High Speed Sintering for 3D printing applications

XAAR®

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Introduction

High Speed Sintering (HSS) is a transformational inkjet-based 3D printing technology which is being further developed at Xaar by the original inventor, Prof. Neil Hopkinson. This 3D printing (also called Additive Manufacturing) technology involves depositing a fine layer of polymeric powder, after which inkjet printheads deposit a single IR (infrared) absorbing fluid directly onto the powder surface in the required cross-sectional pattern where sintering is desired. The entire build area is then irradiated with an infrared lamp, causing the printed fluid to absorb this energy and then melt and sinter (consolidate) the underlying powder. This process is then repeated layer by layer until the build is complete.

The use of digital inkjet printing makes the process considerably faster than point based systems, for example those requiring a laser to sinter/melt material. As with all 3D printing processes there is no requirement for new moulds, plates or other design template related fixtures. High Speed Sintering is a self-supporting process; this means that solid, hollow and complex shapes with internal features are possible without the need to create and subsequently remove support structures, at much higher speeds than other additive manufacturing processes.

Today there are many 3D printing technologies and several other sintering technologies available. This paper demonstrates how High Speed Sintering (HSS) fits in the 3D printing space as a fast and cost-effective route to develop and manufacture customised prototypes and products.

For any new printing system the desired end goal is to replace incumbent technologies with something faster (higher throughput), more economic, scalable and with greater flexibility and added value. Regarding throughput, many different units of measurements are quoted in the industry; this is an area where greater clarity may be useful for anyone who is interested in HSS processes.

History of High Speed Sintering

JULY 2003

Loughborough University

High Speed Sintering patents filed

Loughborough University files patents for a revolutionary technology, with Neil Hopkinson as primary inventor, supported by Higher Education Funding Council for England (HEFCE). The new technology uses inkjet printheads and infrared heaters to manufacture products layer by layer from polymer powder materials at much higher speeds than other additive manufacturing processes.

SEPTEMBER 2005

First High Speed Sintering machine

Selective Laser Sintering™ machine is retrofitted with Xaar 380 printheads, able to print infrared absorbing inks to create parts with properties comparable with laser sintered parts.

OCTOBER 2005

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Ink development

Xaar sponsors research to develop new inks for High Speed Sintering.

AUGUST 2006

£1.2M funding

5 year award from EPSRC to develop High Speed Sintering for sport and leisure applications.

OCTOBER 2011

First dedicated High Speed Sintering machine delivered

World's first dedicated machine is installed at the University of Sheffield.

MAY 2015

Fine feature upgrade

Xaar 1002 printheads added to High Speed Sintering machine, enabling production of 0.5 mm fine features.

JANUARY 2017

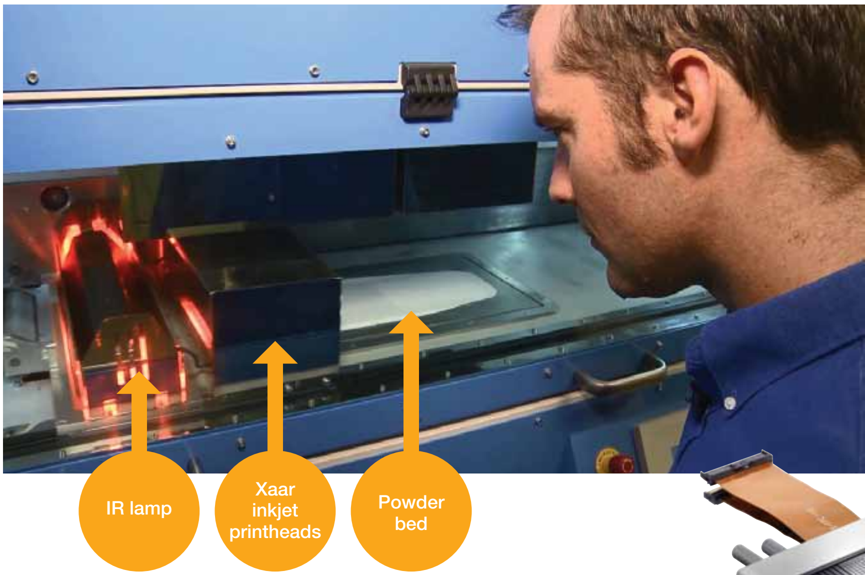
XAAR

3D Printing Centres

Xaar opens 3D Printing Centres in Nottingham (UK) and Copenhagen (Denmark) to accelerate the development of the High Speed Sintering technology.

