The processing of parts with group technology in an individual CNC machining center

B.Z. Gong

Faculty of Engineering, Ningbo University, Zhejiang Province, P.O. Box 315211, Ningbo, China

Abstract

This paper proposes a new machining method for parts using group technology suitable for workshop condition in China. The method divides the parts of each product into similar kinds according to their features, and installs each kind of parts on different working platforms. By changing the platforms in turn, nearly all of the parts of one product can be processed with one CNC machine, and can be sent directly to an assembly shop. Thus the number of management links is reduced and the production rate is increased. This paper presents theoretical analyses of the working platform, coding classification, cluster analysis and fixture planning.

Keywords: Working platform; Coding classification; Cluster analysis; Fixture planning

1. Introduction

Group technology (GT) is a highly efficient processing method, which divides different parts of a product into different types according to their shape, size, material, processing pattern and necessary equipment. GT runs through the whole production process including production planning, designing, processing preparation, manufacturing and economic accounting.

Currently, most research on GT focuses on the following: (1) introduction of information management systems to enterprises; (2) development of CAD/CAPP/CAM systems using parameters and blocking; (3) development of FMS units suitable for processing parts with different features; (4) establishment of material-flow storing and transporting systems based on similar principles; and (5) development of software systems based on the management of the production plan and manufacturing resource plan.

All of this is mainly directed at large-scale enterprises, with little focus on the use of GT by middle and small-scale enterprises, especially for those with few CNC machines.

A new processing method for parts using GT is proposed in this paper. This method divides all of the parts of each product into similar types according to their features, and installs each kind of part on a different working platform. By changing the platforms in turn, nearly all of the parts of one product can be machined in one CNC center, and can be sent directly to an assembly shop. Thus the number of management links is reduced.

2. Working platform unit

The working platform, as a unit, is designed to be flexible and is interchangeable. It can be hung on or fitted to the CNC working table. In order to be a mounting datum, the platform should be made with high accuracy according to the requirement of CNC, and should be drilled with many screw holes on its working face so that different group parts may be mounted on it.

Fig. 1 shows one of the working platforms at the Hartford machining center with a set of parts mounted on it ready for processing. There are many screw holes on the working face designed for fixing the clamp devices. When a set of parts is removed, the working platform can be used for another set of parts. Several working platforms may be needed when several different types of parts are being processed. However, to reduce production costs, it is necessary to limit the similarity coefficient of part classification, as limiting the number of different kinds of parts limits the number of working platforms needed.

3. Coding classification

There are many ways to classify parts [1]. The feature-coding classification method is better for processing parts...
with GT in individual CNC machines, i.e. according to the features of parts and some standards of similarity.

Before classifying, it is necessary to translate the design and manufacturing information into codes, and to merge the parts having the same coding number together.

In general, parts can be divided into two clusters, the design-cluster, and the machining-cluster [2]. When machining parts with GT in an individual CNC processing center, the machining-cluster is the principal consideration.

One of the problems of coding is that a reasonable similarity is required. A too high or too low similarity standard is unfavorable in gathering parts and in limiting the number of working platforms, so a suitable algorithm and standard of similarity should be chosen.

3.1. Coring the parts of plastic injection machines

The length of the code depends on the complexity and the structure characteristics of the parts. A practical classification code made by the author is for plastic injection machines. Ten numbers, 0–9 are used to express the different functions and the main features of the parts in the first code rank (see Table 1). Other feature coding, such as machining precision, can be worked out in the same way. An insufficient classification may be offset by applying cut, store, and adjusting functions to the processing program in the CNC machine center, thereby allowing a set of parts which are not completely similar to be processed on a single working platform.

3.2. Technological process

Before a set of parts with incomplete similar features is machined on a working platform, it is necessary to plan a reasonable technological process, for which the authors adopted an optimum method aimed to shorten the working period so as to increase the production rate.

In order to shorten the working period, two main aspects should be considered: one is to make a part be machined continually, where the time, represented as \( T_1 \), for machining the most complex part may be the shortest necessary time in a period, whilst the other is to make a processing program section process as many parts as possible. The time for processing most parts by a program section, represented as \( T_2 \), may be the shortest necessary time in a period also. Thus the lower limit of the working period can be defined as \( T = \max(T_1, T_2) \)

For example, suppose that four parts A, B, C, and D on a working platform should be machined in four processing program sections \( F_1, F_2, F_3, \) and \( F_4 \) cross-wise. Listing their technological processes (see Table 2), and working time for a single part (see Table 3), the total time can be calculated, as is shown in Table 4. By comparing the data of the table, a lower limit of optimum solution can be educed.

It can be seen from Table 4 that the total processing time for part D is the longest: 27 min; and the total working time of processing program section \( F_2 \) is the longest: 25 min. Comparing them, it is seen that the lower limit of the working period is 27 min.

The first step dealing with part A and the second step dealing with part D are completed by processing program section \( F_1 \), both A and B having the same process steps (shown in Tables 2 and 3); but the total time for processing part A is 15 min, and that for part B is 16 min, so the sequence for program section \( F_1 \) to process parts should be \( B \rightarrow A \rightarrow D \).

