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DETERMINATION OF PIN CONFIGURATION FOR CLAMPING FIXTURE BY MEANS OF SOLID MODEL CONTACT ANALYSIS

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ABSTRACT

A pin-type fixture as a part of setup free attachment has been investigated for locating and clamping the irregular shape of workpiece during machining process. The system is integrated with special developed CAD/CAM software for automated operation. Manufacturing program as the output of CAM system is processed to generate machining model geometry by removing material step by step using tool sweep operation. Fixturing capability of the pins is evaluated prior to perform the real machining process using solid model operation. Boolean operation of CAD Solid model is utilized to find satisfies pin. Optimum pin configuration respect to the part geometry is determined by a proposed algorithm.

Keywords: CAD/CAM, Reconfigurable fixture, Machining.

1. INTRODUCTION

The ultimate goal of challenges for the factory automation of low repetitive manufacturing will be to realize automated manufacturing of products in shortened product life cycle and increasing requirement for quality and reliability. Typical application may be fabrication of various fixtures and prototypes in which substantial preparation for fixture and others are necessary for each machining process. In order to satisfy the ever-increasing demand in product variety, production systems need to be improved, i.e. to develop reconfigurable manufacturing system.

In manufacturing industry, many new production lines are designed and established every year. Although the car models could be different very much, many parts remain very similar. The manufacturing plans for processing these parts are also similar, based on the long time experience and so called proven best practice knowledge.

Therefore, the new manufacturing systems may be designed based on the existing systems. The question is how to generate the manufacturing plan rapidly and how to optimize the plan with ensure quality and short cycle time as well as low cost. While the manufacturing system design is constrained by fixtures to be applied, it also provides guidelines for fixture design. When the manufacturing systems are reconfigured, new fixtures need to be realized accordingly.

Fixturing system can be categorized into two dedicated modular and pin-type system. A pin-type fixturing system can be used for locating and clamping a workpiece of irregular shape during manufacturing process. Fixture has been considered as one of main problem to improve flexibility, productivity and part quality. Many fixtures system, modular contact or pin type has been investigated during several years[1].

Reconfigurable fixturing is a necessary component of a reconfigurable manufacturing system. Most of the fixture system only considers the machining the part in one setup. No fixture available for machining all surfaces of the part component without changing the setup. When whole surfaces of the part are necessary to be machined, two or more process should be considered by changing and resetting part orientation.

A solution to this problem has been proposed in previous articles in which block like components are machined without using a fixture[2]. The article introduced a method for machining all six faces of a block like part in one process. However, certain part geometries are not possible to be clamped due to lack contact clamping area. Setup free machining attachment with reconfigurable clamping pin capability as illustrated in Fig.1 which is suitable for automate the machining process of low repetitive component in single setup has been improved by determination the pin configuration.

2. SETUP- FREE MACHINING ATTACHMENT

Setup-Free attachment has been proposed as the system to machine block like components without using a fixture. Several geometry of block like parts can be machined from a long round bar material in one process. Prototype of the attachment, as shown in Fig. 1, is

mounted on the table of Machining Center. A long round bar raw material is feed into machining tool and hold by the attachment for continuous machining operation.

2.1 Configuration of the Attachment

A specially designed attachment with setup free machining methodology has been developed for horizontal machining center. By the attachment mounted on the table of a horizontal machining center, a block-like component designed by specially developed CAD/CAM software can be automatically machined from all of the six orientations in only one process without using other fixtures.

The attachment is composed of the Material indexing device, Sub clamp, Rotating table and Material pulling device. Function of the material indexing device is to hold the round bar material and index it for every 90 degree. Rotation of the bar, for machining the circumference faces, is programmed by optional auxiliary codes M60, M61, M62, M63 for indexing 0, 90, 180 and 170 degree respectively. Sub clamp which is have two flat surfaces is used to increase the rigidity on machining process and become a main clamping device after part is parted off from round bar material.

Geometry of the part to be machined is strictly depending on the sub clamp. The Sub clamp mechanism of the attachment is designed for a capability to clamp the round bar without causing excessive bending of the bar.

Different from conventional fixture system, in which the fixture never releases until a process is finished, the Sub clamp should open and close frequently during a process.

