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Laboratory intensive mixer with integrated rheometer and tribometer

The Kniele KKM-RT 15/22.5 combines a laboratory intensive mixer with a rheometer that provides the rheological properties of the mixture in either relative or absolute units. A mixer probe for moisture analysis and a dosing unit for addition of liquid components expands the scope and enables automated parameter studies of mix development.

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Catalogue of requirements for the new laboratory mixer

Mixing volume and material selection

Approximately 5-6 L of fresh concrete must be prepared to carry out classic fresh concrete tests such as slump spread, slump flow measure, VdZ (German Cement Plant Association) funnel, LCPC box, etc. Several more litres of material are required to produce samples for the determination of mechanical properties. However, by setting the maximum fresh concrete volume at 15 L, there is an opportunity to produce the small quantities required in laboratory practice at the same time in a compact, user-friendly mixer. To make mixer cleaning easier and also enable applications beyond concrete technology investigations, the mixer is almost completely made of corrosion-resistant stainless steel.

Overall view of the new KKM-RT 15/22.5 laboratory intensive mixer with integrated rheometer and tribometer

Material discharge and mixer cleaning

With a maximum filling quantity of 15 L, concrete applications result in a mix weighing approx. 35 kg. Even with the light construction of the removable mixing container, the container could only be handled by one person with difficulty. Consequently, the proven cone with the opening at the lower end is used. If the closure flap is opened, almost all of the mixture drops into the previously positioned container under the influence of gravity and can be extracted for further use. When the closure flap is opened, very free-flowing concretes tend to pass through the resulting narrow gap at high speed. By arranging a rubber skirt around the discharge flap, the material is directed into the previously positioned container. This also makes cleaning of the mixer easy and fast. Following discharge of the mixture, the flap is closed, the drum is filled with water and the mixing tools are run at high speed. In the process, the deposits on the mixing tools come off and are carried out with the water when the closure flap is reopened. To limit deposits in the closure flap area, the closure flap deflection mechanism is moved further up and thus outside the contamination area.

Mixing tool

To increase mixing intensity, minor improvements were made to the conical mixer's mixing tool. The disagglomeration of fine materials and the separation of fine fibres will be significantly improved and accelerated with the arrangement of short pins on the outer edges of the mixing paddles. To resist the increased loads, the highly stressed areas were provided with a suitable coating.

Drives and function as a rheometer (relative measured values)

The Kniele KKM conical mixer is characterized by an outer scraper and an inner, centrally-positioned mixing tool. The functions of coarse mixing and supply of the mixture to the inner mixing tool primarily belong to the outer scraper. At the same time, the outer scraper can be operated with variable, but relatively low, tool speeds and reversal of direction. On the other hand, the inner mixing tool only engages part of the mix volume and, moreover, does not reach the walls (large distance to the mixing container walls). This makes it possible to achieve high tool speeds with manageable motor power, without high wear loads due to the jamming of coarse aggregate against the container wall. At 6 m/s, the maximum attainable tool speeds are also reasonable for the production of mortar or concrete and significantly higher than those in classic concrete mixers (maximum approx. 1.5 m/s). While normal concretes with high water content and low additions and admixture content

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can be produced without problems at low tool speeds, the situation changes with more demanding concrete mixing. With a lower quantity of water and larger quantities of additions and admixtures, mixing regimes with (occasional) higher tool speeds lead to noticeably better results. This has less impact on the liquid limit (that is, the slump flow measure), but more upon viscosity, which is relevant for workability. A higher proportion of particle agglomerates are broken up at high tool speeds, which results in lower viscosity of the material. Since the tool speed of the inner mixing tool is variable over a very large range and its direction of rotation can also be reversed, mixing systems that are in use in practice can be reproduced. For operation of the mixer, there are only requirements related to torque and rpm range, which can be easily and cost-effectively covered by conventional asynchronous motor transmission units.

