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AM porous Filters: Aperture size using X-ray Computer Tomography

Additive Manufacturing or 3D printing manufactures components, layer by layer, according to the 3D CAD design. The layer wise construction can allow greater complexity in component design.
Croft has designed and manufactured novel innovative filter media exploiting the design freedoms of AM to produce metal AM filters that had a decreased resistance due to the design and the resultant fluid flow path. Here the apertures were mainly a regular repeating size arranged to minimise disruption in fluid flow through the filter. There are many classes of filters which can provide different properties to suit different filtration needs. Depth filters use a porous filtration medium to retain particles throughout the medium rather than just on the surface of the medium. They can consist of different medium containing different aperture sizes and so can remove a broad range of particles. Depth filters are made from a wide variety of materials from plastic, cotton, glass fibre, sand and metal amongst others.

Porous metal filters can have regular apertures such as sintered metal filters or they can be irregular shaped apertures such as in open cell metal foam and metal porous filters. These structures are lightweight and have a relatively high porosity and can be made by conventional processes from different metals including aluminium, copper, titanium etc. Metal foam has been used in thermal engineering as heat exchangers and as light weighting and impact resistant material. In sintered metal filters, same size metallic powder is subjected to heat treatment, partial melting of the particles occur and the porous filter formed has uniform regular apertures.

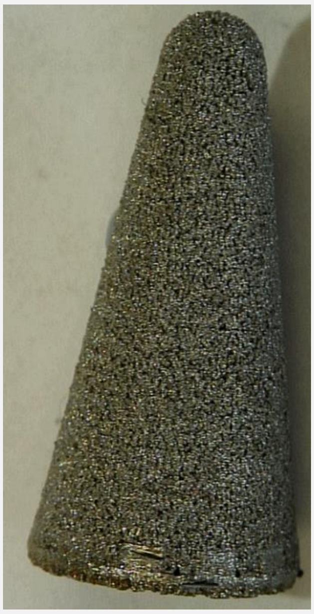

Figure 1: SS316L AM porous filter

Metal powder bed AM technology uses a laser to melt the powder according to the CAD design in successive layers to form the final component. Increasing or decreasing the size of the melt pool determines the melt pool size which then determines the overall density of the part. Manipulation of the build settings, including laser power, spot size and duration can increase or decrease part density. Here Croft changed build settings to manufacture an innovative porous metal AM depth filter (Figure 1) . The size of the apertures/holes in the depth filter determines the filtration level. However, measurement of aperture size in the AM porous filter is challenging. Light microscopy can be utilised to examine pores located on the external surface of the filter but cannot determine pore size within the filter. Bubble point tests, used to determine the smallest pore size in a filter, was trialled however the results for the AM porous filter were highly variable.

X-ray Computed Tomography (X-Ray CT) has been used to visualise the internals of components in 3D. The component is typically rotated 360 degrees with hundreds if not thousands of 2D X-ray images being taken at different angles. These 2D DR (digital radiography) images can then be viewed separately or can be reconstructed into a 3D model of the component. North Star Imaging has a wide range of industrial X-Ray CT systems www.4nsi.com. For this study, we used an X5000™ that has both a 225kV microfocus X-ray tube and a 450kV mini-focus tube to visualise the SS316L AM porous filter (Figure 2). The X5000™ X-ray system at North Star Imaging UK can achieve a best possible voxel size around 5um but could be set up for a maximum resolution of ~500 nm with the correct X-ray tube/detector combination. The system has a nominal part envelope of 32 in (81 cm) diameter x 48 in (121 cm) tall. This allows for 3D imaging of the metal part that then allows for dimensional analysis, part integrity ie demonstrating areas with a lack of material, i.e. porosity. It is this second feature that will be fully exploited to allow analysis of pore shape and size in our AM porous filters.

Figure 2: NSI's X-5000 X-ray Computed Tomography system used to visualise the porous AM filters

Images of the porous filters from the X-Ray CT are shown in figure 3. There is a clear distinction between the material present (white to grey) and material absent (black). The images are from the x and y planes. A total of 150 measurements of the aperture length were taken from each plane and the pore size distribution determined.

