FLEXIBLE FIXTURING SYSTEMS FOR LOW PRODUCTION QUANTITIES

[1]FATIH HAYATI CAKIR, [2]SELIM GURGEN, [3]MEHMET ALPER SOFUOGLU, [4]OSMAN NURI CELIK, [5]MELIHCEMALKUSHAN, [6]SEZAN ORAK

[2]Anadolu University, Vocational School of Transportation, Eskisehir, Turkey
[1,3,4,5,6]Eskisehir Osmangazi University, Department of Mechanical Engineering, BatiMeselik, Eskisehir, Turkey
E-mail: [1]fcakir@ogu.edu.tr, [2]selimgurgen@anadolu.edu.tr, [3]asofuoglu@ogu.edu.tr

Abstract—Machining is the most common method used low amount production like prototyping applications. Tooling cost of prototype manufacturing increases the cost of trials. Producing prototype without tooling investment is a quite challenging issue. Studies are focused on 3D printing applications mostly, but the solution could be much simpler. Machining processes generates serious heat, force and vibrations. These effects should be balanced properly to obtain desired part properties. There are many approaches to solve the issue; some of them are Phase changing materials fluidized beds, bed of fingers. This study focuses on phase changing materials. Summarizes previous works and informs about a novel application of Rene 41 aerospace material.

Index Terms— Flexible Fixturing, Fixturing, Prototype Manufacturing, Encapsulating, Qualify

I. INTRODUCTION

Material removal processes such as turning, milling, drilling are the most widespread metal shaping processes in mechanical manufacturing industry. Turning is the leading method for rotational symmetrical parts with its capability of high material removal rate and surface finish results. Operational input parameters are cutting speed, feed rate, depth of cut and number of passes. There are work piece related parameters such as hardness, tensile strength, ductility etc. and also cutting tool related parameters like tool shape, material coating etc. All these parameters are input parameters of turning processes. There are output parameters like dimensional accuracy, surface roughness, production cost, cutting tool life, cutting edge temperature and cutting forces, power consumption [1]–[6]. All of these parameters are considered while implementing a design to mass production. Perfection of manufacturing processes can be done with time and investment. However low amount production cases like prototyping process does not include so many time and investment. These processes require skillful technicians and special care. In most cases for machining, the most challenging stage is holding work piece in place. Parts complexity and geometry determines parts producibility. It is a design criterion at some cases especially for small size of manufacturing orders. These problems are also valid for batch type manufacturing too. Investing in complex and expensive fixturing is not feasible for low order applications. There are three main fixturing concepts using to design universal work holding systems. First of and the most generally used version of this systems are phase changing fluids. Low melting point alloys such as bismuth, Tin and some polymers are used like rigidax are used for these applications. There are some applications at Pratt & Whitney aerospace company where this method is used for manufacturing [7] .There is some studies about magnetorheological fluids [8]. Other methods used at flexible fixturing systems are fluidized beds and bed of fingers.

II. LITERATURE REVIEW

Ahn and Wright investigated the phase changing materials which can be used at fixturing approaches. Fusible alloys (BiSn, BiSnZn) thermoplastic polymers (Rigidax) and fixturing waxes were investigated. Several experiments were performed to determine the most suitable material for the application. Shrinkage tests, compression tests, interfacial shear test, cooling time test were performed [9]. As in stated in the study material should be selected due to the application and maximum allowable temperature and force characteristics. Experiments showed that Rigidax offered the best interfacial strength. General fixturing concept based on balancing machining forces. Vertical forces are balanced with reaction forces and damping effects. Lateral force balancing is secured by the friction between workpiece and fixture surface. At this approach interfacial strength is an indication of the materials capability of balancing lateral forces. In this manner Rigidax was determined as the best material for general use phase changing material. According to study fusible alloys offered better thermo mechanical properties. Using composite materials should be considered for further studies.

Choi and others [7] designed encapsulation machine for fixturing purposes. They offered an automatic system that can be used at variable part manufacturing systems. They used Bi/Sn alloy to encapsulate workpiece. The system works similarly to plastic injection systems. First of all raw material is encapsulated. While other features are machined, cut of features are filled with encapsulation material. Excessive material is machined so cubic shape of part remains same while machining is proceeded. In the final stage encapsulation material is melted by

applying heat and final part is obtained. This system makes machining of oddly shaped parts possible. This idea is based on moving part datum to mounting surface. All these systems were integrated with the automatic manufacturing planning software.
Sarma and Wright [10] pointed the complexity of process planning. They stated that regardless of flexibility of manufacturing machines there is an inevitable time loss of fixturing setup and adjustments. This issue limits the workshop planning flexibility. Adjusting RFPEM will make it possible to change machined workpieces much easier without loading fixtures and making adjustments.
Lim and others [11] studied about using phase changing alloys in machining of thin walled components. This can improve the rigidity of thin walls and could be a solution to vibration based chatter marks and precision of work piece.

Rong and others [8] studied on flexible manufacturing systems. They used magnetorheological fluids to stabilize the work piece. Phase changing alloys explained are used heat as an activator to melt and solidify. They are low melting point materials. Magnetorheological fluids use specific electric currents to solidify. Their responses changes according to applied current, they could be solid or fluids so quickly. Their shear strength is quite promising.
Shin BS and others [12] studied the RFPEM on rapid prototyping applications. They machined 3D skull by using RFPEM. They used high speed milling technique. Manufacturing of skull was performed in four stages. Positions of features of skull were obtained properly. This study shows that this method could be used at oddly shaped biomedical applications such as bones and knee caps.

