# A Novel Predictive Deep Bed Filtration Model Using a Void Network Simulator

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## Background

Before release to the market place, new filtration products require testing and validation to ensure they perform to customer specification. This testing and validation requires a major financial commitment by filtration companies before financial gains can be realised from sales. Construction of a reliably predictive filtration model could reduce the number of tests required.

Many attempts have been undertaken to model the processes of deep bed filtration, from semi-empirical to totally mathematical approaches (Sahimi, *et al*. 1990. Elmelech, 1998) Although some offer good correlation with experimental data, the calculations are often laborious, and therefore impractical in their application to manufacturing situations. We describe the adaptation of an existing void network simulator, Pore-Cor, which combines a simplified void network with a robust mathematical approach.

## Aim

The aim of this project is to formulate a predictive, dynamic, deep bed filtration model for use in both pre- and post-manufacture testing and validation, to enable optimisation of marketable filtration products.

## Method

### Experimental

Samples of stainless steel filtration media have been analysed using a Micromeritics Autopore III mercury intrusion porosimeter. The resulting mercury intrusion curves provided the input data for a the void network model.

Pass tests have been undertaken on graded samples of stainless steel media, using ISO test dust as simulated contaminant and oil as carrier stream fluid.

### Modelling

Experimental results have been modelled using the Pore-Cor void network model. This software creates a stochastic realisation of a void network, comprising 1000 cubic pores connected by up to 3000 cylindrical throats, arranged on a regular Cartesian coordinates. The characteristics of the void network are optimised using a Boltzmann-annealed simplex, such that the simulated percolation characteristics match the whole of the mercury intrusion curve, rather than simply concentrating on the point of inflexion as in the traditional approach.

The permeability of the void network was calculated using a modified operational research algorithm originally developed by Dinic (1970). The flow capacity of each of the 3000 pore-throat-pore arcs was calculated using a parameterised Navier Stokes algorithm. All flow capacities were then formed into a hierarchical network, allowing for periodic boundary conditions, and the maximal flow capacity calculated through each path between the fluid super-source and super-sink. The total flow capacity was then converted to the absolute fluid permeability of a single unit cell, and hence of the porous medium as a whole. The addition of trapped particles to the network allowed the calculation of straining and deep-bed filtration effects. The particles could either be added assuming complete accessibility of features to the fluid super-source, or by assuming that particles are fed into the network along the maximal flow routes. Aggregation of particles was modelled by assuming simple 3-particle bridging, or by calculating the progressive aggregation effects within individual void features.

## Results

Figure 1 shows a colour mapping of the flow through the cylindrical throats of a simulation of the random porous network of a stainless steel filter ( Porvair S31). The bluer/darker throats are those containing the most flow. The enlargement on the right shows the route of 100% of the maximal flow, through the two blue/dark throats. (Flows in pores are not indicated). Simulations of straining and deep-bed filtration have also been undertaken assuming 3 particle bridging, Figure 2. The results agree to within 2% of the media's particle capture efficiencies as measured by a pass test (Porvair Technology Ltd. Data Sheets). Further results cover a range of samples of various grades, tested with different test dusts. They give a clear picture of the limitations and usefulness of the novel modelling approach when applied to a wider range of samples under different filtration conditions, in terms of both capture efficiency and loading capacity of the filtration media. The predictive capabilities of the new model are also discussed.

