Additive Tooling for Thermoforming

Case Study: Making a Cowling of an UAV using Binder Jetting

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Overview

- Introduction
- Thermoforming using conventional tooling
- Additive tooling using Binder Jetting (BJ)
- Case study of a cowling of an UAV
- Design and additive manufacturing of the tool
- Economic considerations
- Conclusion

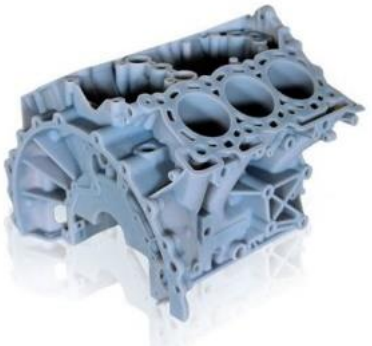
Introduction
Laboratory Rapid Prototyping

Profile and aims

- Rapid Prototyping
- Rapid Tooling
- Reverse Engineering

Projects:

- Training in additive processes
- Rendering of services for companies
- Research for new applications



Rapid Prototyping

Rapid Tooling

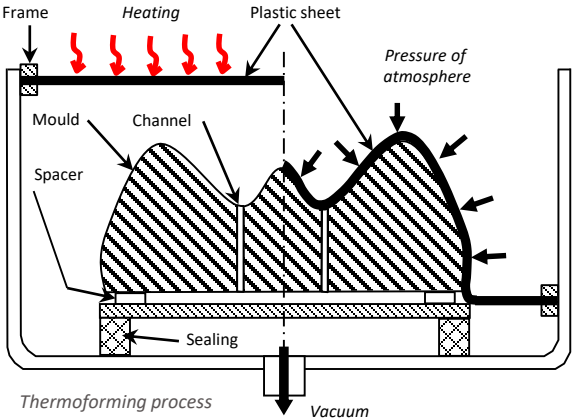
Thermoforming process

Thermoforming of thin plastic sheets

- Plastic sheet is clamped and heated
- Then pulled over an mould
- Additional vacuum to pull the sheet on the shape of the mould
- Reshaped sheet is removed after cooling

Applications (e.g.)

- Packaging (transport container)
- Housings



Thermoforming process


Thermoformed parts (Source: Kern GmbH)

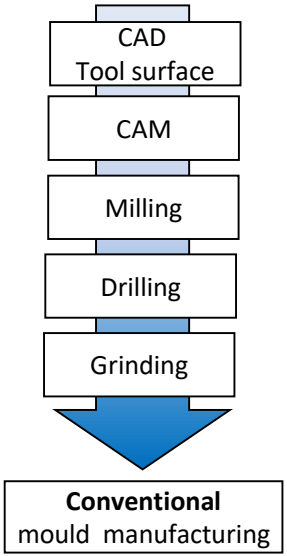
Conventional Tooling

Conventional mould manufacturing

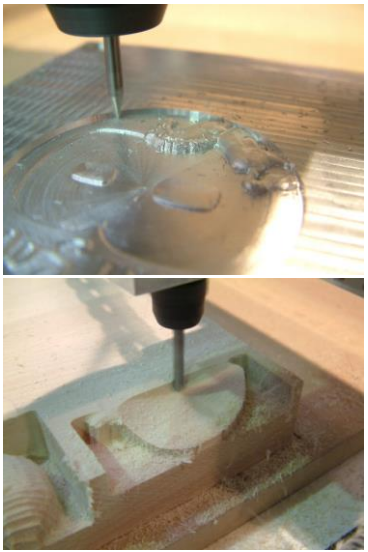
- Design of tool surface using CAD
- Generation of the tool-path (G-code) for CNC-machining (CAM)
- Conventional manufacturing: milling, grinding
- Additional manufacturing steps: drilling holes, assembling of spacers

Tool materials

- Hardwood, Resin or Plaster (small quantities)
- Aluminium (high quantities and mass production)



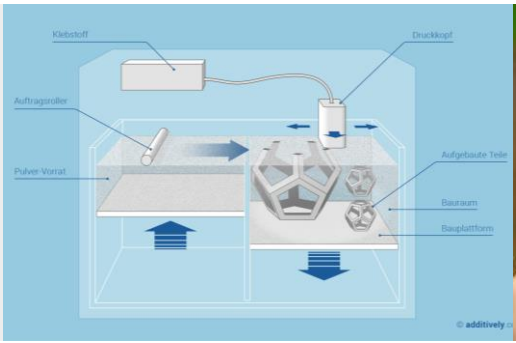
Conventional mould manufacturing



CNC-milling of aluminium and hardwood
(Source: CNC-Technik Heiz)

Binder Jetting (BJ)
3D colour printing using polymer plaster

- Construction material: Polymer plaster powder, no support needed
- Joining Technology: Jetting binder (and colored ink)
- Post Processing: Blowing off superfluous powder and infiltration
- Build Speed: 2–4 layers per minute
- Build Size: 381x 254 x 203 mm
- Layer Thickness: 0.1 mm (z-axis)
- Resolution: 600 x 600 dpi (x-/y-axis)



