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Advanced Process Chains for Prototyping and Pilot Production based on Additive Manufacturing

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MADE – Manufacturing Academy of Denmark

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Background to the project including short statement of state of the art:

For many years, Additive Manufacturing (AM) has been a well-established production technology used mainly for rapid prototyping. But the need for increased flexibility and economic low volume production led to the discovery of Additive Manufacturing as a suitable fabrication technique (Mellor 2013). With technological progress and the development of new processes, AM technology now starts to become a serious option for mass production. It enables new options for material choice, shape and internal structure. Productivity in production of e.g. metal parts can be increased due to mass and cost reduction and better parts functionality (Ponche 2014). Also, the use of AM machines for spare parts can potentially reduce costs and downtime, and lead to a higher robustness to supply chain disruptions (Khajavi 2013). Control and optimization of the involved process chains are crucial for a fast and robust implementation of AM technology in the industrial world.

Positioning of the project in relation to the state of the art:

Process Chains

Production of advanced and more complex parts often includes different technologies and processes. The links between them can be represented in a so-called manufacturing process chain (Afazov 2012). Currently, most products are not immediately suited to Additive Manufacturing (Cozmei 2012). But production time and costs can be reduced significantly by using AM technology in conjunction with other technologies in a process chain (Gibson 2010). Companies will have to rethink the flow of product data, standard supply chains practices will be disrupted (Wohlers 2012) and current process chains might be changed or replaced.

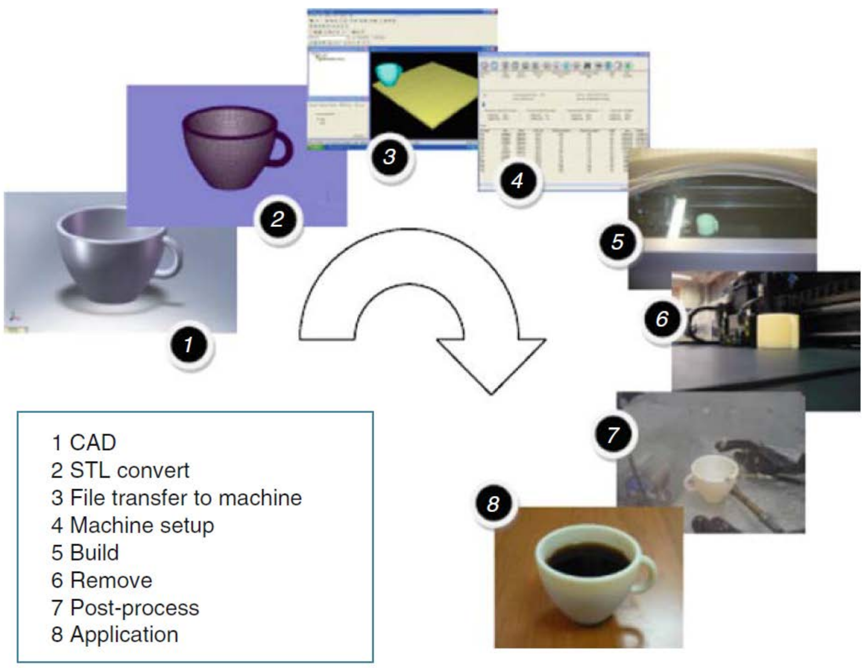

Figure 1 - The eight stages of the (classical) AM process (Gibson 2010)

The classical Additive Manufacturing process chain can be seen in Figure 1 (Gibson 2010). The product is designed in a CAD-software, converted to an STL-file and built with a respective printer. Post-processing can be performed, if necessary.
In comparison to that, the manufacturing part of a common process chain representing a “conventional” way of manufacturing (in this case classical injection moulding) is given in Figure 2.

Figure 2 - Conventional Way of Manufacturing

Both processes are well-established and include clear advantages and disadvantages. A combination of e.g. those two process chains could potentially lead to significant increase in production efficiency. Even further, products can be designed as hybrid modular products (“…3-D puzzles with modules realized individually by the best manufacturing process…” Kerbrat 2011, Figure 3).

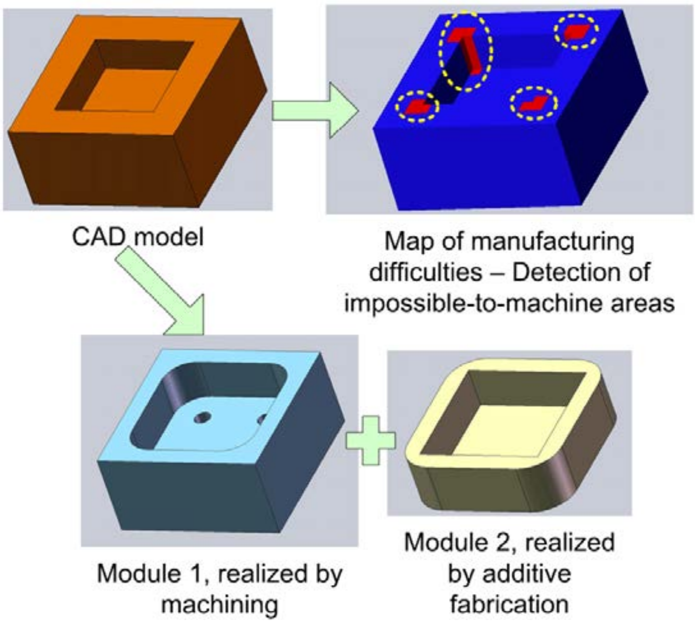

Figure 3 – Academic example of the hybrid approach in reducing manufacturing difficulties (Kerbrat 2011)