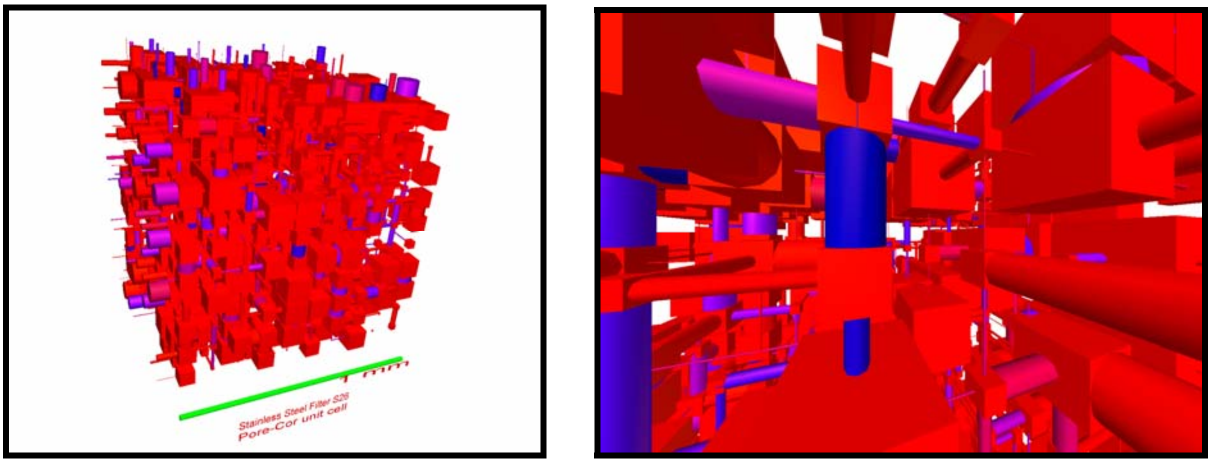


**Figure 1** Three dimensional visualisations of the filtration media. Flow rates represented by variable shading of cylindrical throat features (the darker blue areas representing higher flow rates with lighter shading representing lower flow rates respectively). On the left, a complete unit cell and on the right, the feature containing maximal flow rate of the unit cell.

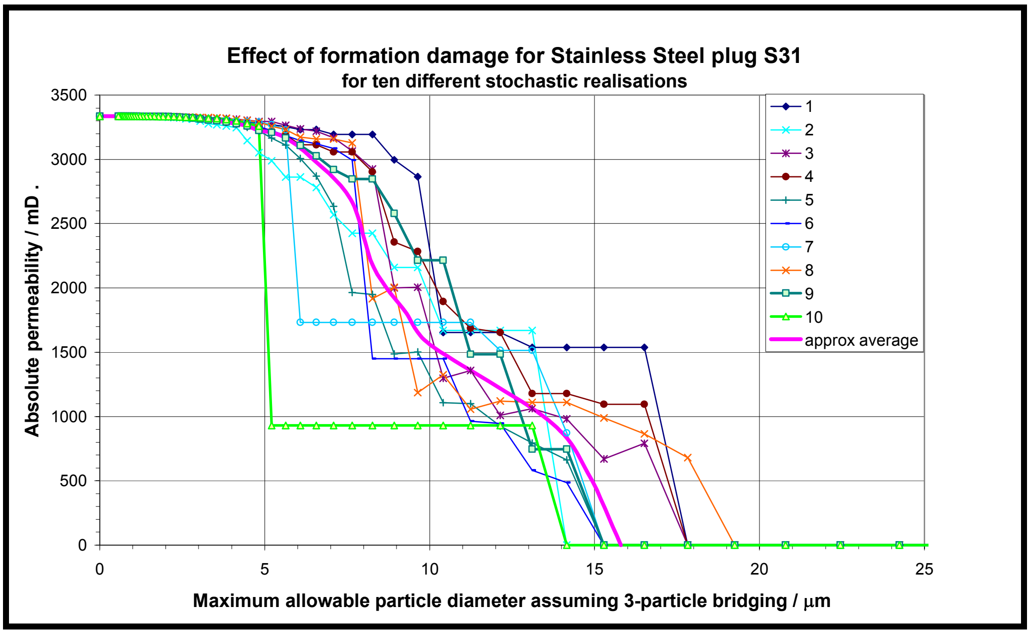


**Figure 2** Decline of absolute fluid permeability decline for 10 stochastic realisations of an S31 stainless steel filter medium, assuming 3-particle bridging . (Permeability units are milliDarcies = 9.9 x $10^{-16}$ $m^2$ )

## Key Words

Depth Filtration, Testing & Validation, Filter Media, Simulation, Void Network, Pore-Cor.

## References


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Further publications and structures viewable in virtual reality are available at the site: http://www.pore-cor.com/