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High-volume kneading reactors

For thermal processes with extended retention times

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Today's manufacturers are calling for processes that are environmentally sound, energy efficient and yield products of high, consistent quality. These demands are causing a shift away from traditional stirred-vessel technology - towards processes that work with high concentrations. As a result, product rheology requires the use of special processing equipment capable of achieving the necessary heat and material transfer by means of intensive mixing and kneading.

The process equipment used has to provide:
- an excellent mixing and kneading effect in all phases (liquid, high viscosity, solid),
- avoidance of stagnant product zones,
- precise temperature control,
- mechanical robustness; i.e. ability to handle the very highest viscosities (to the point of transition to the solid),
- extended retention times,
- closed contained construction for pressurized or vacuum operation,
- models for both batch and continuous operation.

For many years, processes like these have been carried out with paddle dryers, Sigma-blade mixers and variants thereof. DISCOTHERM B kneader/dryers and dual-shaft AP mixing/kneading reactors have also performed well in this market segment. None of these processors however have been capable of meeting all the above requirements satisfactorily. The DISCOTHERM B, for example, provides excellent self-purging of its heating surfaces but leaves something to be desired in terms of mixing/kneading efficiency and the processing of ultra-viscous products. AP reactors, on the other hand, provide the necessary mixing and kneading intensity but do not guarantee complete self-purging.

Now, however, two new processors have been developed that fulfil all of the above requirements and open up new process optimization possibilities. They are the ORP and the CRP (Co-Rotating Processor).

Operating principle

The LIST dual-shaft processors ORP and CRP are large-volume, continuous or batch mixing/kneading reactors for thermal processes involving highly viscous or pasty products and solids that pass through a sticky, encrusting phase during processing.

Two inter-meshing agitators mounted parallel to each other rotate in a horizontal housing with a figure of eight cross-section.

Both the main and cleaning agitators are equipped with radially mounted, heatable or coolable plates with U-shaped mixing/kneading bars welded to their peripheries. The kinematic motion, form, and position of the mixing/kneading bars are selected in such a way that each totally cleans the other shaft's core, plates, and mixing/kneading bars as they inter-mesh. At the same time an intensive mixing and kneading effect is produced. The flow patterns and self-cleaning effect are illustrated in the following sectional drawings (Fig. 1 and 2.).

The two agitators turn at different speeds in both processors. In the ORP they rotate in opposite directions, but in the CRP they co-rotate. These differences make it possible to meet the widely varying kneading requirements encountered with different products.

The intensive lateral mixing effect is largely independent of the axial conveying of the product. Because the processors are opera-

