

Production of CO₂-blown flexible slabstock

Slots or screens – that is the question

The extent to which liquid CO₂ is used as a physical blowing agent in the production of low-density flexible slabstock has been growing steadily over the last few years. There is one essential difference between the various slabstock manufacturing methods that are available on the market today. That is the design of the mixture dispensing system, i.e. the device that stress-relieves and controls the CO₂-polyurethane mixture on discharge.

In practice, we distinguish between two types of design. One method to relieve the reaction mixture's pressure is to dispense it through an extension slot. The other design is based on a so-called "screen pack", i.e. a series of screens through which the mixture passes, which too means that the pressure is reduced.

Hennecke GmbH, the leading supplier of slabstock production technologies, uses a specially developed screen-type **creamer** in its NovaFlex[®] and NovaFlex[®]-MultiFill technology. This patented creamer has actually had a decisive impact on the world-wide success of NovaFlex[®] because of the fine, uniform pore structure of the foams produced (see typographic box).

What is the difference between NovaFlex[®] and NovaFlex[®]-MultiFill technology?

NovaFlex[®] is an environmentally compatible process for manufacturing low-density flexible slabstock on the basis of liquid CO₂ as physical blowing agent as an alternative to CFCs or methylene chloride.

Foams with more than 6 parts by weight of CO₂ and with densities below 14 kg/m³ can be produced with NovaFlex[®]. Liquid CO₂ can nowadays also be added in low concentrations to make foams with far higher densities. CO₂ gives foams a pleasant, soft touch.

Hennecke and Bayer had launched NovaFlex[®] technology in 1995. Only six years later, the September issue "K-Magazine" plastics journal stated that NovaFlex[®] had "since become an industrial standard" because 75 production lines had been sold until then. By now, 90 production lines of this type are in operation worldwide.

The latest further development of NovaFlex[®] is **NovaFlex[®] MultiFill**. This technology can be used for processing functional fillers, such as melamine or calcium carbonate, together with liquid CO₂ as physical blowing agent. This method combines the advantages of the NovaFlex[®]

technology with a polyol-powder mix production method developed by Hennecke. It is for example possible to use this process to make flame-retarding foams with a density of 21 kg/m³ containing 30 parts by weight of melamine powder in relation to the polyol component. NovaFlex® MultiFill technology was launched in 2001.

Which criteria does the dispensing unit have to meet to use liquid CO₂ as a physical blowing agent?

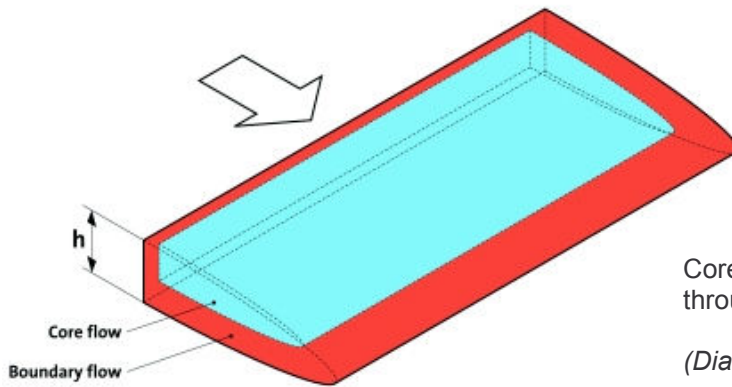
The dispensing unit actually plays a decisive role because CO₂, which is dissolved in the reaction mixture, must be reduced from solution pressure to atmospheric pressure.

Pressure relief and reaction-mixture dispense at a moderate speed must take place within a matter of only a few split-seconds because the rapidly expanding creamy mixture is sensitive to mechanical stresses even at this early stage. During pressure relief, the mixture expands rapidly to well over ten times its original volume. Purpose of the dispensing unit is to control this almost explosion-like volume increase in such a way that the outcome is a fine-celled foam with a uniform cell structure.

Nucleation is responsible for cell formation and therefore also for the final cell structure. In this context, it is a release of ultra-fine gas bubbles in the liquid. Nucleation is the result of an abrupt solution-pressure drop in combination with high shear velocities. Sufficiently high shear velocities are generated in the boundary layers when the liquid passes through tight holes or slots. Shear velocities at the core of the flow are on the other hand low, which means that there is practically no nucleation.

