Viscosity measurements with Melt Flow Indexer

Melt Flow Index Tester also called plastometer are used to measure the melt flow rate (MFR) in g/10min and the melt volume rate (MVR) in cm³/10min of pellets, powder or fine granules by using a weight as the constant force. Melt Flow Indexer (Plastometer) are general used to carry out measurements according ISO 1133, ASMT 1238 as well as ASTM D3364. The new viscosity option for Melt Flow Indexer (Plastometer) mi40 is developed to carry out measurements according the standardized measurement with capillary rheometer ISO 11443. Using a capillary rheometer, the measurement is more challenging to operate and time consuming compared to a standardized melt flow index tester (Plastometer). Now using the viscosity option for mi40, running these viscosity tests can be done like normal MVR (Melt Volume Rate) or MFR (Melt Flow Rate) measurements.

mi40 is using an integrated motor to push the piston at a defined speed in the test mode. The resulting pressure is measured with a force transducer in the piston holder. Compared to normal MFR-Measurements, it is possible to reach higher shear rates which are more relevant for actual production processes. Therefore, viscosity test by this GÖTTFERT Melt Flow Indexer (Plastometer) is more like a processability test as a standard Melt Flow Index Test.

Setup of Melt Flow Indexer mi40 with integrated viscosity option

The Viscosity option for Melt Flow Indexer (Plastometer) mi40 covers the followed components:

- Modified motor controller which control the piston speed between 0.1-40 mm/s in 0.1 mm/s steps
- Modified Test piston to meet ISO 11443 measurement standard
- Measurement force of up to 800 N (max. pressure of 110 bar)
- Viscosity die with length 10 mm and a diameter of 1 mm (L/D=10/1 mm)
- Easy to use software extension for viscosity measurements