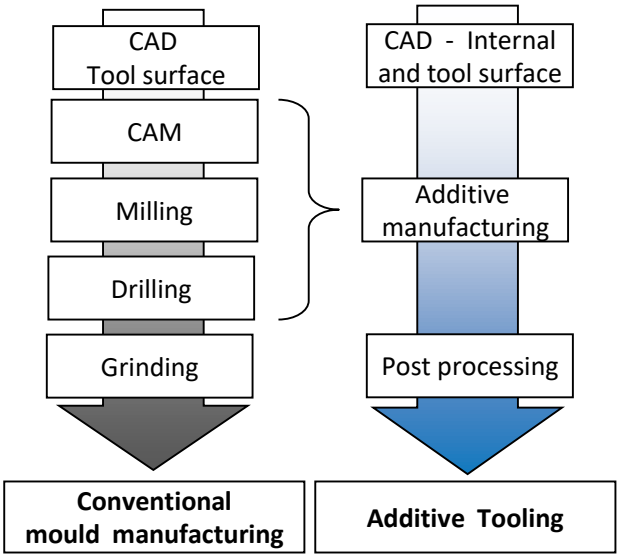
Additive Tooling using Binder Jetting

Binder Jetting process

- Process start: design of 3D model using CAD-system (e.g. CATIA V5)
- AM process
- Post-processing (cleaning, infiltration)

Advantages of Additive tooling

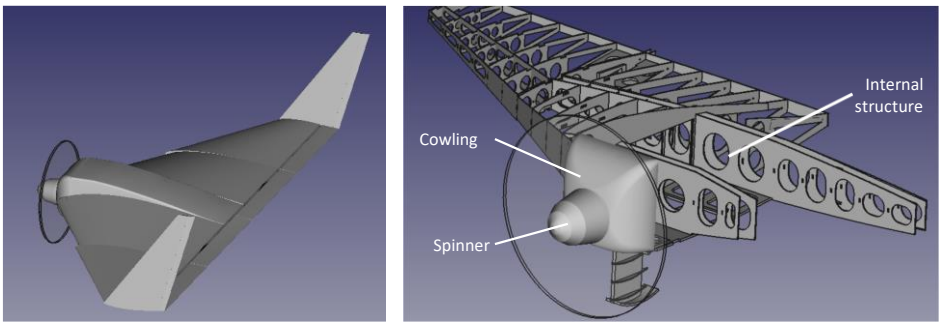
- Reduction of the number of process steps
- No CAM-systems required
- New geometries possible (e.g. angled channels with various cross-sections)



Comparison of Conventional mould manufacturing and Additive Tooling

Case Study

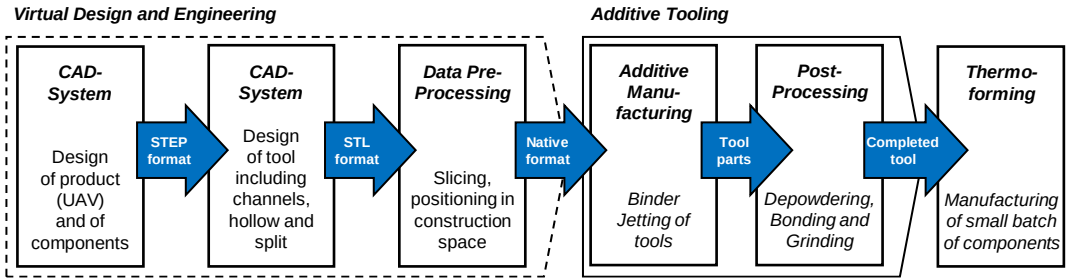
- As case study the bonnet (cowling) of an Unmanned Aerial Vehicle is used.
- Structure and planking of the UAV is largely made of wood, as this material is light and flexible while providing sufficient strength.
- Due to the complex shape of the cowling an indirect manufacturing process is chosen → thermoforming
- Overall, only a small series of about 10 cowlings should be formed.
- Dimension of the engine bonnet of approx. 284 x 262x 141 mm.



CAD-Modell of the UAV (left) and details of the bonnet (cowling) and the internal structure (right)

Process Chain in Additive Tooling

- Basis for additive tooling is the CAD data of the cowling, which is provided by the project partner responsible for the aircraft design
- These CAD data, which contain only the surface, are first transformed into a solid body that corresponds to the tool.
- To save printing material, the body is hollowed out (wall thickness ~30 mm)
  → sufficient strength for the subsequent forming process
- Tool was added by a circumferential edge of about 10 mm height, which is needed for the cutting of the formed part.
- A number of channels were placed in the lower part of the tool to allow vacuuming at these critical points during thermoforming.