Figure 1: The history of High Speed Sintering (HSS)

The technology behind High Speed Sintering



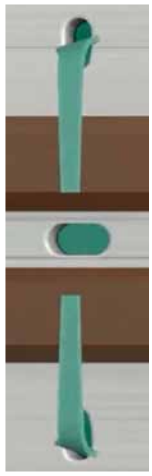


Figure 2: The first dedicated High Speed Sintering (HSS) machine built in 2011, the relative location of the IR (infrared) lamp, printheads and powder bed are indicated. To the right is the Xaar 1003 printhead currently used and the associated Xaar's TF Technology® ink recirculation which renders it the most reliable printhead for industrial printing applications.

The speed and object throughput of 3D printing

Point based 3D printing processes such as Fused Deposition Modelling and Laser Sintering require multiple, typically hundreds, of raster passes within each layer to define the part as it is being manufactured. Conversely, approaches that employ a swathe of printheads are able to define the part in a single pass or a very small number of passes.

The speed of some inkjet-based 3D printing technologies, such as print and cure, in which a photo-curable resin is deposited by the printhead and then cured using UV radiation depends on the ink throughput of the printhead itself. This is because all the material which forms the part (and additional support material) must pass through the printhead to make the part(s) and support(s). As such, printhead ink throughput, often also referred to as ink flux or ink laydown, is the process rate-limiting step.

For 3D printing based on High Speed Sintering, this is not the case as less than 5% of the manufactured part passes through the printhead (i.e.> 95% of the part being comprised of the powder which is sintered in the process). The process rate-limiting step for HSS processes is, therefore, not printhead laydown but the rate at which the powder can be deposited.

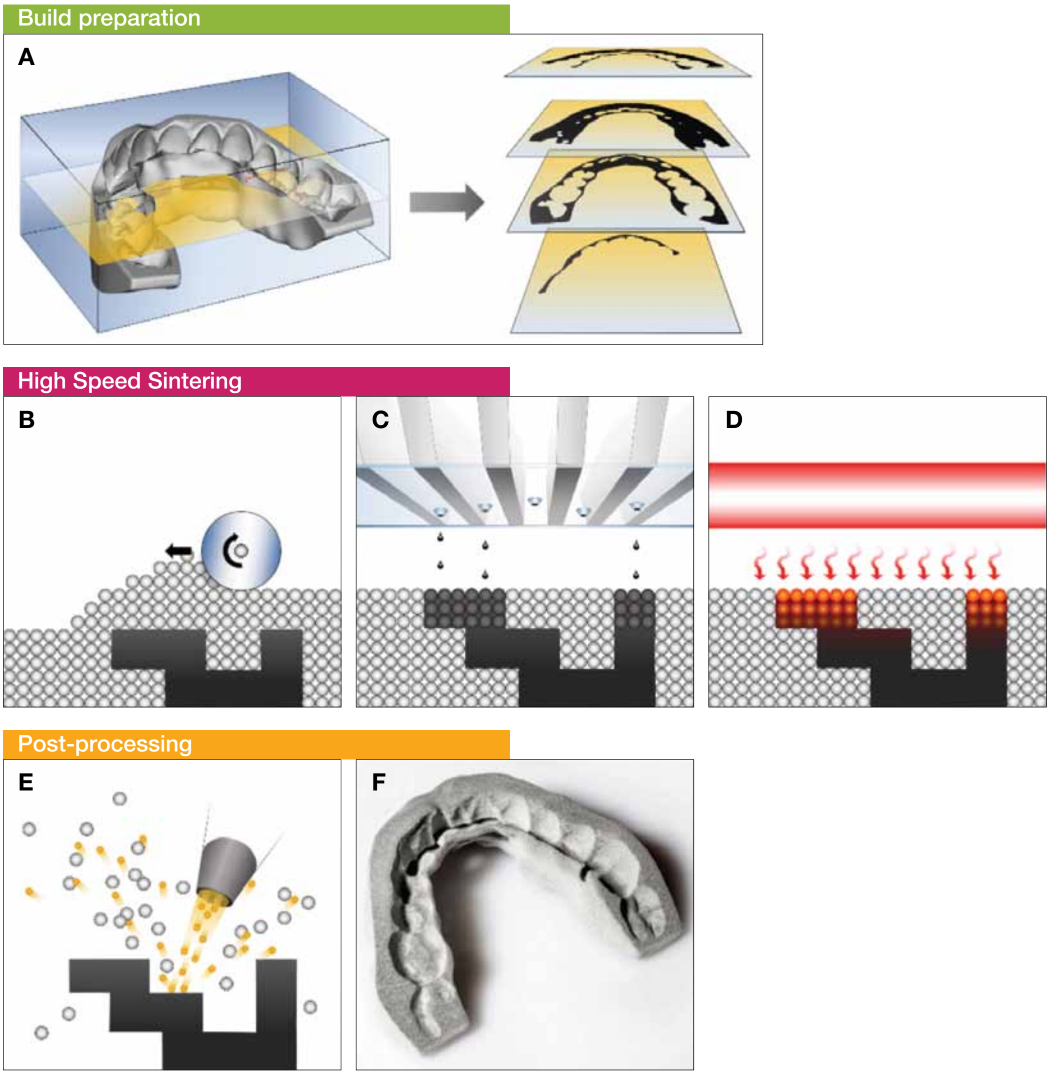
Laser Sintering is a powder bed fusion process in which a laser is used to consolidate the feed powder material into a part. In this case the process rate-limiting step is the scanning speed of the laser. Consequently, if a large cross-sectional area is scanned, the layer build-time is increased. With High Speed Sintering, however, the entire layer is printed in one pass, removing the speed limitation. This allows HSS processes to achieve throughput rates up to ten times higher than Laser Sintering for a comparable build volume, where build volume is defined as the dimensions of the build volume (length x width x depth).