<table>
<thead>
<tr>
<th>Function factor</th>
<th>Feature code</th>
<th>Content</th>
<th>Topological relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotating style</td>
<td>0</td>
<td>Bowel and bush</td>
<td>Function factor</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Link, bearing bracket</td>
<td>Axial line and hole</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Screw thread and join</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Shaft and lever class</td>
<td>Shape</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Wheel class</td>
<td>Size</td>
</tr>
<tr>
<td>Non-rotating style</td>
<td>5</td>
<td>Rectangular and plasmodium</td>
<td>No topological relation of function factor</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Having definite function</td>
<td>Changeless topological relation</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Section material</td>
<td>No topological relation</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Solid combination piece</td>
<td>Solid combination</td>
</tr>
<tr>
<td>Other</td>
<td>9</td>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>
Steps 1, 2, 3 and 4 for parts C, A, B and D are completed, respectively, by program section F2, so the sequence for program section F2 to process the parts should be C → A → B → D. Other decisions can be reasoned by analogy.

4. Cluster analysis

The matrix expression has been adopted for cluster analysis [3], defining \( A = [a_{ij}] \) as an \( m \times n \) relational matrix, where \( i \) represents the number of working platforms, and \( j \) is for the code of the parts. Making the element of the matrix only be “0” or “1”, then \( a_{ij} = 1 \) means that the working platform \( i \) processes part \( j \), otherwise \( a_{ij} = 0 \). The transposed matrix of \( A \) is written as \( A^T \). Let \( B^{(1)} = AA^T \), using \( x_i \) for the line vector of line \( i \) in matrix \( A \), thus the element \( b^{(1)}_{ij} \) of \( B^{(1)} \) expresses the amount of the elements including “1” in \( x_i \cap x_j \).

Letting \( B^{(0)} = A \cdot A^T \), the element \( b^{(0)}_{ij} \) of \( B^{(0)} \) expresses the amount of the elements including “0” in \( x_i \cap x_j \), and letting \( D = B^{(1)} + B^{(0)} \), the element \( d_{ij} \) of \( D \) expresses the total amount of the elements including “1” and “0” in \( x_i \cap x_j \).

The authors define \( s_{ij} \) as the similarity efficient, and let
\[
s_{ij} = \frac{d_{ij}}{n}
\]
It is necessary to consider \( d_{ij} \) only when making the cluster analysis. Refs. [4,5] support the use of similarity algorithms for this machining method.

5. Fixture planning

A modular fixture is recommended for mounting a set of parts on a working platform. In general, a modular fixture has a basic board and a set of disassemblable locating and clamping elements. There are two general kinds of basic boards, a dowel-pin series and groove series. Because the working platform can be used directly as the main locating datum in this processing method, it is unnecessary to design another basic board. However, if a working platform is to be used for different sets of parts, it is better to design it as a dowel-pin series basic board, with many locating holes and clamping screw holes drilled in it according to practical requirements.

Because the locating elements can only be fixed in the locating holes of a basic board, the position of locating elements cannot be infinitely variable according to the outline of parts which creates problems for planning modular fixtures. At present, planning a set of modular fixtures is mainly dependent on the experience of the designer, and by trial and error. Brost [6] proposed a complete algorithm for designing planar fixtures, but this requires further development for practical application. Wu et al. [7] demonstrated a new method of using the principle of a linkage mechanism for automatically fixing on the position of locating elements on a basic board. The method is generally suitable for parts with linear and circular edges.

Wu’s theory for the fixing of the position of a locating pin is used in the processing method discussed in this paper. An example is given in Fig. 2. In this figure, “circles” represent locating holes used for fixing pins; “crosses” represent screw hole used for fixing clamping elements. The working face of the platform is regarded as the first locating reference, and parts are fixed directly to this surface. If the side face of a part is perpendicular to the face of the platform, i.e.

![Fig. 2. Sketch of locating condition with pins.](image-url)
the projection of its side has a linear or circular edge, the other locating reference position may be located easily on the edges.

Because the first locating reference only restricts three freedoms of the part, another three freedoms should also be restricted with pins. This can be achieved by finding three positions of pinholes on the platform, making sure that the three pins all touch the edges in the appropriate positions, thus forming a secure locating scheme.

If some parts are not fitted tightly to the face of the platform, the three freedoms cannot be restricted by the first reference. In this case, other locating elements should be added to appropriate positions of the platform to ensure that the first reference functions.

6. Conclusions

The processing method proposed in this paper is generally suitable for middle and small-scale enterprises which do not have many CNC or complex FMS machines. The greatest advantage of it is that after changing the working platforms several times, most parts of one product can be processed in one machining center, and be directly sent to an assembly shop, thus reducing intermediate links.

Because of the limited number of working platforms, fine classification of parts is unfavorable. Some special parts may need additional processing in other machines.

References