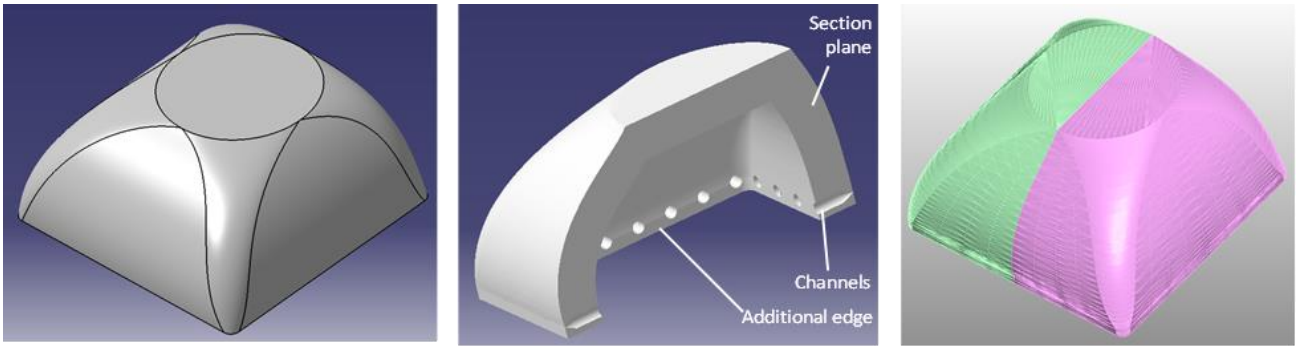


Process chain from product and tool design to thermoforming

Tool design

- As part of data preparation, the data of the tool are positioned and aligned in the construction chamber of the BJ printer.
- Process parameters (e.g., layer thickness and build speed) are selected.
- Since this is a relatively large component, the tool has to be divided into two parts
- The rough model is infiltrated with a resin or instant adhesive.

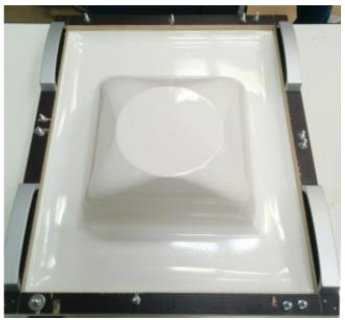
  → Infiltration reduces the fragility of the model and its strength increases.



Initial CAD-Model (left), CAD-Model of tool part (middle) and completed tool in STL-Format (right)

Additive Manufacturing of the tool

- Since the tool was made in two parts, additional steps in the post-processing were necessary → filling an grinding
- Tool was mounted on a wooden base plate with spacers, that must be provided so that the negative pressure can be generated under the tool.
- Plastic sheets (material: ABS, thickness 1.0 mm) were formed in one step.
- Tool hold a thermal load of 120 to 180 °C, at least at low quantities quite well.
- Finally, the components are cut out of the plastic sheet and supplied to the research partner who is responsible for the assembly.



Mounted tool (left), cowling manufactured by thermoforming in clamping frame (middle) and cowling and spinner during assembly (right)

Economic considerations
Material costs

- When comparing the material costs, it can be seen first that in the conventional production of the tool by means of machining much more raw material is consumed.
- In conventional production by cutting a metal block, over 63% of the volume is wasted as chips and thus as waste.
- This shows the advantage of BJ, since only the material for the final shape is consumed and all excess material can be reused without special treatment.
- The material costs at the BJ consist of the costs for powder, binder and resin.
- However, the material costs for the additive materials are significantly higher than for an aluminum block for conventional manufacturing.

❖ Material Costs: 775 €

Economic considerations
Manufacturing costs

- The BJ-process of one tool half takes about 10.5 h (in total 21 h).
- By using a 3D printer with a larger construction chamber, the construction time reduces by approx. 30% to approx. 14.3 h.
- Because acquisition and operating costs of 3D printers for BJ are well below those of laser based AM systems as well as conventional CNC machine tools, the machine hourly rates for additive tooling is cheaper compared to other methods.

➢ Thus, the relatively long production times in AT can be partially offset by the favorable machine hourly rate.

- Post-processing by infiltration, gluing and grinding needs about 8.5 h.
- By running a one-part tool, these costs can be further reduced by 23%.

➢ This makes the costs for the reworking of conventional and additive tooling almost comparable.

❖ Machine Costs: 70 €

❖ Personnel Costs: 550 €

Conclusion

- This case study has shown that Additive Tooling using Binder Jetting can be used to manufacture a thermoforming tool.
- In the design, channels and spacers can already be integrated into the CAD model.
- The manufacturing of the tool takes only a few hours.
- The additional effort due to the division of the tool can be avoided by using 3D printers with a sufficient size of construction chamber.
- Due to the low material consumption and the favorable machine hourly rate, Additive Tooling with 3D printers is a sustainable and economic alternative to conventional tool production, especially during testing and in small batch production.

❖ Total Costs: 1.395 € (excl. VAT)

❖ Manufacturing Time: 2-3 days

❖ Buying the tool: 1.250 € (excl. VAT)

❖ Delivery Time: 4-6 weeks

Thank you very much for your Attention!

Questions?