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Direct rapid tooling for polymer processing using sheet metal tools

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Abstract

The rapid tooling notion has been discussed since the beginning of the additive manufacturing processes. The concept consists on using fast manufacturing technologies to develop tools to process other materials. New incremental sheet metal forming processes operation allows a parity to the former rapid prototyping perception, and so feasibly considered a smart manufacturing process. This processes encounter industrial applications not only in prototyping and part manufacturing but also in tool development and fabrication.

This paper discuss the fundamentals of the rapid tooling concept and presents four examples of the use of incremental forming for the development of sheet metal moulds. The research concludes with a proof of concept for the use of rapid sheet metal tools for processing thermoplastics and thermosets. The use of incremental forming as a rapid tooling technology contributes to decrease the time to market, decrease tooling cost and increase tooling complexity and consequential part design freedom.

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1. Introduction

Product development takes advantage on the use of computer aided design (CAD) systems to define the geometry and its various dimensional characteristics. Besides, the products feasibility can be predicted using computer aided

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engineering (CAE) software for the analysis of product performance and for the simulation of manufacturing processes without the need of physical prototypes. While this iteration strongly improves the probability of success, in many cases a physical assessment of the real component is still needed. This often requires the creation of prototypes and tools to be produce, becoming one of the most time consuming and costly phases in the development of new [1, 2].

Rapid tooling (RT) is the term used to the production of tools or tooling components with reduced lead time, as compared to conventional manufacturing techniques, through direct or indirect processes. The direct processes consist in use one technology capable to reproduce tools with similar properties to the actual tools. The indirect processes involve the use of more than one technology, first to produce a pattern and second to obtain the actual tools through the pattern. Besides, the tooling process can also be classified according to the used materials. If the tooling material can only be used to produce few production copies before it wears, such process is referred as soft tooling. Hard tooling on the other hand involves the production of tools capable of producing thousands of parts [1-3].

The leading characteristics of a rapid tooling process should ensure: (i) Tooling time is much shorter than for a conventional tool. Typically, time to first market ready products is below one-fifth that of conventional tooling; (ii) Tooling cost is much less than for a conventional tool. Cost can be below five percent of conventional tooling cost; (iii) Tool life is considerably less than for a conventional tool; (iv) Tolerances are wider than for a conventional tool and have worst surface finishing [4].

Conventional manufacturing technologies, such as casting and injection moulding, are often used in the manufacture of products. These technologies required tools or tooling components (e.g. moulds, inserts) that need to be development, especially as used for a particular purpose or new product. Machining technologies and heat treatments, frequently used, augments time and costs in product development process. Sometimes, these factors invalidate the low volume productions and limit the market introduction of custom solutions or niche products [1, 5].

The adoption of rapid manufacturing technologies allows create skills on production of tools for low volume products production, as wells as reduce product costs and make time to get products to market faster. These technologies are also applied to test and valid projects with the manufacturing of 3D physical models. These steps allows to detect errors early in the product development process and designing better products. Improvements or tools modifications are sometimes required during the manufacturing process. The rapid manufacturing of parts and tools can benefit both the product development and production set up, allowing the achievement of faster solutions [1].

2. ISF as a rapid tooling process

Incremental sheet forming (ISF) is a sheet metal forming technique where a sheet is formed into the final workpiece by a series of small continuous incremental deformations. The process is controlled entirely by CNC processes and no die is needed as is in traditional sheet metal forming. The removal or simplification of the die in the manufacturing process decreases the cost per piece and improves turnaround time for single parts or low batch production runs. On the other hand, the differences in the forming principle lead to a loss of accuracy and differ the possible achievable part design. Incremental forming processes can be considered as rapid prototyping as they are well-suited for small-batch production, and rapid production of service parts and may reduce time to market [6, 7].

Mainly due to their novelty and the technologies used in most processes, the RT haven been majorly associated with additive manufacturing (AM), often called fast freeform fabrication. ISF processes can be seen as rapid prototyping processes [7], and so, also considered rapid manufacturing methodologies. Besides, being compatible with flexible manufacturing systems, with parts manufactured from CAD models without considerable dedicated tools in short time, ISF processes can be seen analogously to AM technologies. Thus, it is reasonable to apply the RT term when describing the fabrication of tools for different industrial processes using ISF techniques.

Some conventional polymer manufacturing processes involve low pressure and temperature for moulding materials (e.g. thermoforming, rotomoulding, hand lay-up, compression moulding). In these cases, the mechanical requirements are low and the operation benefits from low mould thermal inertia. In such a way, ISF technologies finds an interesting applicability for the moulds production from sheet metal, attaining low cost tooling with high strength over weight ratio.