Breakthrough in mesh development

Numerical simulation of the bubble point test

For quality control and quality assurance of filter media, the bubble point test has been the standard for many years. It is used to determine the diameter of the largest pore in a filter medium. This is done by translating the pressure value measured in a laboratory test into a pore diameter value using a predefined capillary pressure constant. These capillary pressure constants – determined according to the bubble point pressure standard BS 3321:1986-02-28 – relate specifically to circular pores. But in reality, due to the way they are constructed, this is not the case for woven filter meshes. As a result, for woven meshes, the linear correlation between measured pressure and pore size using the standard constants has so far only allowed relative statements to be made about the actual pore size – even when using the capillary correction factor C, which was specifically introduced to cater for random pore geometries. Consequently, to get an absolute value for the diameter of the largest pore, time-consuming screenings were always necessary. Now, through the simulation of the bubble point test and the application of capillary pressure constants determined from the simulation, GKD – GEBR. KUFFERATH AG (GKD) has found a method with which the maximum pore size for all standard woven meshes can be precisely established in no time at all. But the international technology leader for woven filter media uses these "Computational Fluid Dynamics" (CFD) tools for more than just quality control. The method is also uniquely suitable for purposeful development of new precision filter meshes or for application-specific adjustment of existing woven mesh types to meet customer-specified bubble point values.

Filtration efficiency for industrial requirements is usually quantified as the size of the largest pore in a mesh filter. Determination of the maximum pore size using the bubble point test allows a quantitative comparison between batches of mesh. In this conventional measuring method, a coupon of the filter mesh is fixed in the test device and wetted with a fluid – in the case of stainless steel wire mesh, for example, with isopropyl alcohol. In the pressure chamber underneath the mesh coupon, the pressure is slowly increased by pumping in air until the first bubble penetrates upwards through the mesh. The laws of physics dictate that the first bubble will always form at the largest pore of the mesh. Once this bubble detaches itself from the upper side of the mesh, the pressure in the chamber underneath the mesh drops. The highest pressure value measured just before the bubble appears is called the bubble point pressure. This value along with the surface tension and the wetting angle of contact can be used to calculate the diameter of the largest pore in the mesh. However, the value determined is only valid for round pores, and these do not occur in woven wire meshes, which characteristically have a wide range of different pore geometries. For this reason, at this point the so-called capillary correction factor C is additionally taken into the calculation to determine the maximum pore size through the bubble point test. But because this correction factor varies according to the specific geometry and size of the pores, it has to be empirically determined for each individual pore geometry in order to provide a correct definition of the maximum pore diameter. In practice, this was previously done by means of screenings and numerous lab measurements.

Precise capillary correction factors for woven mesh pores

In search of a way to replace this time-consuming and at the same time uncertain process for determining the capillary correction factors for the complex pores of woven filter media, GKD developed a multiphase simulation model using the "volume of fluid (VOF) method". This implies that the form of the computational grid is of crucial significance for the accurate reconstruction of the phase interface. As the basis for its numerical simulation of the bubble point test, GKD used the mesh types models that have been stored over the years in its simulation software GeoDict. GKD exported these virtually generated 3D models into further CFD tools, where it then created an appropriate computational grid. Thanks to this multiphase simulation model – an in-house development - GKD now gets a stable value for the correction factor constants immediately. As is also the case with experimental screening, this value via simulation has to be determined for each different mesh type and not just for each different weave type. With the correction factor value determined in this way and the measured bubble point pressure, GKD can calculate the largest pore size very precisely. For all of its standard weave types – square meshes, optimised dutch weaves (ODW), twilled dutch weaves and reverse dutch weaves – GKD has already determined the capillary pressure constants for each mesh type using the simulation. This means that the company can now calculate the size of the largest pore – in a matter of seconds and with extreme precision – on the basis of the numerically simulated bubble point test. Apart from the significant savings in time and money through being able to dispense with the physical screening test, the diameter of the largest pore determined with this new method is, in fact, considerably more accurate than is the case with the conventional bubble point test. For example, a bubble point test of a dutch weave mesh using the PSM 165 – Capillary Flow Porometer from the company Topas and the capillary pressure constant specified by this supplier determined the size of the largest pore as 12.5 µm. In contrast, using GKD's numerically determined capillary pressure constant, the largest pore diameter came out as 7.86 µm. The reference measurement via screening and sizing with the Beckmann Coulter – MultiSizer 4 returned a value for the largest pore diameter of 8.00 µm.

Deviations from the screening test in the range of mere tenths of a micron

To validate the results of the numerical simulation, GKD conducted comprehensive reference measurements. A total of ten measurements were conducted for each of three different mesh types. The thirty models were calculated in parallel. This verified that the method was applicable to every mesh geometry. The validity of the reference value was verified through ten measurements for each mesh type. Their respective averages were taken as reference values. The simulation results are almost identical to the results determined through physical experimentation. However, the numerically calculated pressure values are always slightly higher than those established in the laboratory. The reason for this lies in the perfect geometric structure of the mesh model generated with the GeoDict Software Suite. Experience shows that real pores are minimally larger due to wire tolerances and the weaving process, which is why the pressure values measured in the bubble point test are correspondingly lower. Even so, the deviation between pore diameters determined experimentally and those calculated geometrically are in the range of mere tenths of a micron. Simulation of bubble point pressure and numerical calculation of the capillary correction constant are a significant breakthrough for GKD, not only terms of quality control during production runs but also for its mesh development processes. The precision that has now become possible in fulfilling bubble point specifications gives customers the solid guarantee that GKD filter media comply with the tightest of performance parameters and thus really do make a significant contribution to the requisite efficiency of demanding filtration processes.

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GKD – GEBR. KUFFERATH AG

The owner-run technical weaver GKD – GEBR. KUFFERATH AG is the global market leader for metal and plastic woven solutions as well as transparent media facades. Under the umbrella of GKD – WORLD WIDE WEAVE the company combines three independent business units: SOLID WEAVE (industrial meshes), WEAVE IN MOTION (process belt meshes) and CREATIVE WEAVE (architectural meshes). With its six plants – including the headquarters in Germany and other facilities in the US, South Africa, China, India and Chile – as well as its branches in France, Great Britain, Spain, Dubai, Qatar and worldwide representatives, GKD is never far from its customers.

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