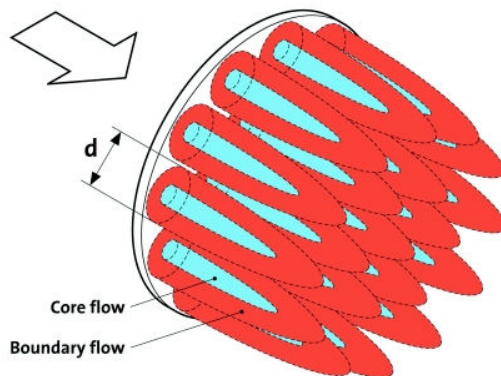
When solution pressure drops, it is important to achieve a high-percentage of **boundary layer flow** in relation to **core flow** to ensure a sufficiently high nucleus density and in turn optimum nucleation. Equally critical is how the zones with high and low shear velocities are distributed. Only when these zones are uniformly and homogeneously spread within the stream, nucleation on the whole will also be uniform and homogeneous. A screen, which splits the stream into a multitude of individual jets, has therefore major advantages in comparison to a single slot.

Firstly, in screen perforation the ratio of volume to area is twice that of a slot, which means that there is more boundary layer flow than core flow and therefore also a higher overall nucleus density. Furthermore, the core flows with low shear velocities are each fully enclosed by boundary layer flows with high shear velocities. A slot on the other hand produces only one core-flow continuum at the centre. This means that screens result in a much more uniform and homogeneous distribution of zones with high and low nucleus densities. Cell formation is therefore considerably more homogeneous



Core and boundary layer flow through slots

(Diagram: Hennecke GmbH)



Core and boundary layer flow through screens

(Diagram: Hennecke GmbH)

Another drawback of slots is that the reaction mixture has to be distributed across the entire width of the slot before pressure relief takes place. As a result, the reaction mixture will already have major **age differences** by the time it enters the relief zone. Depending on design, there may be either dead zones in the peripheral areas or different velocities at slot centre and periphery. However, both foam age and flow velocity have an impact on the crucial cell-formation phase and early cell growth. Ideally, the reaction mixture has a consistent age during nucleation and flow velocities are as homogeneous as possible.

In comparison, a dispensing unit with a screen pack that splits the flow into a multitude of individual jets can be designed as a round and compact unit. Problems described above will therefore be eliminated.

Another important criterion with regard to the dispensing unit's design is its **filler compatibility**. Generally applicable to both screen and slot designs is the fact that the size of the openings is not freely selectable because not only must an abrupt pressure drop be feasible at moderate velocities but also the necessary shear velocities should be achieved. For this reason, the process – both screen and slot designs – is limited to openings no greater than 0.5 mm, particularly when the CO₂ content is relatively high.

Screens in general tolerate slightly larger openings than slots. The reason for this is firstly that the zones with high and low shear velocities are better distributed. Secondly, **pressure relief** will be much faster in individual compact jets than in flat jets given the same velocity and same

slot depth. The pressure drop in round apertures is more than two and a half times faster in comparison to slots with the same width.

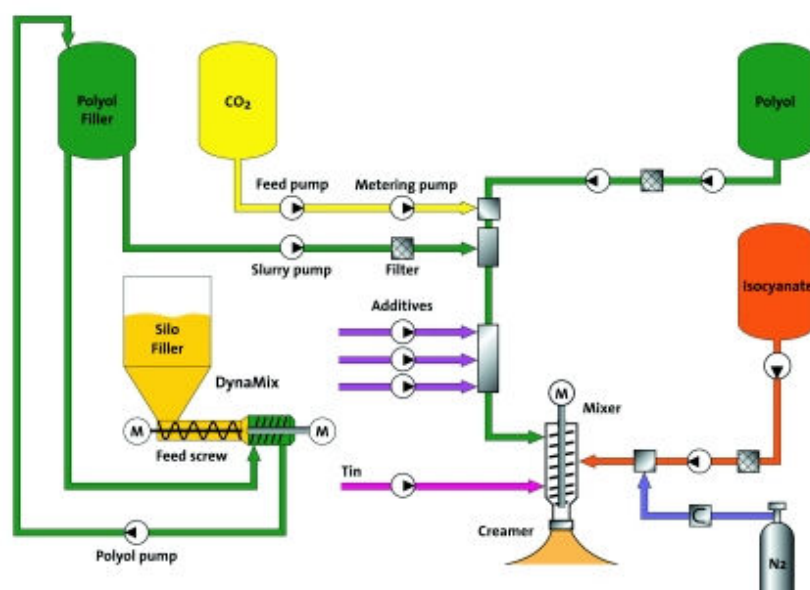
Screens therefore do not only support nucleation because foams containing fillers are particularly sensitive, but they also diminish the risk of clogging to a considerable extent. This applies especially to "wedge particles" that may get stuck in the perforations because they have the same size as the apertures. Suitable mix preparation is however important for both dispensing-unit designs to ensure that the small apertures in the relief zone will not get clogged. This is particularly significant in operations that last several hours. Hennecke's NovaFlex® MultiFill technology proves that this is by no means an unsolvable problem.

