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Ramping-up 3D printed corona devices – additive manufacturing opposing injection molding

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Abstract: Additive manufacturing (AM) represents an excellent tool to accelerate the product development process. As a modern manufacturing technology it still has to compete with traditional technologies e.g. injection molding. Having both technologies in-house, cirp GmbH experiences first-hand the decision-making process for the adequate tool. A good example is the ramped up development of two corona devices namely a reusable respirator mask and a protection face-shield. This contribution assesses the cost and benefits of both technologies and the subsequent decision-making process using the example of those two devices.

I. Introduction

With the sudden emergence of COVID-19 as a highly infectious respiratory disease the whole global supply chain for relevant protective equipment was pushed on shortage. Instantly the call came up to solve the supply bottleneck as well as the need for local production was addressed. Additive manufacturing (AM) as a suitable fast reaction tool to produce the needed protection equipment seemed to be a perfect answer to many aspects of the situation. cirp GmbH ramped up 2 protection devices in high demand within a joined effort of the development team in a 2 stage process: first fast reaction by small series production with AM was followed by a second stage of injection moulded (IM) devices. The underlying decision making points towards core questions of this industry: which applications benefit from the advantages AM offers compared to the traditional manufacturing technologies and in which cases can the latter come in handy? This of course depends on the individual application matrix being addressed.

I.I. Use case respirator mask

cirp decided to develop a reusable mask design, as this mask class features advantages in costs and sustainability and can help to save the limited stock of disposable certified masks for critical medical areas. Aforementioned reaction time was one focus at the early stage of the event. Consequential cirp GmbH ramped up a first small series of several thousand pieces from Polyamid (PA12) using the in-house AM EOS Laser sintering (SLS) machine park. The whole process starting from scratch, implementing several prototype iteration cycles took only seven days. Looking at the application matrix and the mid-term quantity projection it soon became clear that IM, using rapid aluminum molds, could bring advantages.

Figure 1: different development iterations of cirp´s reusable respirator mask: pure SLS (right), SLS with soft sealing lip (mid right), 2-part IM (left) and 3-part IM solution (above).

Based on the AM design concept, the professional team of designers and engineers at cirp was able to execute the whole IM process within 5 days: from design freeze and IM adapted construction, proper flow simulation and detailed tool construction, milling programming, CNC-tool production (24h), tool mounting and adjustment process to the final out-of-tool IM parts. Design for AM namely SLS and for mould based IM had to fulfil quite different requirements. SLS gives a large design freedom and thin walls can be created. For IM demoulding direction and draft angle requirements have to be fulfilled. Depending on the flow length and material, thicker walls are needed compared to SLS. On the other hand the materials choice for IM is considerably broader.

Finally functional reasons lead the team choose IM over AM. The snugly fitting on the wearer’s face in the practical application led to decisive implications: desirable good surface quality, best inheriting smoothness, easy to clean and skin-friendliness. The target of a proper tightness pointed to the use of a soft sealing lip. Those properties are better achievable by IM using soft material namely in our case TPU.

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Issues like cycle time and cost per piece played as well a prominent role on the making: With AM being able to output, depending of the size of the machine park, several hundred pieces daily, IM holds the possibility to output 3000- 5000 pcs daily even with a simple single cavity mould. IM components have a much lower price per piece (of around 20% to 30% in our case), which offsets the slightly higher cost of IM development in a short time. This also stayed permanent even though the IM construction changed from an initial two-part AM design to a three-part IM design.

Figure 2: Final tool dropping 3-part IM samples of cirp's reusable respirator mask with replaceable filter.

I.II. Use case face shield

Due to its deployment location the functional requirements of the face-shield vary considerably from the respirator mask, hence the relevant product properties are less sensible to some of the topics aforementioned

Figure 3: rendering of cirp face shield with the headband on top and added 3 level protection shielding front, top and bottom area (left) and finished face shield in use (right)

This could point the production towards AM technology. Thus just like in the first use case, the production using first AM veered afterwards into IM. cirp's decision towards IM is based on two key factors: unit costs and surprisingly comparable reaction time. This resulted from the nature of the central product component, a forehand band.

cirp, holding excellent professionalism in the IM domain, and its partner Fazua had set up the IM face shield production in record time, thanks to their quick response and joint effort. From the original AM concept to the first 800 tool dropping IM parts it took less than three days.

II. Results and discussion

Comparing AM with IM in the two named use cases led to the following implications at cirp GmbH: Pros of AM are certainly to be seen in the ultra-short reaction time owed to AMs small construction effort and vast design freedom, in its production lead-time and the consequential small entry costs. Having entered this stage oneself can be entangled easily in some of the drawbacks of this technology like comparable long cycle-times and high costs per piece as well as limited material choice. With AM being able to output, depending of the size of the component and the machine capacity, several hundred pieces daily, IM, using fast aluminium moulds, holds the possibility to output 3000-5000 pcs daily. In addition the numerous available and applicable IM materials enable enhanced product features. Other than one might expect, IM with fast aluminium moulds achieves similar time to market as AM. Not to forget - the vastly lower price per piece plays a decisive role. Rapid aluminum moulds often last for several 10,000 shots. Obviously they don't stand for millions of parts as much more expensive hardened steel moulds do.

III. Conclusions

With AM being a fast and more and more cost efficient tool, its applications are increasingly gaining ground for small series production. Thus a closer look at the application matrix of the individual use cases is indispensable to take well-grounded production decisions.

To ramp up a small series production with IM, in our cases using aluminum molds, might not take substantially longer than AM. In our examples the delta reaction time to AM added up to only 0 - 4 days. Summed up with its numerous advantages IM might emerge as the better small series production decision despite of its drawbacks.

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AUTHOR'S STATEMENT

Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study.

REFERENCES

[1] Numerous examples for 3D-printed corona devices at e.g. 3d-druck.com