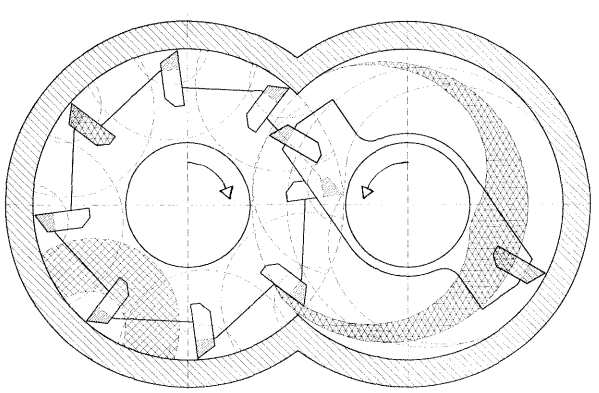

Fig. 1 Flow pattern and self-cleaning effect in ORP

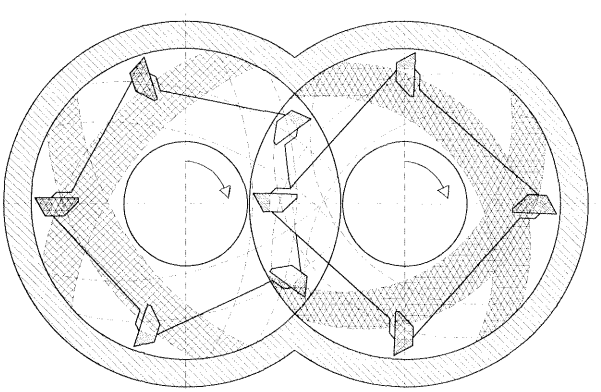

Fig. 2 Flow pattern and self-cleaning effect in CRP

Tab. 1
Processor characteristics

ORP	CRP
counter-rotating agitator shafts	co-rotating agitator shafts
typical speed ratio 1:4 self-cleaning of the agitator shafts	typical speed ratio 4:5 excellent self-cleaning of the agitator shafts
intensive mixing and kneading effect with powerful compression-tension stressing and plastification effect	intensive mixing and kneading effect with powerful shear stressing of the product

ted in the 40 to 75% fill level range, large quantities of gases or vapours can be readily disengaged and withdrawn.

General features

The processors provide very intensive mixing and kneading effect in all phases (liquid, pasty, highly viscous, encrusting and free flowing). The mechanical processing of the product can be adapted optimally to particular requirements by selecting either the counterrotating ORP or the co-rotating CRP to achieve anything from compression tension action to pure shear stressing.

A continuous intensive renewal of the phase boundary layers enhances both mass and heat transfer.

Effective self-purging of contact surfaces eliminates „dead spots" and provides open passages for gas at all times.

Large heat exchange surfaces permit precise temperature control in the case of processes with limiting heat tolerances.

Large useful volumes together with filling levels of 60-75 % permit high throughputs, even for processes requiring long retention times.

The combination of very little axial mixing and intensive lateral mixing maintains a narrow retention time distribution. Several agitator geometries can be selected in order to vary the retention time distribution over wide limits.

Large cross-sections facilitate the removal of gases and vapours. This is particularly important for flash evaporation of superheated solutions and for foaming products.

The closed construction permits processes under vacuum or pressure and the handling of toxic or potentially explosive substances.