Filler metering – how does NovaFlex® MultiFill do it?

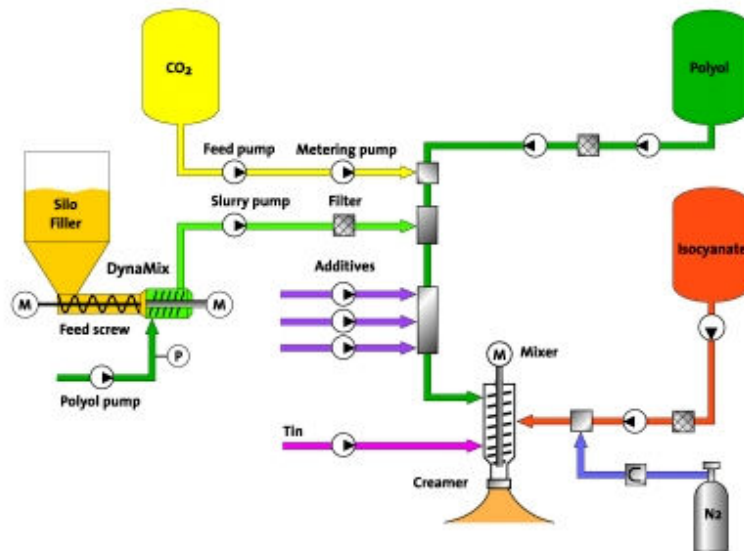
Fillers can be metered either in batches or in an online process. **Batch processing** means that fillers are blended into polyol and the resultant suspension will then be conditioned in a separate batch tank for further processing.

Online filler processing is another alternative. Here, a filler is blended with polyol on the basis of the patented differential-flow metering principle. A defined quantity is continuously metered from the polyol tank into a pre-mixer. A downstream mixture pump is set to a higher volumetric feed rate per unit of time. The differential flow between both pumps is made up by a certain percentage of filler material, which will be supplied by a feed screw. The result is a polyol-filler mixture that will be metered straight into the main polyol flow.

The decision on which of the two processing methods is more suitable for a manufacturer depends on local production conditions and the individual requirement profile. However, no matter which of the two processes will be used, foams will still have the same high quality.



Filler metering – batch principle (Diagram: Hennecke GmbH)



Online filler metering based on the differential-flow metering principle
(Diagram: Hennecke GmbH)

How is agglomerate-free filler feed ensured?

When fillers are processed with CO₂ technology, it is particularly important that they enter the liquid phase without agglomeration. This prevents blockages in the creamer and so-called "weak links" in the foam structure caused by insufficient wetting.

In both batch and online processing, polyol and filler will be homogenized in a special mixer, the so-called **DynaMix**. This ensures the formation of an agglomerate-free dispersion and optimum incorporation of the filler in the PU matrix. In the NovaFlex[®] MultiFill process, melamine and calcium carbonate up to a particle size of 100 µm can be processed in this way without problems. Work is currently underway to facilitate the addition of other fillers too.

Sophisticated technology

The large number of NovaFlex[®] production lines that have been sold to date and that are successfully in operation actually explains why the use of liquid CO₂ as a physical blowing agent is growing on a world-wide scale. It also demonstrates how CO₂ technology has been fully mastered with Hennecke's patented creamer.

NovaFlex[®] MultiFill production lines have been field-proven in everyday production routines. They are used for making flexible slabstock with filler-contents. The foams produced for the upholstered furniture and automotive industries have the renowned NovaFlex[®] quality. In practice, both the batch and the online process are used for adding fillers.

Advantages of Hennecke's patented creamer

Modular design

The creamer assembly group is put together on the basis of a modular principle. It means that a range of components with different geometries is available to get the right combination for almost every application. Key parameters such as the pressure-reduction profile and flow velocities can be influenced in a selective way. The modular principle also permits flexible and precise adaptation to very different formulations (CO₂ percentage and outputs) as well as the use of different fillers.

Simple handling

The creamer and its components are easy to fit, remove and clean. This means that the same equipment can be employed over long periods, which is essential for accurate process reproducibility and high production reliability.

Compact design

The creamer's compact round design ensures that the mixture has an absolutely homogeneous dwell-time distribution when it exits the creamer. This in addition to good nucleation forms ideal conditions for a uniform expansion of the reaction mixture, particularly in the early stages of cell growth.

Excellent, uniform pore structure

Foams produced on the basis of NovaFlex[®] or NovaFlex[®] MultiFill are renowned for their excellent pore structure, which is quite often superior to that of conventionally produced foams.

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