Sintered Castings

Pore-Cor Research Suite
Application Note 1

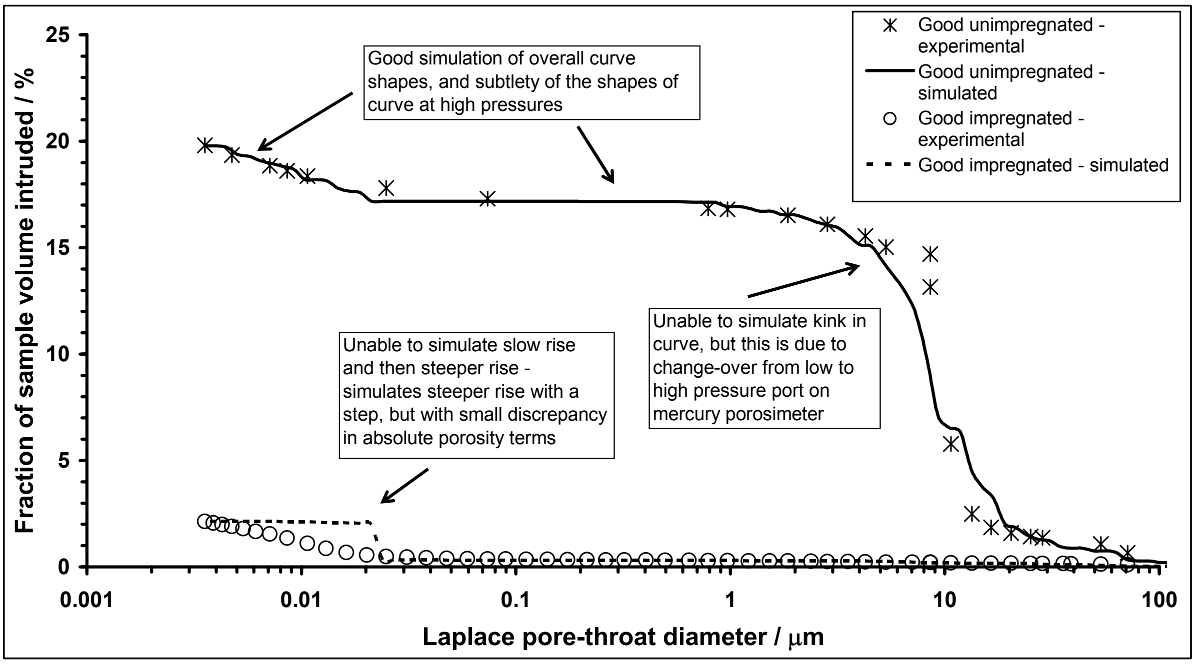
Discovering the Pore Structure of an Impregnated Aluminium Sintered Casting using Mercury Porosimetry and Pore-Cor RS

Use of mercury porosimetry in conjunction with the software Pore-Cor Research Suite (Pore-Cor RS) allows elucidation of subtle features within the pore structure of porous solids which would otherwise be undetectable or uninterpretable. This is exemplified here for an impregnated aluminium sinter.

High precision castings for applications such as compressor casings are made by blowing aluminium powder into an evacuated mould, then heating to cause the powder to sinter. However, the resulting sinter can be slightly permeable to the compressor fluid. So the whole sintered casting is impregnated with a resin. The effect of this resin on the internal void structure can be discovered by measuring the mercury porosimetry curves of an unimpregnated and impregnated sample, and then interpreting the results with Pore-Cor RS.

Pore-Cor RS is very sensitive to experimental data, so it is essential that the mercury porosimetry curves are measured with great accuracy (see e.g Micromeritics Application Note number 20). It is also advisable to pre-process the results using Pore-Comp (a component of Pore-Cor Research Suite) to compensate for sample chamber, mercury and sample expansion and contraction effects. Examples of results after this compensation are shown in the figure below.

Before using Pore-Cor RS on their own samples, all users should work through the Pore-Comp and Pore-Cor tutorials in the Pore-Cor RS Help system. This Help system is supplied with the software, and is also downloadable from **http://www.pore-cor.com/downloads.htm** Attendance at a two-day training course is also recommended.