To prevent the roundbar bends during clamping operations, Sub clamp is designed with auto-centering capability. The principle of the auto-centering mechanism is a floating vise, which slides over the vertical column as shown in Fig.1. Hydraulic cylinder c1 provides the counter balancing for the floating vise and Cylinder c2 clamps the workpiece. Cylinder c1 is activated first to support the weight of the vise and then Cylinder c2 is activated to push the upper vise downward. As the upper vise jaw touches the workpiece and further pushes, the floating slider mechanism prevent the imbalance of clamping forces between upper and lower vise jaws. After satisfied clamping force is achieved, the floating slider is fixed to the vertical column using two floating slide clamps.

2.2 Attachment Operation

The attachment is suitable for machining block like components falling into a small size range (smaller than 80mm square in cross section and 200mm length). As shown in Fig. 2, machining process is started by machining from circumferential surfaces. To orient a surface placing to machining spindle, the block indexing device is indexed and Sub clamp hold the end of round bar. After geometry on circumferential surfaces are finished, as shown from (1) to (5) in the figure, the part is parted off from the round bar (5). After the part is parted off, Sub clamp holds the workpiece to continue machines the surface (7) and (8). For current fabricated prototype, only the part which have two parallel flat surfaces is possible to be machined. To increase the geometry of the part, pin-type fixture is considered to be used instead of the flat surface sub clamp fixture.

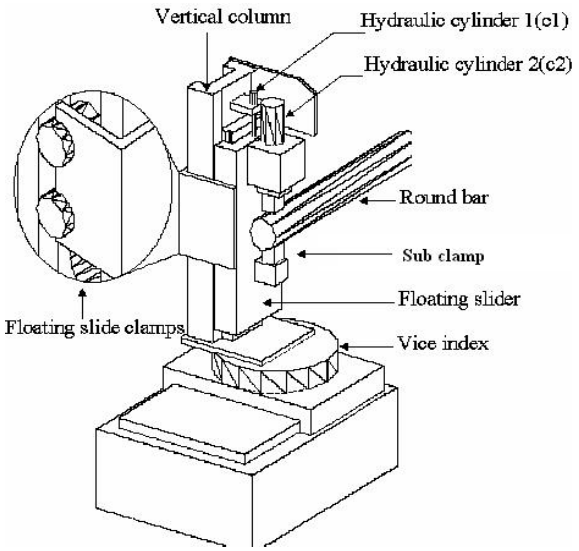

Fig 1. Setup Free machining attachment

3. PIN TYPE CLAMPING FOR SETUP FREE

A pin-type fixture can be used for locating and clamping an irregular shape of workpiece during machining process. A pin type fixture as illustrated in Fig. 3 consists of a main body or base that contains a two-dimensional array of orthogonal to the base roads or pins. Each pin is protruded downward independently, and therefore all the tips of the pins form a cradle conforming to the shape of the workpiece which is fixed during manufacturing operation. Different locking methods have been used including mechanical methods, pneumatic pressure and phase change material for holding the pins after touching the workpiece surfaces. A low-melt alloy (bismuth-lead-tin-cadmium) is a kinds of material used as the holding mechanism. The low melt temperature allows the use of hot water or induction heating as the power source of phase change.

For current fabricated prototype of setup free attachment, only the part which have two parallel flat surfaces is possible to be machined. The result after practicing several cutting experiment, surface area to be clamped become smaller while certain geometries are created and workpiece is difficult to clamp. To increase the variety geometry of the part, the pin-type reconfigurable fixture is considered instead of the flat surface sub clamp as illustrated on Fig.4. Three conditions may happen for every pin touching the workpiece surface; full contact, partial contact or not contact. Automatic clamping evaluation need to be performed to determine suitable clamping condition.

3.1 Workpiece Holding Calculation

To restrain the workpiece during machining operation, the clamping force should strong enough to fix the workpiece. There are two types of supporting when a workpiece is held on machine tool table; friction force and body support. Depending of direction of cutting

force, one of the following clamping conditions may be happen; hold by body support, hold by friction force and body, and hold by friction only. Friction force restrains the workpiece for direction of the cutting force right angle to the pins axis while the body support restrains in the direction of pin axis.

