Unconstrained manufacture of plastic parts – a novel concept of hybrid manufacturing process

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Abstract

Today, the design of a part is still significantly constrained by the capabilities of the manufacturing process used. The major reason behind this bottleneck is each individual type of manufacturing process only deals with specific manufacturing requirements and application areas. In recent years, hybrid manufacturing technologies that combine different processes (e.g. additive and subtractive processes) together have gained significant attention. This is due to their ability to capitalise on the advantages of each individual process, whilst minimising their disadvantages. Furthermore, by using an additive process that reuses existing material has the potential to further reduce manufacturing costs in terms of reducing material consumption. However, current hybrid processes are unable to effectively utilise existing material. This paper introduces a novel concept for hybrid manufacturing, enabling a plastic part to be manufactured from zero material or by adding material to an existing part. It illustrates how rapid prototyping, CNC machining and inspection processes can be used interchangeably to manufacture example polylactic acid (PLA) components.

1. Introduction

Manufacturing technology has gone through a number of evolutionary developments over the past decades. However, the processes currently used have always been constrained by the manufacturing capabilities either from technical limitations, such as limited materials and complex part geometries, or production costs. CNC machining, a highly developed subtractive process, still has difficulties in machining complex shapes due to tool accessibility and setups. On the other hand, rapid prototyping completely solves the tool accessibility issue but this increased flexibility and automation is achieved by compromising on part quality. Another typical process is injection moulding, which is not cost-effective in making customised products as individual moulds are required. With the purpose of enhancing individual process capabilities, the concept of hybrid manufacturing begins to emerge [1]. Some typical examples are: combining CNC machining processes, which has high accuracy with additive processes will provide a new solution to the limitations of current additive manufacturing capabilities [2]. Other notable research related to the concept of hybrid manufacturing has been achieved by Heisel et al. [3], where they integrated ultrasonic vibration and drilling to reduce the cutting force and tool wear rate. Zhang et al. [4] also showed that laser drilling and ECM significantly removes the recast layer and heat affect zone.

2. The hybrid manufacturing concept

The current concept of hybrid manufacturing (iAtractive) being investigated at the University of Bath consists of combining additive, subtractive (i.e. CNC machining) and inspection processes. This is based on the need to reuse and remanufacture existing parts or legacy products, improve the flexibility of CNC machining and remove the moulding process in low volume and customised production. Incorporating an additive process releases design constraints caused by tool accessibility in CNC machining. Then, using CNC machining methods the final part can achieve comparable accuracy to that of an injection-moulded part. Furthermore, dimensional information of existing parts can be obtained by using an inspection process, enabling the existing part to be further manufactured by additive and/or subtractive processes, providing new functionality to products.

2.1 The hybrid manufacturing process

The iAtractive process is outlined below and in figure 1:

- Raw material is first inspected using a co-ordinate measuring machine (CMM). The importance of this step is to obtain the actual geometry attributes of the raw material, which becomes the basis of the process plan for determining subsequent operations.
- Decisions can then be made on whether to manufacture the product from zero or reuse the existing part geometry to further process it to the final shape.
- For the first scenario, additive, subtractive and inspection processes are utilised interchangeably in a serial manner, by which the final part will be produced.

• For the second scenario, according to the dimensions of the existing part, a new CAD/CAM model is generated. The new model shows the shape of the rest of the material required to produce the designed part. Then the existing part is further manufactured to the final shape and part tolerances by the use of additive and subtractive processes.

• At the end of both scenarios, the part is inspected again, identifying which dimension is out of tolerance, in which case another decision will be made on whether to add more manufacturing operations until the dimensions are in tolerance.

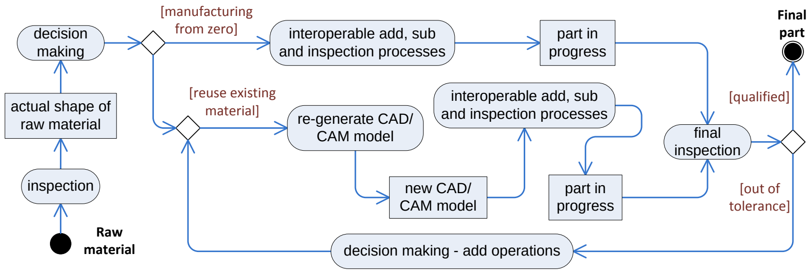

Figure 1: The proposed iAtractive process

3. An example of the iAtractive process

To test the iAtractive process three existing different shaped parts were used as the start material for the manufacture of three identical test parts.

• *Part I (B)* was produced from an existing part (part I (A)) with a boss as shown in Figure 2. Based on the measurement results, the decision-making process provided two options to reuse this existing part. One of the options was to remove the boss and subsequently add new material on to the machined surface. The part was finish machined and finally inspected to make sure the dimensions were in tolerance.

• *Part II (B)* was also manufactured from an existing part (part II (A)) with a pocket. The additive process was used to directly deposit layers on top of the existing part.

• *Part III (A)* was identified as an unqualified product in the final inspection process (see figure 1) as the dimensions of the boss were out of tolerance. Therefore, three independent operations were added in the process plan, where the original boss was removed and a new boss was added/deposited and subtracted/finish machined.

These three final test parts were measured on a CMM. The measurement results showed that all of the actual dimensions were in tolerance.

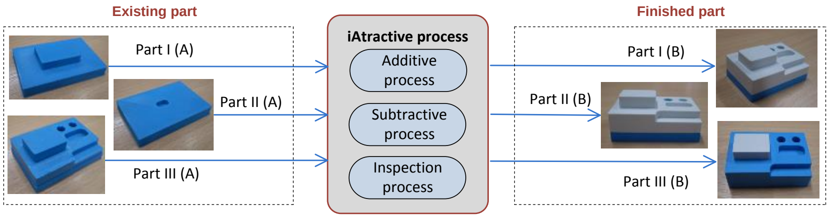

Figure 2: Manufacturing of test parts by using iAtractive process

4. Conclusions

This paper introduces a novel concept for hybrid manufacture where additive, subtractive and inspection processes are combined together in a serial manner, presenting a manufacturing method that has the potential to be unconstrained by part geometry. This hybrid manufacturing concept enables a part to be manufactured from either zero or existing material. The inspection process precisely collects dimensions of the existing part or parts being manufactured, enabling the decision-making process to decide on the implementation of further additive and/or subtractive operations. In addition, due to high flexibility and accuracy provided by combining additive and subtractive processes respectively, hybrid manufacturing of plastic parts provides the capability for on demand manufacture, to change designs instantaneously and provide enhanced functionality to existing parts.

References:

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