Inkjet Printing for Rapid Manufacturing

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Rapid Manufacturing by inkjet based technology has been investigated by Polymer Jetting and Solder Jetting (Direct Inkjet Printing), and 3D Powder Printing (Indirect Inkjet Printing). Polymer Jetting is suitable for higher viscosity (up to 400 mPa·s) polymers, while Solder Jetting is suitable for various solder alloys and 3D Printing for ceramic powders.

Rapid Manufacturing

Rapid Manufacturing is defined as the layerwise, additive production of functional parts directly from 3D CAD (figure 1). Various techniques are in use, one of which is inkjet printing [1]. An overview of the inkjet related research at TNO Industrial Technology is given.

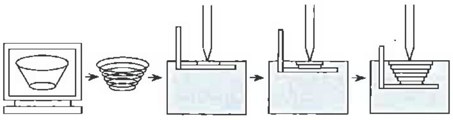

Figure 1.
Schematic of Rapid Manufacturing: a product is sliced in the computer and built by additive techniques.

3D (Powder) Printing

In 3D Powder Printing the building material is spread onto a thin layer of loose powder. The inkjet print head selectively deposits a binder fluid, which glues the powder particles in each layer and also to the preceding layer. The research is focused at ceramic powders for structural ceramic parts. Plaster based powder as well as alumina (Al_2O_3) has been used to build test products (figure 2).

Figure 2a.
TNO 3D Powder Printer.

Figure 2b.
Alumina test products (teeth).

Building volume is 210 x 297 x 580 mm, layer thickness 0.1 – 0.5 mm, and building speed 1 cm/hr. For alumina a 10 vol% poly (acrylic acid) (PAA) binder solution is used. Printed parts dry inside the powder bed for 12 hours and are cautiously retrieved and dried at 95 °C and low vacuum for 2 hours. The parts are now strong enough to be cleaned of loose powder. Finally the porous parts are sintered at 1650 °C for 2 hours. With 3 – 10 μm alumina particles a final density of 45 % has been achieved.

Direct Inkjet Printing

Polymers

In Direct Inkjet Printing all the material is deposited through the print head. One drawback of current print heads is the limitation of the maximum viscosity of the material that can be used. The viscosity of the jetted material has a direct relationship with the end strength of the product. For attaining maximal structural integrity of the part a novel print head has been developed which enables processing of materials with viscosities up to 400 mPa·s at jetting temperature, with drop frequencies up to 20 kHz, and a drop size of approximately 80 micron (figure 3).

Figure 3a.
Direct Inkjet set-up.

Figure 3b.
Image of deflected and undeflected droplets.

Solder

Using a special drop-on-demand print head (MicroFab SolderJet) solder droplets can be dispensed (figure 4).

Figure 4a.
MicroFab SolderJet.

Figure 4b.
Raster of 100 μm solder bumps [2].

Drop size is in the range of 25 – 125 μm and for solder the maximum drop frequency is around 400 Hz. The printhead may be used in 'step-and-print' and 'print-on-the-fly' mode. Examples of applications are solder bumps for flip-chip mounting and printing of conductive tracks on PCB's.

Future work

The 3D Powder Printing process will be optimised for stronger 'green' parts. Sintered parts will be infiltrated with special glasses for higher impact strength and durability [3]. Various polymers will be tested in the Direct Inkjet set-up for high strength products, and the deposition of specialty polymers. Multiple print heads will allow accurate positioning of different materials in one layer and thus enable producing of multi-material products. Combination of the Polymer print head and the SolderJet in one setup will lead to products with integrated conductive paths. Linking 3D Powder Printing to Direct Inkjet Printing will enable complex composite products. Inkjet printing is one of the most promising technologies for creating 3D graded structures.

References

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[3] Zhu Q., de With G., Dortmans L., Feenstra F., "Subcritical crack growth behavior of Al_2O_3-glass dental composites", J. Biomed. Mater. Res., 65B (2), 233-238, 2003.