Process filters:

What's new in process filtration?

In the last of his 2009 series of articles covering progress in a number of broad classes of filtration and other separation equipment types, Ken Sutherland looks at developments in the equipment used for solids recovery by filtration – the process filters.

The first five parts in this series of six articles have dealt with subjects other than filtration (i.e. sedimentation), or with filtration equipment that is primarily concerned with removing small quantities of suspended solids in order to produce as pure a fluid as possible – the clarification function. However, there is another wide range of filtration equipment types – some would say the only real filters – whose purpose it is to remove high concentrations of suspended solids. This process is termed solids recovery, or harvesting, and the complete range of equipment has been given the name 'process filters'.

Solids recovery is usually employed to separate a valuable solid, which has been produced in a previous process step, from its carrying, or 'mother', liquor. It should not be forgotten, however, that many manufacturing processes produce wastes as slurries or sludges, from which the solids must be removed for recycling or disposal. Harvesting is usually required to recover the valuable material from suspension, and needs to effect this recovery of the solids as free from the suspending fluid as possible, while at the same time losing as little fine solid in the filtrate as can be achieved – because this would represent a production loss.

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There are more different types of filter employed for solids recovery than for any other purpose, and the main reason for this large number is because of the difficulties encountered in removing the recovered solids from inside the filter – solids handling is almost always more difficult than fluid movement. Despite this variety of filter type, the totality of solids harvesting equipment is the smaller component of the filtration and sedimentation market, holding just over 30% of the total, compared with just under 70% for clarification duties.

[It should be noted that the term 'process filter' is being used in this review in a somewhat narrower definition from that which casts it as the opposite to 'utility filter'. In the latter case it refers to all filters that have a key position on a process production line, and without which production would stop – this means that many clarification filters would be included within the broader definition as well as solid recovery designs.]

The relevance of this discussion comes from the realisation that almost all gas filtration applications are clarifying duties, with relatively low levels of suspended material (where there are high levels, these are usually separated by cyclones rather than filters). Almost all harvesting duties are liquid-phase operations, mainly being process applications.

This leads into an important feature of much of the filtration industry: the importance to it of applications technology. Almost all equipment sold into the process industries has to have a guarantee of performance, requiring the supplier to possess the necessary degree of technological competence to enable it to demonstrate this performance or substantiate a guarantee. One other way in which the industry may be segmented is thus between the technology-rich suppliers and those providing standard catalogue items. At one extreme would be the maker of large filter belt presses, which are usually built for a particular application, and at the other would be the supplier of in-line strainers (for which, of course, operating performance will be just as important, but the onus for success lies more with the purchaser than with the supplier).

Range of equipment

The types of equipment that are, in principle, being covered here are:

- screens, as used for dewatering and classification;
- gravity and vacuum driven roll (flat bed) filters;
- batch and continuous vacuum filters;
- pressure vessel filters (i.e. filters consisting of a set of filter elements or a filter structure contained in a pressurised vessel);
- filter presses, covering all variations of the simple plate and frame press, including the tower press; and
- variable volume filters, such as the tube press.

The filter press has long been used for final clarification of product liquids in the beverage sector.

Many, if not most, of these different filter designs have been in use for a very long time, and an engineer practising in the 1930s would probably have no difficulty in recognising examples of them in a modern day works. The companies that produce them have suffered from the same economic rigours as for other types of equipment, and have been subjected to the same merger and acquisition pressures. Nevertheless, many of these companies have survived, even if under different ownership, and a lot of the equipment still exists with proprietor's names intact.

Recent corporate changes that have occurred include:

- the purchase of Amafilter by the Mahle group;
- the move of Dorr Oliver and Eimco to FLSmidth;
- the sale of Niagara Screen Products to Clarcor;
- the disposal of USFilter by Veolia (to Siemens);
- the purchase of the filter business of Outokumpu (including Hoesch and Pannevis) by Larox;
- the sale by Baker Hughes of the Bird/KHD filter and centrifuge businesses to Andritz;
- the purchase of the Groupe Aoustin companies (Filtres Philippe and Filtres Vernay) by Dover Resources; and
- the purchase of Rosenmund (including Guédu) by de Dietrich.

Cake filtration

It has already been said that the complexity of the process filter is very largely caused by the need to remove the collected solids, which usually build up as a cake on the upstream surface of the filter medium. The cake, indeed, provides the effective filter medium for most of the filtration cycle. Most clarification filters operate with very thin, if any cake, so that their performance can usually be characterised by the properties of the filter medium – recovery filters have the additional and less predictable factor of the cake resistance to consider.

The way in which the cake forms, builds up during filtration, and then is removed from the filter medium dictates the design of the equipment and its efficiency in operation. The cycle of operation may include cake washing stages, with filtrate drainage between stages of washing, followed by the most thorough deliquoring of the cake that is possible within the economics of cake production.

Once the cake is adequately washed and drained, it has to be removed from the filter, preferably with as little damage to the accumulated material and the filter internals, including the medium, as possible. The plate-and-frame press, the tower press, the belt press or filter, the rotary drum filter – these are all types of equipment that have been developed to deal with the filter cake problem.