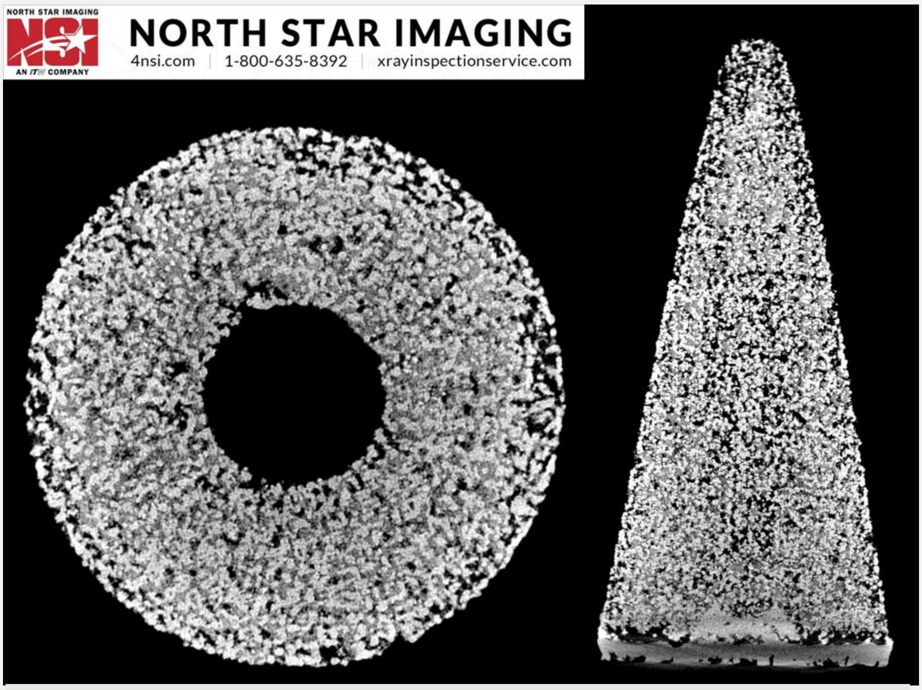

Figure 3: X-Ray CT images of the AM porous filter

The analysis of two different filters showed that the pore size distribution was different between the two filters. This reflects the different build parameter used to build the two filter. X-Ray CT successfully delivered a method of determining the aperture size in the metal AM porous filters. Secondly clear 3D images confirmed the composition of the filter as built, with the support blocks and central core. The resolution and detail exceeded our expectations.

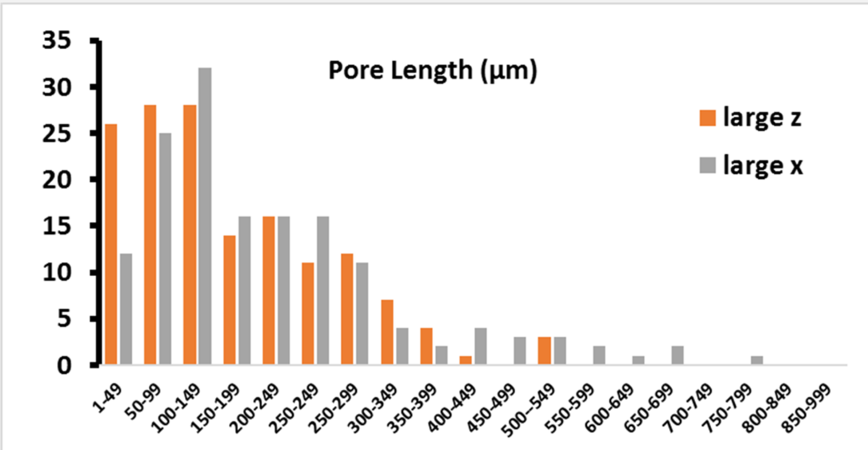

Figure 4: Aperture size distribution of SS316L AM porous filter

This particular X-Ray CT system could also be utilised to produce an stl file from the collected images and with the correct software can compare the CT scan to the original CAD model to determine dimensions of the part and where the part does not correspond to CAD dimensions, a very useful ability especially for AM components. For other components, not porous AM filters the system can illustrate areas with low density/high porosity and be used to determine if faults are present in AM components.