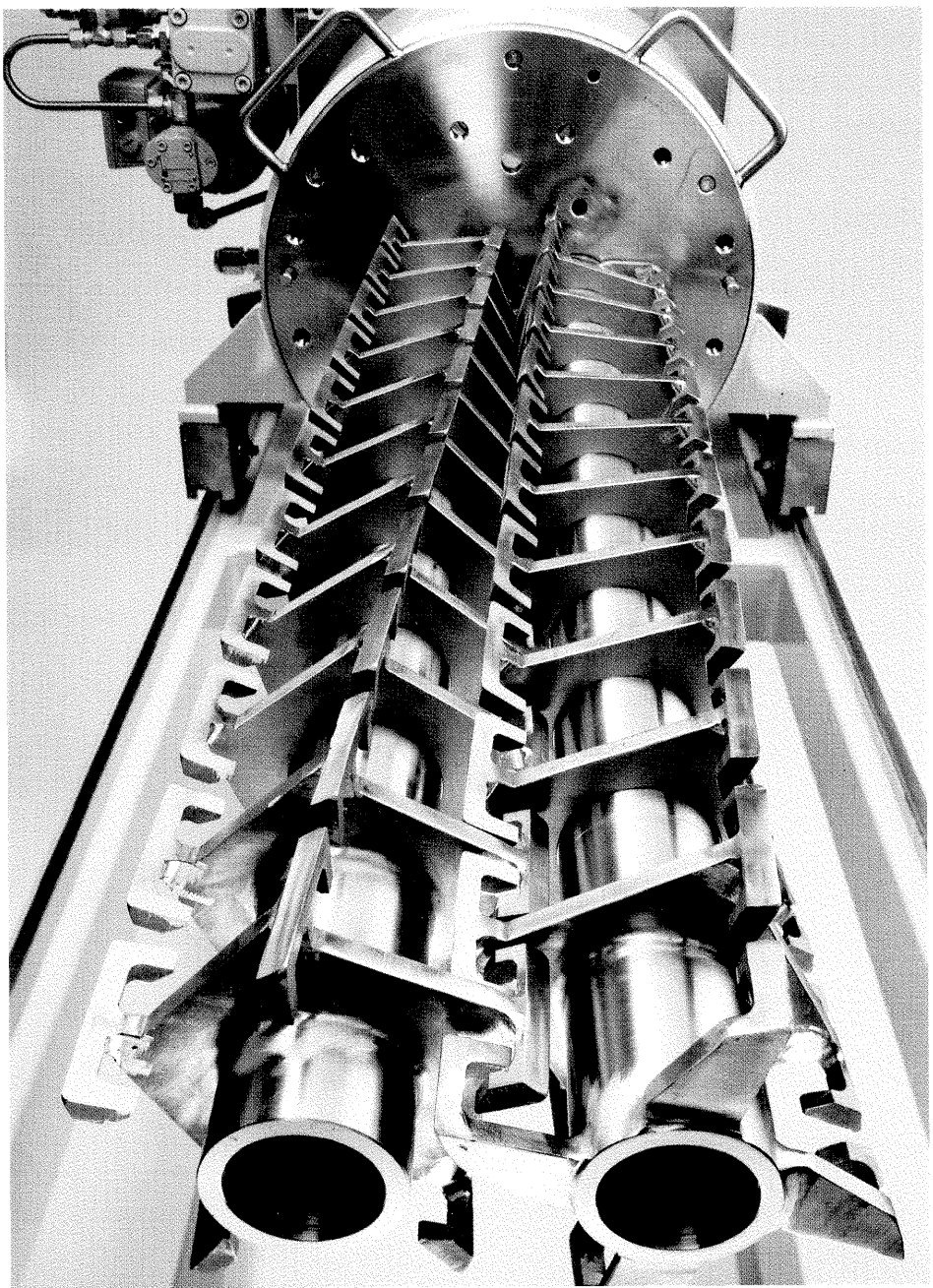

Fig. 3 Agitator shafts of CRP

The use of different agitator geometries allows adaptation of the operating principle to either continuous or batch operation.

Because the dissipated thermal energy is low in relation to that transmitted by the heat exchange surfaces, precise temperature control is possible even for extremely viscous products.

Table 1 summarises the general features of LIST OPR and CRP kneading reactors.

Technical data

- Processor volume: 20 - 10000 liters.
- Design temperature: up to 350°C.
- Design pressure: 0 - 1000 kPa. abs.
- Heating surface area: 1,2 - 98 m².
- Materials: C-steel and all weldable stainless steels.
- Special sizes: on request.

Fig. 3 illustrates the agitator shafts of CRP.

Applications

Due to their specific features these processors can be applied for a wide variety of applications. The following list gives some typical examples.

- *Baking reactions: e.g. polyacetal resins, sulfanilic acid, polyphosphates.*
Precise temperature control, effective self-purging, and the avoidance of dead spots are crucial to high product quality.

- *Polycondensation: e.g. polyester, polyamide, melamine and urea resins.*
This process calls for repeated surface renewal, particularly in the case of high viscosities >2000 Pas, accurate temperature control, and good self-purging of the product chamber and the agitators to prevent fisheyes in the end product.

- *Solid/liquid reactions and solid/gas reactions with slow reaction kinetics: e.g. ilmenite decomposition, Cuphthalocyanine, ammonium polyphospate.*
Retention times from 10 minutes to several hours with a narrow retention time distribution, outstanding mixing effect, and precise temperature control are the main requirements processors have to meet.

- *Polymerization: e.g. elastomers, silicone rubber, hydrogels.*
These processes call for intensive product movement in combination with large heat exchange surfaces for dissipating reaction heat and good self-cleaning of the parts in contact with the product to avoid dead spots.

- *Concentration and drying: e.g. TDI residue, synthetic rubber.*
Concentration and drying of organic products from solutions, particularly those that do not crystallise. These products are usually very sticky and often pass through an extremely viscous phase. For economic operation, processors have to combine large self-cleaning heat exchange surfaces with good mixing and size reduction effects while applying high agitator torques.