Recent developments

As has already been implied, the changes in the various types of process filter have not been such as completely to change the equipment format, the developments coming instead from relatively minor mechanical improvements. The most obvious of these changes has been in the type of filter medium used. From the

earliest process filters, using wire mesh, woven cloth and simple felts, with quite good results, filtration efficiency and filter media life have both increased as media became available. First, as needlepunched felts, then as simple polymeric nonwoven fleeces such as spunbonds (with the ever-expanding varieties of available polymer), then the more complex nonwovens, and now even microfiltration membranes. Quite early on, rudimentary composite media became available, first as coated materials, and now with multi-layer materials. The arrival of each new filter medium material gave an aging process filter a shot in the arm in terms of possible performance – and to some extent slowed down the machinery improvements that might have come without the media improvements.

That said, it should not be assumed that the older materials are no longer used. For example, the Forty-X disc filter, comparatively recently introduced to the water treatment business by Siemens, employs a pleated woven fabric as its filter medium with some considerable success.

As well as the general improvements in filtration performance brought about by better filter media, there has been a general improvement in energy efficiency, especially among the larger equipment, such as belt filters and filter presses.

Among the items in the earlier list of process filter types some have changed but little over the last few decades, with some of the more noteworthy changes being mentioned in what follows. For example, the flat-bed (roll) filters, which are the workhorses for clarification of the machine tool coolant recycle system, have been little changed in basic form, but are becoming more sophisticated, increasingly using vacuum, rather than just gravity as driving force. They are rapidly converting from paper media to synthetic materials, such as spunbonds.

The filter press is almost as old as filtration itself, and still exists in its basic form as the sheet filter, used for final clarification of product liquids in the beverage sector. The major changes in filter press design are now well established – from simple plate-and-frame construction to the single module of the recessed or chamber plate, and to the diaphragm plate (often confusingly termed a membrane plate) in which an impermeable but flexible diaphragm is used to squeeze extra liquor out of the cake – although only from compressible cakes, of course. Nevertheless, into this stable situation, manufacturers are still finding that improvements are possible. Thus, Larox has recently introduced a new range of Hoesch filter presses, which basically have a modular design, with a set of standardised options, further developed by means of a fast opening mechanism coupled with a higher standard of sealing around larger ports.

Given the long history of filter press design, it is surprising to find that the problems inherent in the original design are still present, to a greater or lesser extent. These include the difficulty of sealing at the edges of the plates, with consequent leakage of slurry or filtrate; the problems of cake discharge, batch operation with various degrees of automation, and difficulty of adequate cake washing and dewatering. They also handle partial fills (from the end of a process batch) with difficulty. Poor cake removal leads on to problems with the next batch of uneven filling and channeling. The problem of excess weight on the support beams resulting from attempts to make larger presses with more plates has at least been reduced by the use of all plastic materials. These disadvantages have to be balanced by the ability of the filter press to cram quite large filtration areas into a relatively small footprint.

Two Forty-X disc filters were retrofitted to a wastewater facility in New Zealand to increase plant capacity. Image courtesy of Siemens Water Technologies.

The range of pressure vessel filters is typified by the multiple candle design, with hanging tubular elements or flat leaves, or filters with horizontal plates, but a more interesting group of pressure filters is the rotary drum filter enclosed in a pressure vessel. This is an extremely complex engineering task, especially the continuous transfer of separated solids out through the shell – but successful designs from, for example, BHS-Sonthofen and Bokela have shown the value of the enclosed design.

The belt filter press is a continuous device that squeezes the feed slurry, after an initial period of drainage, and can take a feed suspension of down to 1% solids up to a discharged cake of 35%. It does this by mechanical pressure of rollers as the belt sandwich passes between them. As a result it is a fairly high energy user, and modern designs have concentrated in increasing the energy efficiency.

Batch vacuum filters, among the most traditional items in the separation equipment range, have seen little real change, apart from the increasing sophistication of the batch nutsche filters so common in the fine chemicals and pharmaceuticals sector. The well-established leaf and plate filters, with flat elements hanging from, or supported on, a vacuum manifold, look much as they ever did, but all have benefited from the changes in filter media.

As far as continuous vacuum filters are concerned, there are two main types: the rotating drum or disc, and the horizontal belt. The rotating vacuum filters have been little changed over the last few decades, although Siemens is making claims to a significant improvement in performance with its Forty-X disc filter because of its ability to use pleated filter media on its discs, thereby increasing the filtration area for a given equipment footprint (by some 40%). A different mechanism entirely operates in the Ceramec capillary action disc filters supplied by Larox.

The horizontal belt vacuum filters have been quite noticeably improved in design, as well as in performance, in recent years. Better performance has resulted in part from the ability of the manufacturers to fit wider and longer filtration belts (which can then be replaced much more easily than on older designs), from wire mesh support structures and nonwoven media. An important development here has been to make the vacuum belt filters gas tight, as in the Pannevis GT design, so that they can process solvent-based suspensions without releasing VOCs into the atmosphere – a major operating worry in the modern day. ●

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