Some possible scenarios are described in Figure 4. Option A: Additive Manufacturing Technology is used to produce the core structure of a mould used for injection moulding. The advantages of Additive Manufacturing shall be used to realize mould inserts which conventional manufacturing techniques could only produce at high costs. Whenever necessary, machining is introduced as an intermediate step to ensure a surface quality that AM Technology alone cannot achieve yet. Possible materials include metals, polymers, and ceramics.
Option B: Additive Manufacturing provides a sufficiently high part quality, so that the assembly can take place immediately after the production of the separate parts of the product. Currently, significant progress is necessary to bring this option to a broad application in the industry. Particular challenges exist e.g. in the fields of material selection and process control.
Option C: Hybrid modular products are realized in a high tech pilot production. At the moment, the actual process chain cannot be predicted exactly since it will incorporate the research results from Option A and B. However, a possible scenario is given in Figure 4.

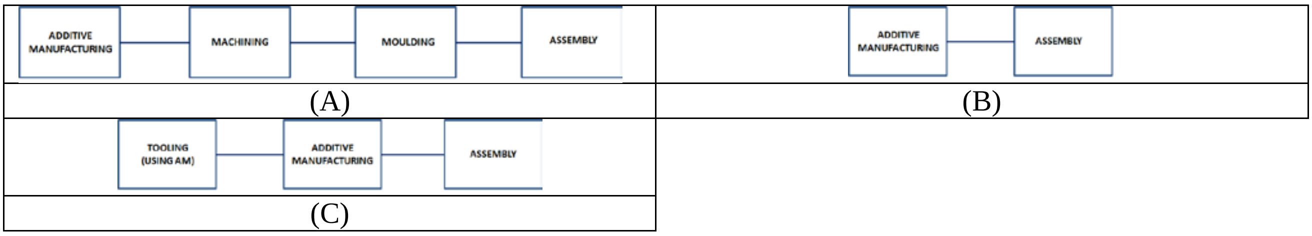

Figure 4 - Alternative Ways of Manufacturing

Goal and purpose of the project:

The goal of this PhD project is to establish advanced process chains in which Additive Manufacturing Technology plays an essential role in satisfying industrial requirements. These include material properties, surface quality, precision, and repeatability. The new knowledge created in this PhD project (research results) shall benefit both the scientific community (publications, conferences) and the industry (put into practice in high-tech pilot production). The objective will be met by working towards two sub-goals:

- Designing, implementing and analysing a process chain based on additive manufacture of mould parts for subsequent injection moulding (Alternative A)
- Designing, implementing and analysing a process chain based on directly additively manufactured prototypes (Alternative B)

Expect methods to be applied and results from the project:

The project is structured into 4 main activity areas:

1. State-of-the-art survey

The project will be initiated by a state-of-the-art survey on AM capabilities. In particular, the Ph.D. student will have to familiarize himself with the practical aspects of various AM technologies by operating machinery. This activity will take place from month 1 to month 6.

2. AM for producing mould inserts

This activity will focus on the use of AM technologies for producing inserts for injection moulding tools. The work will investigate different materials and process types with respect to precision, surface quality, durability etc. Both polymer based and ceramic based AM processes will be investigated to map capabilities. This work will involve two industrial demonstrators coming from LEGO and Danfoss respectively. This activity will take place from month 6 to month 36.

3. Improving AM platforms to produce parts of high quality

This activity will focus on designing and improving performance of 1-2 AM platforms to meet the requirements in terms of geometrical and surface related accuracies. The work will concentrate on looking at the FDM process trying to downscale extrusion units and apply alternative deposition approaches to improve process resolution. It is the ambition to reach a process resolution of 10 µm or below, which is at least a factor 3-4 compared to state-of-the-art. This activity will take place from month 12 to month 48.

4. Design aspects of AM for rapid prototyping and pilot production

This activity will collect information across activities 2 and 3 in an attempt to formulate generic design “rules” and guidelines for the use of AM for pilot production and prototyping. Analyses and optimisation of AM process resolution will be an important part of this activity. This activity will take place from month 6 to month 48.

Discussion of how the results of the project may contribute to the overall goal of MADE.

Alternative A
Facilitating and improving the process of injection moulding represents an important and valuable opportunity for many members of the MADE initiative. Additive manufacturing technology has shown considerable potential in the field of mould inserts which can result in a substantial acceleration of time-to-market and a notable increase in profitability of injection moulding used in small volume production.
Alternative B
The development of a new Additive Manufacturing platform has the potential to significantly strengthen the position of the Danish industry as a key player in global production of high-quality and high-value parts. A thorough implementation of the project can lead to patents and the creation of a spin-off.

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