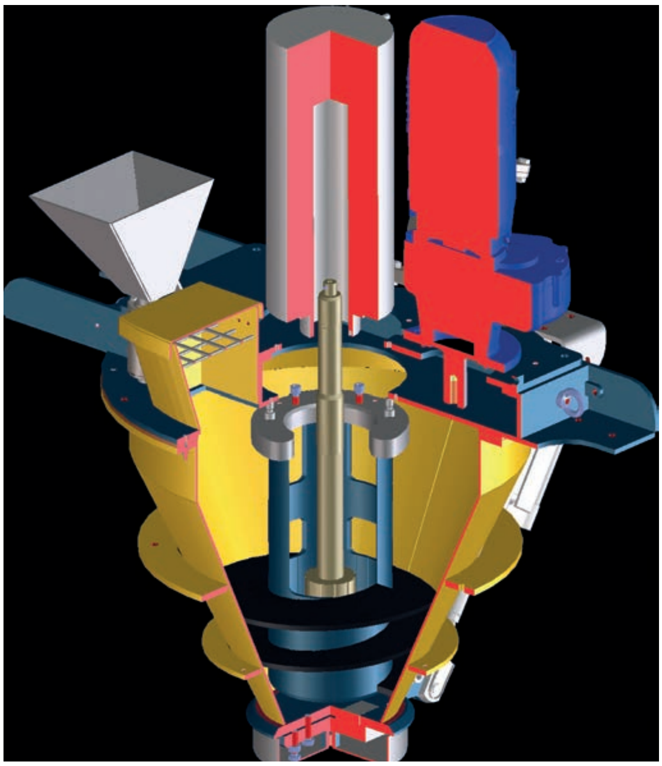
However, in order to carry out additional measurements for rheological evaluation of the mixture at low rpm or torques, a direct drive was implemented using a synchronous high torque drive. In this way, impacts from motor slip and variable losses due to gear reduction are basically excluded. The so-called cantilevered bearing without additional bearings further reduces static and sliding friction. Interaction with a frequency converter that works on the direct torque principle results in a very low-loss drive with significantly higher efficiency than a conventional drive. In addition to speed-controlled operation, this also makes the torque-controlled operation preferred in rheology and oscillating measurements with fast changes of direction possible. Thanks to the frequency converter's very high accuracy in the calculation of torque, a torque sensor can be dispensed with.

The rheological measurements are carried out in accordance with the Searle principle, in which the shear stress is generated by the inner mixing tool and the necessary torque is calculated using the frequency converter. Since neither sheared volume nor sheer areas can be determined precisely, measurements with the mixing tool provide results in the relative units of torque (Nm) and speed (rpm). These results are therefore only meaningful for the particular mixture and fill level and cannot be transferred to other rheometers that work with relative measurement values.

Function as a rheometer for the determination of measurement values in absolute units

In order to calculate the rheological properties in the absolute units Pa and Pa·s, the shear stress must be introduced over defined surfaces. For concrete applications, two coaxial cylinders, between which the material is sheared, have proven themselves. In most cases, the outer cylinder is fixed and the inner cylinder rotates in accordance with a prescribed speed regime. The required torque can then be related to the known shear area and enables calculation in absolute units. For implementation with the laboratory mixer, two fast change systems were developed for the unavoidable and necessary changeover of mixing tools for the coaxial cylinders. The inner fast change system enabled the mounting or removal of tools with a rotary movement. The load carrying connection to the drive is carried out by means of a hydraulic fast clamping sleeve that is activated by a bolt. The outer mixing tool can also be mounted or removed with a rotary movement and is tightly connected to the outer drive by a bolted connection.

The complete upper drive unit can be moved upwards to permit the change of tools at an ergonomically sensible height, immediately after the mixing procedure. The drive unit is then lowered again until the lower base areas of the measurement cylinders sink into the concrete. The inner measurement cylinder then rotates at the prescribed speed and the torque required for this is recorded. Since this involves the portion of torque caused by the bottom surface of the measurement cylinder, it is deducted from the following measurements. Thus, only the torque required for rotation of the cylinder's shell surface is included in the calculations. The drive unit is lowered further and the travel, i.e. the height of the shell surface surrounded by concrete, is determined by data from the travel unit's rotary encoder. The speeds and torques determined during the subsequent rheological measurements can be related to a known shearing area (cylinder diameter and immersion depth h) and issued in absolute units. Three different modes, which can be freely programmed, are available for the actual rheological measurements.



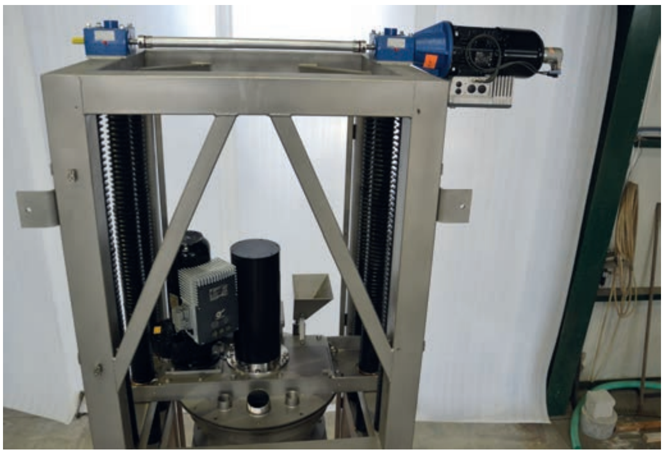
Technical drawing of KKM-RT 15/22.5

Rheological measuring tools and details:

Agitator

Rheometer

Probe installation



Lifting device

1.) In the speed-controlled mode, the speeds of the inner cylinder, are prescribed and the required torques are measured. Using suitable rheological models, the liquid limit and viscosity can be calculated in absolute units from the raw speed, liquid limit and shearing area data.
2.) In the torque-controlled mode, the torque progression is prescribed and the drive speed is recorded. Since the installed drive has a high resolution rotary encoder, the liquid limit can be recognized by an abrupt increase in speed.
3.) With oscillating measurements, a sinus shaped change in rotation direction occurs with increasing amplitude. A selection between torque-controlled operation or a prescribed deflection can also be made in this mode. Thanks to the built-in synchronous direct drive, the drivetrain has the necessary low mass and stiffness. Taking the moment of inertia of the drive train into account, rheological characteristic values can be calculated from these measurements.