III. EXPERIMENTAL WORK

In this study Rene 41 aerospace alloy was used. Part used in experiments was a forged ring with 12.7 mm(0.500") thick. Its inner diameter was 533 mm (21") outer diameter 635 mm (25"). The problem of machining this part is obtaining reference flat surface. Because of its large diameter the part is tend to distort during and after machining. Forged parts do not have flat surfaces generally they have a wavy surface structure. Aim of first machining the qualifying process is to flatten this wavy surface and obtain a flat surface. This process becomes more difficult as the thickness of part decreases. Top of surface clamps cannot be used to secure the part so side clamps were used. Process was tedious to obtain desired surface flatness. In previous method this process was highly labor related. Part was filled with 0.0254 mm (0.001") shims to fill voids between part and fixture in order to eliminate deflection of work piece. At least 0.05 mm (0.002") flatness is needed to perform remaining operations properly.

Table 1 shows the chemical composition of Rene 41 aerospace alloy. Figure 1 shows experimental qualify fixture setup

Table 1. Nominal Composition of Rene 41[13]

Cr	Co	Mn	Al	Ti
18-20	10-12	9-10.5	1.4-1.8	3-3.5
Fe	Zr	Si	Mn	P
≤5.00	≤0.07	≤0.50	≤0.50	≤0.015
C	B	S	Ni	
0.06-0.12	0.003-.001	≤0.015	Balance	

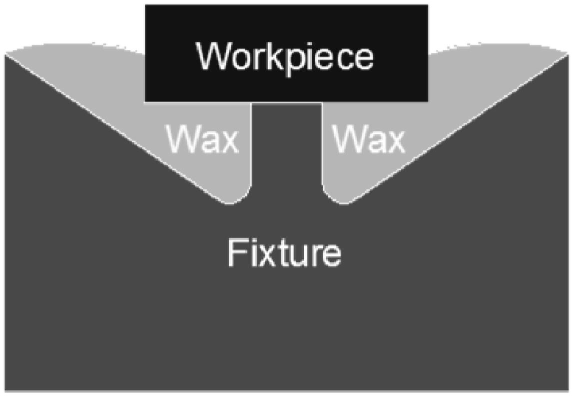

Figure 1. Experimental qualify fixture setup

In this study there are reference surface which is width is near 1/4 of the total surface. Rigidax was melted at 140°C and poured to inner and outer side with the effect of gravity. Fixture material was Ck45. Melted rigidax cools and solidifies instantly and covers the beneath the part surface. Takes the shape of part exactly and cushions the part when machining started.

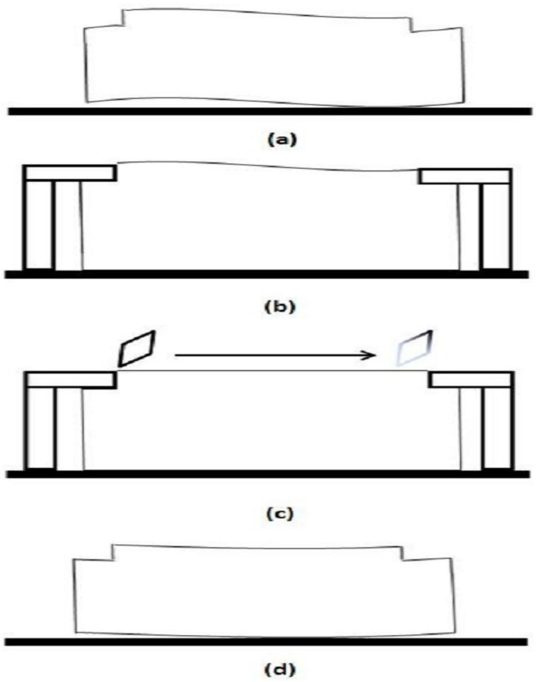

Figure 2. Conventional qualify process (a)Free form (b)Clamped state (c)Machined state (d)Free form after machining

Rigidax is polymer based material. It has a good damping characteristic. Part does not deflect when it is supported with wax material. It can be said that rigidax material is not rigid as fixture but its rigidity is enough to obtain desired dimensions. Parts final shape and application photos cannot be given because of company policy.

Figure 2 shows general case for qualifying to obtain a flat surface is described. This figure is valid for clamping applications and magnetic holding systems similarly. Parts need to be clamped (b) in order to hold the part at the workplace. Clamping the part deforms its shape and machining is performed under this condition. When machining is finished a flat surface is obtained at restrained state (c). But the part is not fixed under free form conditions so pre stress applied by clamping reveals when clamps are unloaded. Part deforms again (d). Final flatness value is usually less than the beginning value. So by repeating this process desired flatness can be obtained. In experimental setup with rigidax material no clamps are used so no further deformation based on clamping error is stayed on the workpiece.

Free form flatness of machined part improved by implementing rigidax fixturing system. According to 10 measured parts free form flatness of machined parts were in the limit of desired 0.05 mm (0.002"). In previous machining strategy this values was so arbitrary and can be up to 0.381 mm (0.015") according to labor skills. Total process time cannot be determined because it's a specific applications but average time was 4 hours for 1 part. This time is only 0.5 hour for machining time and 0.5 hour for setup time. This is a real improvement and standardization of a labor based operation.

CONCLUSION

Using phase changing materials as a fixture material can help rapid prototyping processes. Arbitrary shaped biomedical parts can be easily machined with this technique. Using phase changing alloys can standardize non-standard qualifying processes at casting and forging parts to obtain reference datum. Phase changing materials can improve vibration characteristic of machining applications can improve surface roughness. Thin walled aerospace components can be supported with this method.

FUTURE WORK

Sanjay Sarma and his team produced encapsulating machines. Universal fixturing machines can be produced for specific applications like qualifying casting part surfaces and thin walled component machining. This kind of an approach can improve finished product dimensional accuracy and surface quality.

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