Chemical Tower

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Abstract. By VB secondary development in UG(Unigraphics ） environment, it develops CAM(computer aided manufacturing) on Bill of Materials (BOM) for chemical tower to improve data management. Numerical control(NC) machining is the critical component of CAM. Cutting speed v, feed f, and back engagement of the cutting edge a_p are the most active factors in machining. So it is an important link to optimize the cutting parameters. These parameters can be optimized to mathematical description on NC. With the cutting edge a_p, feed f, cutting speed v taken as independent variables, the multi-objective function can be relied on weighted sum approach to meet the highest production efficiency and the lowest production cost. It will be theoretically and practically beneficial to construct mathematical model of NC on BOM for chemical tower.

Introduction

Chemical tower, also known as column, is the important equipment to transfer liquid-liquid mass or gas-liquid mass. It presents certain common structure characteristics, including extensive use of standard, non-standard parts. The extensive use results in column's complex structure and different size. Most manufacturing enterprise presently have adopted the traditional manual mode for technical data management. Aiming at the issues above, the paper develops CAM(computer aided manufacturing) on Bill of Materials (BOM) for chemical tower to improve the data management.

In UG environment, computer aided design on BOM for chemical tower is developed using the development tools of VB. Mapping algorithms are established to process all BOM data. BOM management module is created accordingly. In NC machining of CAM, cutting parameter library is firstly established to store information of cutting parameter, machining tool, blanks and so on. By the highest production efficiency and lowest production cost as optimization objectives, a model of multi-objective optimal cutting parameter is founded. Based on information of engineering BOM and manufacturing BOM, taking manufacture equipment, cutting parameter as constraint conditions, simulated annealing genetic algorithm of the model is solved to obtain the optimal cutting parameter. By UG secondary development，the CAM module of BOM management for chemical tower is realized, demonstrated as figure1.

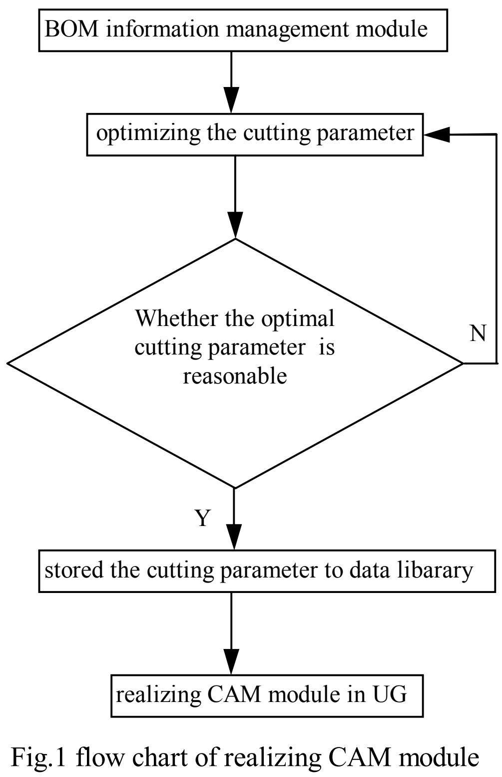

Fig.1 flow chart of realizing CAM module

NC cutting is a complex process. The reasonable cutting parameter will cut cost, increase efficiency, reduce the enterprise cost.

Decision variables in the optimum mathematical model of cutting parameter

NC machining is a critical component of CAM. The quality, productivity, and cost of the production are deeply affected by the cutting parameter reasonable selection. At present, optimizing the cutting parameter is an important link in machining. The optimization is largely effected on economy of the machining process. Back engagement of the cutting edge a_p, feed f, cutting speed v are the most active factors in process. They became objects of study in cutting parameter optimized system. On the premise of meeting quality, cut cost and increase efficiency are carried out to optimize the cutting parameter in NC machining.

In creating the optimization mathematical model, the objective function is important to select. The reasonable optimization can simplify solution procedure, improve optimized efficiency, and solve the optimal solution. The fundamental cutting parameter was set as the optimization objective function, which influenced on the production cost, processing quality. And those cutting parameter remained unchanged can be assigned through human interaction, which have little influence on cutting process. In actual machining, back engagement of the cutting edge a_p is determined by machining allowance, cutting speed v is determined by cutting blank diameter and main shaft speed n. Consult cutting parameter manual to confirm the shaft speed n and feed f. The user experience and programming system recommendation should be also considered when setting them. So the user has the right to determine the back engagement of the cutting edge a_p by cutting depth. To simplify the optimal solution, the shaft speed n and feed f are required to optimize.

Setting up the optimization objective function

To maximize economic benefit, the highest efficiency and the lowest cost of production are factors to be considered in optimizing, based on quality guarantee and processing safety. In practice, the following three parameters are set as the optimization objective.

The highest production efficiency(or the shortest production time) optimization function

To realize the highest production efficiency, more products are produced in a certain period of time. It can also be expressed producing each product in minimal time T_T. Machining process consists of three steps. They are workpiece fixing, cutter-changing and cutting process. Formula 1 is the highest production efficiency(or the shortest production time) optimization function in the abstract.

$$f(t) = \min(T_T) = \min(T_m + \frac{T_m}{T} T_c + T_a) \qquad (1)$$

Where T is cutter durability, T_a is fixing time, T_c is cutter-changing time, and T_m is cutting process time.