However, the measurement systems used in rheology in accordance with, for example, DIN 53019-1 [1], cannot be used for mortar and concretes without adjustments and compromises. On the non-profiled surfaces, due to the formation of an adhesive layer, it would be just that layer that would be sheared and not the filled material. In addition, the surcharge requires a wider gap. That is why fine profiling is also milled into the surface of mixing tools with rheometers for adhesives (e.g. Rheotest RN 4.1). Some rheometers for concrete use rotor assemblies, where the assumption is made that these shear the material cylindrically. However, investigations in accordance with [2] prove that this assumption is not correct. For this reason, both cylindrical measuring tools in the Kniele KKM- RT 15/22.5 were given vertical depressions that prevent slippage without significantly influencing the flow conditions.

Two demixing phenomena must be taken into account in the operation of a rheometer for mortar or concrete. Through sedimentation as a result of gravity, there is a fundamental danger that the surcharges will sink below the measuring tool because of their higher density. Then the measurements do not take place in a homogenous material, but in a partial volume, low in surcharges, with divergent rheological characteristics.

If a rheometer is operated in accordance with the Searle principle (driving the inner tool), a migration of particles to the fringe occurs, depending on their size and density. A pre-shear phase for rheological measurement is absolutely necessary to break down the structure formed in the mixture while at rest. But the pre-shearing may cause demixing and lead to false measurement values during the measurement procedure. Both forms of segregation are reinforced by repeated tests on one charge.

To actively counteract both phenomena, and thus enable repeated measurements on one charge, the outer measuring tool was enhanced with an additional function. A helix was installed on the outer skin surface. This assembly is rotated by the outer scraper's motor gear unit and transports the material from the lower region of the cone to the top, where it is directed into the gap between the measuring tools. This achieves circulation and homogenisation of the mixture inside the cone. Since a relevant mixing effect can be achieved in this way, there is also an opportunity to mix admixtures into the mixture with the required mixing intensity, even with installed measurement tools. The subsequent mixing-in of admixtures and measurement of the changed rheological parameters in absolute units can therefore be carried out in one machine without changing tools.

Function as a tribometer

The KKM-RT 15/22.5 can also be used as a tribometer to determine the pumpability of a concrete from the mixture. High-performance concrete pumps produce flow rates of several m/s in the pump lines. In the process, a thin adhesive layer forms on the inner surface of the pump line and the vibrated concrete glides over it in "plugs". To adjust these boundary conditions in tribological measurements, a cylinder rotates in the mixture with appropriate speed. The essential difference from the rheological measurements is that the cylinder has a roughness similar to the interior surface of the pump line. Here, the glide film formation is brought about intentionally. At a nominal speed of 500 rpm, the high torque drive can also reproduce the conditions of the most powerful concrete pumps.

Mixer probe

To control and check the average water/binder ratio, even when using raw materials with variable inherent moisture, a miniature mixer probe was integrated into the closure flap. The mixer probe also delivers additional information about the mix quality, because fluctuations in the moisture values supplied by the probe decline as a result of increased homogenisation of the liquids and dry substances.

Control

Control is based on a soft PLC and is implemented using a Beckhoff touch panel PC. This makes a proven, robust industrial system available that can integrate components using every relevant bus system. Problem-free data transfer is assured, because Beckhoff uses the Microsoft Windows operating system.

Options: Camera and liquid dosing device

To observe and document the mixing procedure, installation of a mixer camera was taken into account. The camera lens is protected from contamination by a pneumatic pinch valve during addition of dusty dry substances. Display takes place on the touch panel PC that is already in place for operation of the mixer. A further option is a liquid dosing device that enables highly accurate, individually adjustable addition of liquids. If, for example, water is continually added to the dry substances of a mix during the mixing procedure, the ideal quantity of water, which is defined as the transition from granular aggregate material to the granular suspension, can be read from the torque progression. Similarly, the quantity of water can be dosed to a defined torque value, thus making use of the consistency mixer function. If admixtures are dosed, important findings can also be derived here, especially if the rheological measurements are carried out.

Bibliography

[1] DIN 53019-1:2008-09: Viskosimetrie - Messung von Viskositäten und Fließkurven mit Rotationsviskosimetern - Teil 1: Grundlagen und Messgeometrie, Beuth-Verlag

[2] Ovarlez G. et al.: Flows and heterogeneities with a vane tool: MRI measurements. J Rheol, 55 (2011), Seiten 197-223

FURTHER INFORMATION

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