High Speed Sintering is able to produce parts with mechanical performance equal to or above Laser Sintering, this is particularly the case with elastomers in which High Speed Sintering has been able to achieve parts with very high ductility. The standard material for both technologies is Nylon 12; using this powder enables HSS processes to achieve dimensional tolerance of ±200 microns and it has achieved feature resolution of below 0.5 mm.

With Laser Sintering, 3D printed parts are typically built using a layer thickness of 100 microns. However, in High Speed Sintering, if sufficient IR energy can be absorbed by the printed area, thicker layers can be used. To achieve this, highly loaded and, therefore, viscous droplets are required. This is enabled by Xaar's TF Technology® which allows printing of fluids much more viscous than water. Higher IR-absorber loading means more sintering energy is transferred to the powder below, allowing thicker layers to be employed; further improving the already superior HSS process throughput relative to Laser Sintering.

Currently, the ink for High Speed Sintering is heavily loaded with infrared absorbing pigment. This aligns well with Xaar's renowned expertise as the world leader in the reliable jetting of highly loaded, industrial inks for ceramic tile printing. TF Technology® prevents sedimentation and nozzle blocking, particularly in heavily pigmented inks and allows air bubbles to be carried away. The Xaar printhead is often operating in a hot environment and TF Technology® removes heat directly from within the actuator channels, virtually eliminating print density variations. This is particularly advantageous in High Speed Sintering, where the printheads are exposed to elevated temperatures.

Xaar's printheads can be used to jet different coloured fluids which means that coloured parts can be manufactured in situ with High Speed Sintering.



A The CAD model is sliced into multiple 100 micron thick layers, each of which is converted into a bitmap to be printed.

B A fresh layer of powder is deposited by a counter-rotating roller.

C A radiation absorbing fluid is printed directly onto the powder surface using a Xaar printhead.

D The entire build surface is irradiated with infrared causing the printed areas to melt. Steps B, C & D are then repeated until the build is complete.

E The powder cake is removed from the machine and the un-sintered powder is removed using compressed air and glass media.

F The final part.

Figure 3: Schematic showing High Speed Sintering (HSS) from start to finish.

Comparing High Speed Sintering with injection moulding

Previous analysis by Hopkinson and Dickens calculated that for a small, complex geometry the economic cut-off production volume compared with injection moulding was 14,000 units.[1] The figure below has been adapted from the original work by Hopkinson and Dickens to show that for a large High Speed Sintering machine this number increases to 200,000 units. However, if the material price is set at a point that is comparable with today's polymer powders for volume applications, the economic cut-off volume increase to over 1,000,000 units.

