Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
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COMBINING ADDITIVE FABRICATION AND CONVENTIONAL MACHINING TECHNOLOGIES TO DEVELOP A HYBRID TOOLING APPROACH

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Abstract: *The paper will report on progress made in Hybrid Moulds for injection-moulding, as a specific focus area in mould-making. Hybrid Moulds refers to a hybrid between Additive Manufacturing (AM) and conventional methods, which amongst others, use Direct Metal Laser Sintering (DMLS) techniques combined with conventional CNC machining (High Speed) techniques. Intricate mould details, normally quite time-consuming to manufacture through EDM processes, can now be manufactured (with DMLS) as inserts, while the less complex parts are machined in Aluminium using 3 and 5 Axis High Speed CNC machining. By using a 3-axis CNC wire cutter, pockets are created where the more complex DMLS inserts can be fitted. Research is being conducted to identify the most economical and appropriate manufacturing solution for injection moulding tooling production.*
Key words: *Additive Manufacturing, Conventional Machining, Hybrid Tooling, Direct Metal Laser Sintering*

1. INTRODUCTION

Potential customers must be assisted to convert their ideas, concept products or final designs into physical models at a desirable price, without sacrificing quality. Product developers require prototypes in the end material as verification prior to commencing production. Thereafter, a crucial decision must be taken whether to go to the final step of production tooling, trusting that the decision was correct and that the product can justify the expenses.

The major expenses associated with new product development are usually a function of tool-making. Producing injection-moulding tools can be slow and expensive due to the intensive labour required when using conventional tooling methods.

The risk involved in new product development, associated with conventional tooling, is in many cases no longer an issue, as Rapid Tooling (RT) has developed into a capable technology giving the option of an intermediate (bridge tooling) or even a final tool (dependent on the number of products (injection shots) needed to be manufactured in the moulds). However, RT has to be available at an affordable price - otherwise it will defeat the purpose.

Experimental results proved that in order to find the most economical and appropriate manufacturing solution, it sometimes is necessary to combine conventional mould making techniques with RT techniques to develop “hybrid” moulds. “Hybrid” moulds refer to moulds where part of the tooling is grown using Direct Metal Laser-Sintering (DMLS), and inserted into/onto parts machined with conventional techniques. This approach will be determined by the tool-geometry (Booysen, 2007).

2. LITERATURE REVIEW

Direct Metal Laser Sintering

The Direct Metal Laser-Sintering (DMLS) process on EOSINT M systems is suitable to manufacture mould and tool inserts, using the Direct Tool process, together with functional prototypes, using the Direct Part process. Powdered metal with a grain size of less than 20 microns are sintered by a high power laser.

Conventional Tooling

Injection moulds are made conventionally by various processes such as EDM (Electric Discharge Machining), CNC milling and wire cutting, as well as combinations of these processes. However, constructing a mould using these processes can be a time/labour intensive exercise. Steel cavities appear to be more expensive than those made in other materials. In spite of this, steel cavities are normally the preferred option, due to the longer service life of the mould.

3. METHODOLOGY

The research aims were to evaluate the effectiveness of “hybrid” tooling in injection moulding of plastic articles and to identify parts of the tooling that could be grown and inserted into/onto parts machined with conventional techniques to minimise the cost of tooling for injection moulding.

4. RESULTS

4.1 Case study 1: Spear gun handles

The Centre for Rapid Prototyping and Manufacturing (CRPM) was asked to assist with the manufacturing of 1000 spear gun handles and due to various factors it was decided to use the “Hybrid” approach. The core and cavity inserts were machined in Aluminium, but the sliding core parts, that make the hollow features, were grown in Direct Metal 20 alloy. See Fig 3.

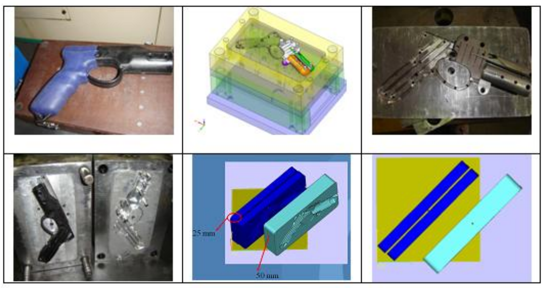

Fig. 3. The tool design, manufacturing and optimising designs of the inserts

The design was optimized to determine whether it would improve the cost to produce the two cavities at a reduced height of 25 mm. The height of the original insert design was 50 mm and had too much extra material at the back of the insert. To produce the inserts using conventional CNC or DMLS process, a minimum of 8 mm is required, as extra material from the deepest part of the cavity to the back part of the insert. Table 1, 2 and 3 shows the different calculation options. From the data it is clear that the DMLS process, using the 0.02 or 0.06 mm layer thickness option, is not suitable for prototypes of this size geometry. It was decided to CNC machine the two cavities with 50 mm thickness. The available bolster already had 50 mm pockets machined into it, resulting in no significant difference in the cost.