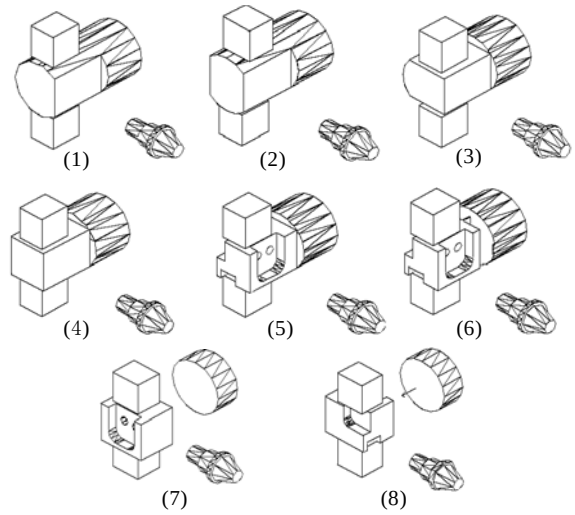

Fig 2. Machining operation using Setup-free attachment.

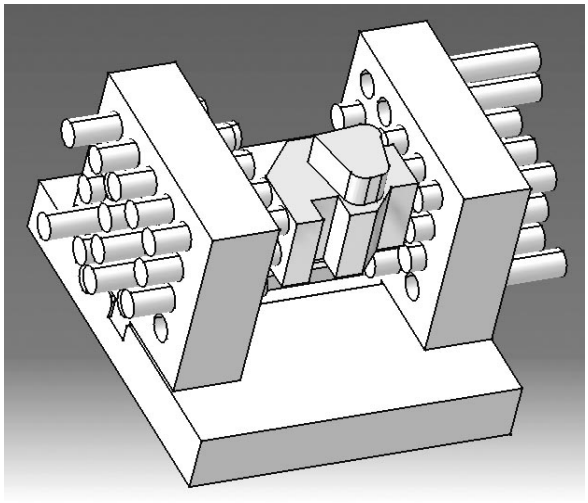

Fig 3. Illustration of pin type reconfigurable clamping fixture.

Friction force is the main factor to be evaluated on workpiece holding using pin type clamping mechanism because the amount of force much lower than supporting force. The amount of friction support is the function of surface contact area between pin and workpiece. Friction force for every pin is calculated as following formula ;

$$Fs_i = \mu \times F. \quad (1)$$

Fs : Friction force.
μ : friction coefficient
F : clamping force.
i : index for pin.

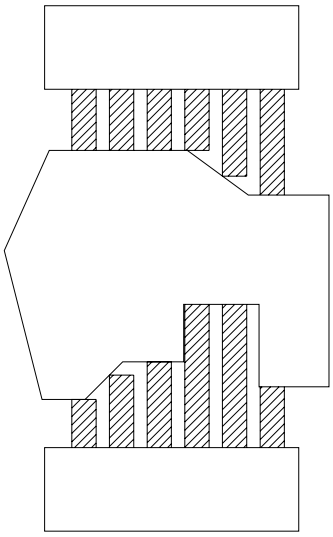

Fig 4. Pin-type reconfigurable fixture replacing the flat surface clamping.

Elastic deformation of pin penetrated into workpiece surface which should not exceed to the certain clamping error criteria is maintained trough contact area. Contact area (A_r) is considered as the factor that influences the deformation of pin penetration. Minimum contact area with 20% of the pin-end area is assumed as safety factor.

$$A_r \text{ min} = 0.2 \times \text{Pin area} \quad (2)$$

Clamping force and balance are determined by Newtonian approach:

$$\Sigma F_i = 0 \quad (3)$$

$$\Sigma M_i = 0 \quad (4)$$

On real machining process, force direction for each pin is influenced by the direction of cutting force. Several possible cutting forces with variable directions are applied to calculate clamping force and balance.

3.2 Pin Configuration Determination

The next step is calculating the clamping force and clamping balance for all useable pins using formula (1) to (4). Initial clamping force for every pin is total clamping force which is equal for upper and lower pin divided by total number pins in one side. Clamping balance is performed by comparing the force resultant position in upper and lower pins. On the ideal condition, distance of resultant between upper and lower pins is zero. Fig. 6 shows the condition of pin configuration with not acceptable (a) and acceptable (b) condition. When the distance is bigger than certain value and no pin located at opposite position of another pin resultant, meaning that clamping balance is not suitable for the configuration and rearrangement of pins is necessary. The rearrangement is performed by releasing certain pins and calculates the clamping force and balance for such configuration. This procedure is repeated until minimum distance between upper and lower force resultant

achieved. Part will be categorized as *unmachinable* when there is no satisfies clamping configuration possible after rearrangement process.