This economic production volume depicted below for High Speed Sintering is enabled thanks to the scalability offered by inkjet technology. While laser-based processes are unable to scale up to large build volumes, High Speed Sintering uses an array of printheads which can be readily scaled to cover a large area in one pass. This pushes HSS processes beyond prototype manufacturing into tool-less low and medium volume production runs. For example, for a standard test specimen measuring 75 mm x 10 mm x 2 mm and assuming a warm up/cool down cycle of 3 hours, a layer time of 20 seconds and a 2 mm gap between all parts, a High Speed Sintering printer with a build volume of 1m^3 would produce parts faster than 1 part per second.

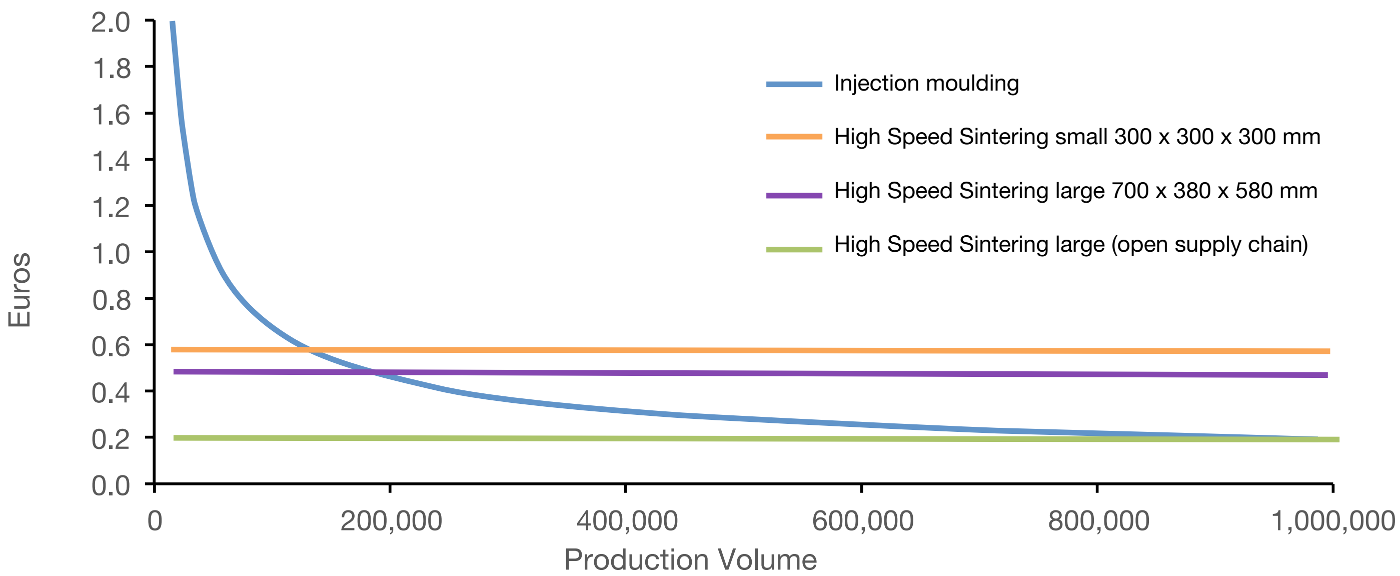


Figure 4: Volume of production vs cost in Euros comparing injection moulding with HSS processes.

1. Hopkinson, N., & Dickens, P.M. 2003. Proceedings of the Institute of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 217 (C1), pp. 31-39.

Summary

High Speed Sintering (HSS) processes using Xaar printheads offer the fastest powder bed sintering process available today that is built on industrial inkjet technology; it is a robust industrial solution for the growing 3D printing market. The key advantages of HSS processes are:

- Wide range of 3D printable thermoplastic materials; extending from nylon to thermoplastic polyurethanes and other elastomers
- Highly scalable 3D printing technology makes it possible to produce parts at a rate of less than one second per part
- For many geometries, it is more economical than injection moulding for part production in the range 1 to 1,000,000 units
- Rugged design; long lifetime piezo inkjet printheads negates the need for very frequent printhead replacement
- Xaar offers a complete 3D printing solution, including printheads, approved inks and powders, with access to new printhead technology upgrades as and when they become available.

Xaar's experienced High Speed Sintering team has expertise in:

- Powder bed machine and software design and development
- Materials development
- Process optimisation
- Business opportunity analysis
- Applications development.

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