The graph above shows the compression-corrected mercury intrusion curves after the applied mercury pressures have been converted to pore-throat entry diameters using the Laplace equation:

$$d = -\frac{4\gamma \cos\vartheta}{P} \qquad (1)$$

where γ is the interfacial tension between mercury and air (0.48 N m^{-1}), P is the applied pressure, θ is the contact angle and d is the throat diameter. (See the Pore-Cor RS Help files for references regarding the uncertainties in this equation). The commonly accepted value of θ is 140° for mercury intruding sandstone against residual air, whereupon Equation (1) reduces to:

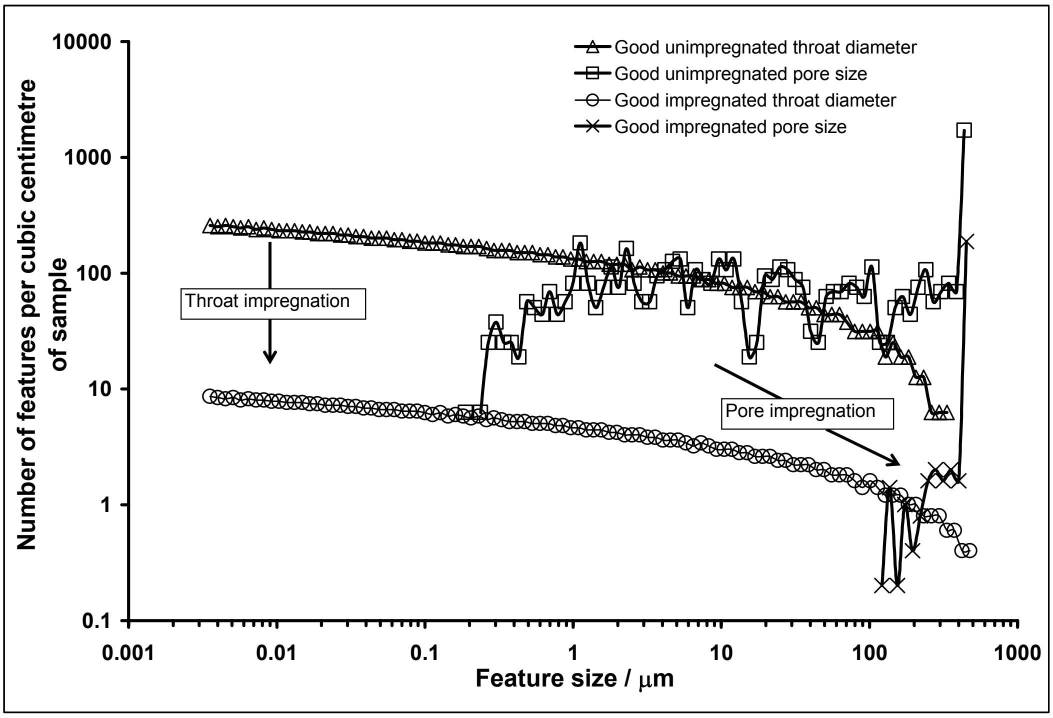
$$d = -\frac{1470}{P} \qquad (2)$$

where d is the throat diameter in microns, and P the applied mercury pressure in kPa.

The porosimetry curves are now modelled with the 'brain' of Pore-Cor RS – i.e. its Boltzmann-annealed Simplex. It can be seen in the previous graph that good fits are obtained, except for (i) a kink due to change-over from low to high pressure penetrometer (sample cell) which could be eliminated with better experimental procedure, and (ii) the steeper rise at very high pressures / small diameters of the intrusion curve of the impregnated sample.