Cutter durability T and cutting process time T_m in lathing are different in different selectiion of processing manner and parameters.

$$T = \frac{K_T C_T}{n^m f^q a_p^s} \qquad (2)$$

$$T_m = \frac{60L}{nf} \qquad (3)$$

Where C_T is tool life coefficient, K_T is corrective coefficient, L is cutting length whose unit is mm. The m, q, s are influence coefficients of n, f, a_p separately. They can be found in cutting manual. To T, T_m into the formula 1 to go. The time to cut workblank in lathing is expressed in formula 4 .

$$f(X) = \min(\frac{60L}{nf} + \frac{60Ln^{m-1} f^{q-1} a_p^s T_c}{K_T C_T} + T_a) \qquad (4)$$

In the same way, cutter durability T in milling is expressed as follows too.

$$T = \left(\frac{C_V D q_V K_V}{V_C f_z^{y_v} a_p^{x_v} a_e^{u_v} Z}\right)^{1/m} \quad (5)$$

The time to process in milling is expressed in formula 6 .

$$T_m = \frac{1000\pi DL}{Zv_c f_z} \quad (6)$$

Where D is milling cutter diameter whose unit is mm. Z is the number of cutter. C_v, q_v, k_v, x_v, y_v, u_v and m are constant coefficients, which can be detected in cutting manual. To T, T_m into the formula too. The time to cut workblank in milling is expressed in formula 7 .

$$f(X) = \min\left(\frac{1000\pi DL}{Zv_c f_z} + T_a + \frac{1000\pi DLT_c}{Zv_c f_z}\left(\frac{C_v D q_v k_v}{v_c f_z^{y_v} a_p^{x_v} a_e^{u_v} Z}\right)^{-1/m}\right) \quad (7)$$

The lowest production cost optimization function

The lowest production cost optimization function is expressed as follows in the abstract, to meet different processes.

$$f(c) = \min(C) = C_m\left[T_m + T_a + \frac{T_m}{T}\left(T_c + \frac{C_r}{C_m}\right)\right] \quad (8)$$

Where C_m is man-hours, and C_r is work costs.

According to the processing method as the above, production and cost in lathing is expressed in formula 9.

$$C(X) = \min(C) = \min\left(C_m\left(\frac{60L}{nf} + T_a + \frac{60Ln^{m-1} f^{q-1} a_p^s}{K_T C_T}\left(T_c + \frac{C_r}{C_m}\right)\right)\right) \quad (9)$$

While production and cost in milling is expressed in formula 10 too.

$$C(X) = \min\left(C_m\left(\frac{1000\pi DL}{Zv_c f_z} + T_a + \frac{1000\pi DLT_c}{Zv_c f_z}\left(\frac{C_v D q_v k_v}{v_c f_z^{y_v} a_p^{x_v} a_e^{u_v} Z}\right)^{-1/m}\right)\left(T_C + \frac{C_r}{C_m}\right)\right) \quad (10)$$

Multi-objective optimization function

In the practical, product efficiency and cost are contradictory. High product efficiency certain raise the cost. In order to achieve the best performance, each objective function must be considered at the same time. So it has researching for multi-objective optimization function. Considering the relative importance of each parameter, the optimum result of the overall performances is obtained to strike a balance among goals. The optimization is a process that turns the statistic indexes of different dimension into relative values(or as dimensionless). A multiple-parameter comprehensive evaluation method is obtained by integrating those evaluations.

Solving multi-objective optimization is expressed as follows.

$$F(X) = (f_1(X), f_2(X), \ldots, f_n(X))^T \quad (11)$$

Where the variables $X = (x_1, x_2, \ldots x_k)^T$ are to optimize. They were satisfied to $g_i \le 0, i = 1,2,\ldots, j$, $h_i = 0, i = 1,2,\ldots,k$.

There are many methods to solve multi-objective optimization function, such as objective programming approach, voting analytic hierarchy process (VAHP), evaluation function method and so on. The common evaluation function method is weighted sum approach. This concept built on each objective's importance in optimizing, gives the weighted coefficient w_i to each objective. The evolution functuin is built as formula 12. The weighted coefficient w_i reflects the importance of each objective.

$$\min F(X) = \sum_{j=1}^{n} w_j f_j(X) \quad (12)$$

Where $\sum_{j=1}^{n} w_j = 1, w_j \in (0,1), X = (x_1, x_2, x_3)^T$, w_j is the weighted coefficient *of* objective *j*.

The evaluation function method is high-efficiency one to process multi-objective optimization function. The weighted coefficient will be determined according to user experiences. The objective function is built upon the concept of weighted sum approach from formula1 and 8, expressed as follows.

$$F_t = \min(\lambda_1 C + \lambda_2 T_T) = \min\left(\left(\frac{T_m}{T} T_c + T_m + T_a\right)\lambda_1 + C_m \lambda_2 \left[T_m + T_a + \frac{T_m}{T}\left(T_c + \frac{C_r}{C_m}\right)\right]\right) \quad (13)$$

Where T, T_m indicates cutter durability and cutting process time respectively in the corresponding method.

Conclusion

In UG environment, computer aided design on BOM for chemical tower is developed.The process parameters can be optimized to mathematical description on NC. The multi-objective function relied on weighted sum approach to optimize man-hour, cost, quality and so on. Setting up the optimization objective function can meet the NC processing requirements. It will cut cost, increase efficiency, reduce the enterprise cost. The work of this thesis will be theoretically and practically beneficial to improving the NC processing, acquiring the best economical efficiency and providing reference for production.

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