	Aluminium inserts with 50 mm thickness	Aluminium inserts with reduced 25 mm thickness
Material cost	€ 180	€ 80
Machining time	58 hrs	57 hrs
Machining cost	€ 1160	€ 1140
Total cost	€ 1340	€ 1220

Tab. 1. Cost to CNC machine two Aluminium cavities of the design showed in Fig. 3

	DMLS inserts (0.02mm) with 50 mm thickness	**DMLS inserts (0.02mm) with 25 mm thickness**
Material cost	€ 8155	€ 3352
Growing time	232 hrs	130 hrs
Growing cost	€ 7540	€ 4225
Total cost	€ 15695	€ 7577

Tab. 2. Cost to produce (0.02 mm layer thickness) two cavities of the design showed in Fig. 3 using the DMLS process

	DMLS inserts (0.06mm) with 50 mm thickness	**DMLS inserts (0.06mm) with 25 mm thickness**
Material cost	€ 6779	€ 3024
Growing time	117 hrs	59 hrs
Growing cost	€ 3803	€ 1918
Total cost	€ 10582	€ 4942

Tab. 3. Cost to produce (0.06 mm layer thickness) two cavities of the design showed in Fig. 3 using the DMLS process

Furthermore, three cores were needed and had to be manufactured as shown in table 4. The geometry of the prototype was difficult to machine conventionally and it was decided to produce the geometry using the DMLS process. Table 4 shows it took only 9 hours to manufacture the cores in one build at a cost of € 365. Extra stock was added to the design on shut off areas and this was cleaned/polished off after the growing process.

DMLS cores (0.02mm)
Material cost = € 84
Growing time = 9 hrs
Growing cost = € 281
Total cost = € 365

Tab. 4. Cost to produce three cores using the DMLS process

The mould was assembled and the first 250 handles were produced in glass filled nylon. Another two cavities were machined in Aluminium without any cores needed to produce the blue TPE (Thermoplastic Elastomer) over mould grip (showed in Fig. 3). The order of a thousand moulds was completed and the client could use these parts to source more funding to make production tools.

4.2 Case study 2 - The Secure Airway Clamp project

A local anaesthetist approached the Centre to design and manufacture a product that holds an Endo Tracheal tube, during anaesthesia, in place in a more secure manner than the normal plaster which is currently used. The first generation Secure Airway Clamp (SAC) was a two-component part with an inner hard nylon part which ensures the stability of the product, and with a soft 60 Shore A TPE that is over- moulded on the nylon part to ensure that the mouthpiece does not hurt the patient's mouth. It was decided to CNC machine the cavities (Fig. 4) to produce the inner part in Aluminium because of its simple geometry. The cavities were machined in two days. The over mould cavities (Fig. 4) were grown on the DMLS process (0.02 mm layers) in 53 hours at a cost of € 2646. The conventional price for the tooling to produce the two component SAC is approximately € 10 000 and will take 6-8 weeks to manufacture.

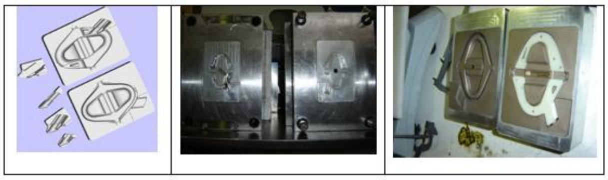

Fig. 4. Design of inserts, Aluminium machined inserts and DMLS produced inserts

After testing the two part injection moulded SAC it was seen that the nylon base, manufactured inside the overmould, did not have enough rigidity to withstand the forces in a human's mouth. The SAC was then manufactured out of three materials (Fig.5). The rigid base was manufactured in Glass filled Nylon and then the hinge part, between the top and bottom part of the SAC, needed to be manufactured in Nylon to ensure bendability. The overmould part of the SAC was manufactured in a 50 Shore A TPE to give as much comfort on the patient's gums as possible.

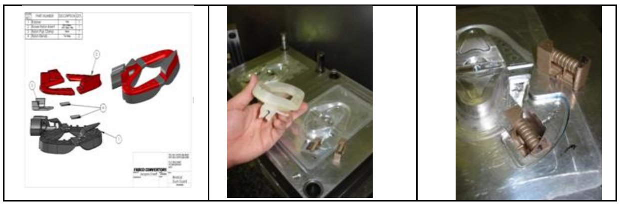

Fig. 5. The three component SAC design; final product and close up on the DMLS produced cores

The high detail pipe clamp cores (Fig.5) were manufactured using the DMLS process.

Manufacturing process	Time	Cost
Conventional Manufacturing	4 Days	€ 2000
DMLS produced	6 hours	€ 451

Tab. 5. Cost and lead time comparison

5. CONCLUSIONS

Larger, less complex inserts are better suited to be manufactured by normal CNC milling. To attain fine features like thread or fine writing inside a complex insert, the EDM process was conventionally required. However, the disadvantage of EDM is that it is a time-consuming process and such inserts will save time and money when laser sintered with the DMLS process.

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