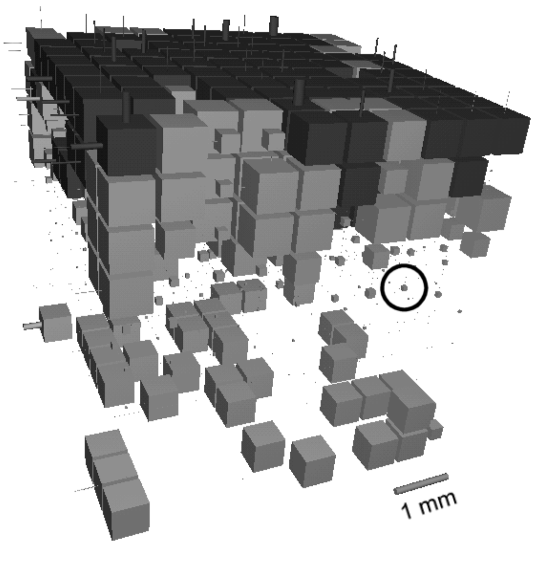
Pore-Cor approximates the void structure to an infinitely repeating array of cubic pores connected by cylindrical throats. (It is also capable of using other shapes such as slits and double-cones). This is clearly a gross approximation, but is nevertheless a great deal better than the approximations implicit in traditional analyses of mercury porosimetry curves, which assume a series of aligned but separated tubes connecting one side of the sample to its opposite face. (The latter approximations are termed the straight capillaric and/or effective hydraulic radius approximations.) The importance about the Pore-Cor RS interpretation is that it allows for the fact that in natural samples, large pores are usually surrounded by smaller throats. Therefore these large pores require a larger applied pressure of mercury than expected before they are intruded.

The graph below shows the absolute numbers of features per cm^3 of sample calculated by Pore-Cor. Note that both axes are logarithmic.

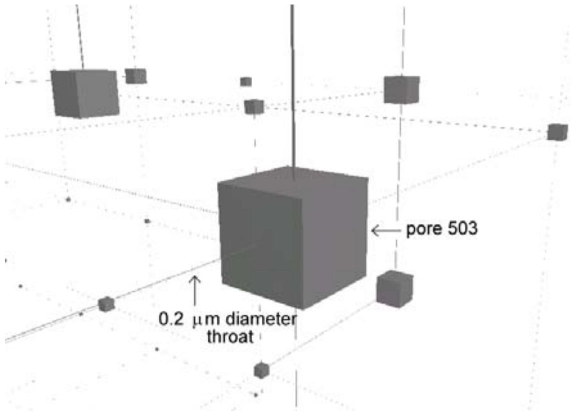


It can be seen that the impregnation process has reduced the number of throats per cubic centimetre of sample by about one and a half orders of magnitude, and the number of pores by at least two orders of magnitude. After impregnation, there are a few of the largest throats left, possibly connected by some very small throats. In practice, the impregnation of these 'Good' samples was successful, and the permeability after impregnation was immeasurably low.

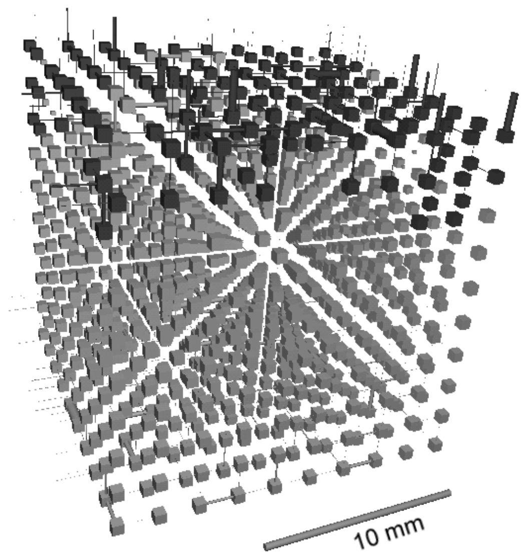
Another facility of Pore-Cor RS is Pore-Eye, its Virtual Reality system which allows the user to walk around inside the sample, and view the distribution of fluids. In the figure below, the void structure has been highlighted by filling it to 49% by volume with a non-wetting fluid such as mercury, shown dark



Using Pore-Eye, it is also possible to examine features which would otherwise be invisible. In the figure above, pore 503 is circled. In the figure top right, the user has walked towards this pore, to reveal more of the void fine structure.



This unimpregnated structure is very different from that of the impregnated sample, shown below. The applied pressure on the dark non-wetting fluid has been increased by 420%, but the fluid has still only intruded 14% by volume of the structure. Note also the different scale bar.



The unimpregnated and impregnated structures are grossly different, due to the successful impregnation process. In a consultancy project, what were most interesting were the structures of 'Bad' samples where the impregnation had not occurred quite as expected. The simulated void structures of these samples showed up effects which the company had never been able to detect before. Their study allowed the factory to optimise its impregnation procedures, and thus produce even more reliable castings.