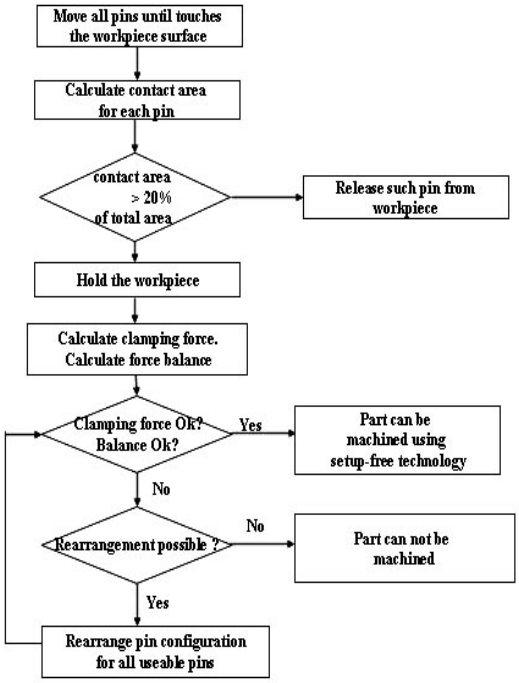

Fig 5. Algorithm to evaluate clamping ability.

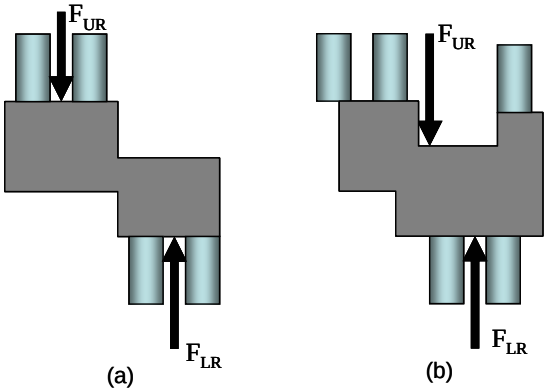

Fig 6. Force resultant for determining pin arrangement. (a) not acceptable condition, (b) acceptable condition

Fig. 7 shows an computer simulation result of a part and pins configuration for one operation machining process.. Before performing the rearrangement, several pins have no contacted to the workpiece, and some the others pins have partially contacted. No contacted and partially contacted less the 20% are categorized as unusable pins. From this configuration the balancing force is calculated by comparing force resultant distance between upper and lower pins. The resultant distance is found 15.3 mm. Rearrangement of pin has been performed to minimize the resultant and the result is 6.5 mm.

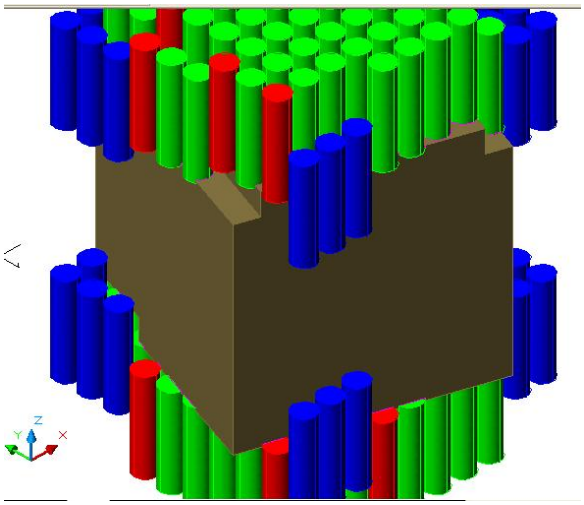

Fig 7. Clamping configuration of pin type setup free attachment.

4. CONCLUSIONS AND FURTHER WORK

Pin type reconfigurable fixture for clamping irregular workpiece shape is one possibility to be used for setup free attachment. New design of the attachment with reconfigurable pin clamping has been integrated with specially developed CAD/CAM software which has clamping evaluation for automate the machining in single process.

Clamping evaluation using CAD model has been conducted to achieve the pin configuration automatically for particular part geometry. No fixture and no setup necessary for machining the wide variety of part geometry using setup-free technology will reduce the product life cycle and preparation cost. Ball-end pin is another choice for clamping the irregular part to be use setup-free attachment. Analysis of clamping ability for the ball-end pins is a chance for the further research. Performing the cutting test on the fully designed attachment with pin-type clamping is the next task before the system could be implemented for real machining process.

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