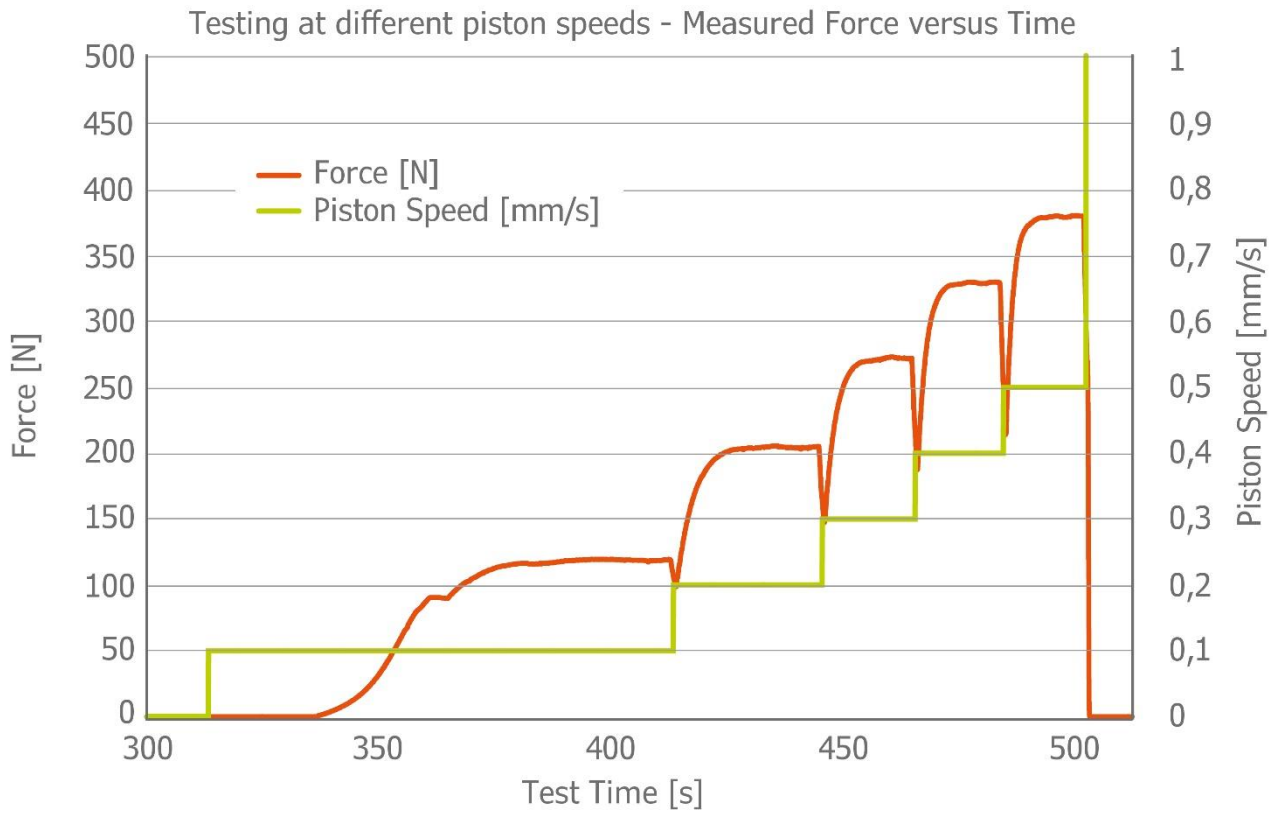
Test procedure

Once established, the actual test procedure is very similar to an MFR/MVR-measurement. The integrated test barrel has to be filled with material (PE, PP etc.) and cleaned after each measurement by the operator. The viscosity measurement itself is carried out by the instrument in a fully automatic mode. Depending on the defined shear rates a test takes between 6 and 15 minutes.

Viscosity Calculation

The apparent shear rate is calculated from the geometry and the piston speed. The apparent shear stress is calculated from the measured force and the test weight. The apparent viscosity is automatically calculated from these two values.

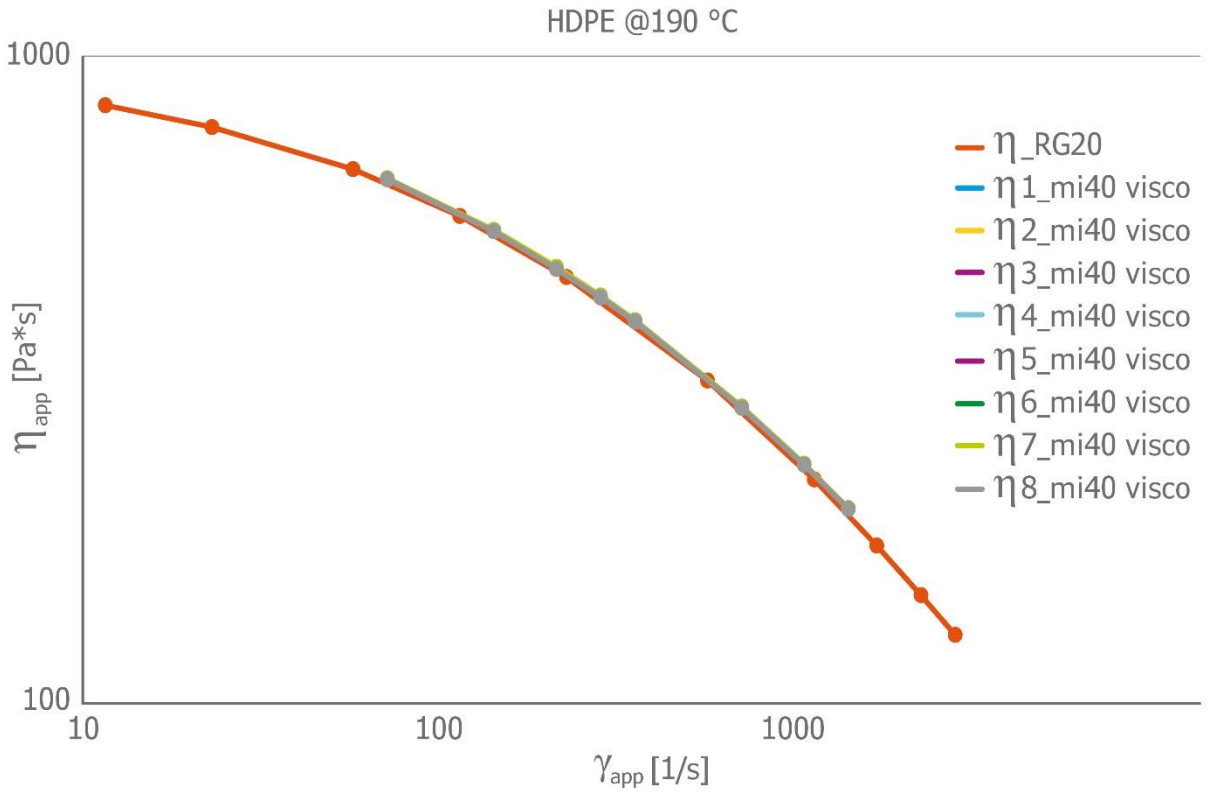
The following graphic shows the real time data recorded during the test. After melting time of 300 s the piston starts to move down with the first velocity which is defined in the test parameter. After the measured force is stable the apparent viscosity of the first step is stored, and the next piston velocity is applied. Up to 10 different apparent shear rates can be measured with one filling of the test barrel.



Application examples:

mi40 visco vs. Capillary Rheometer RG20 with HDPE, MFR (190 °C/2,16 kg) = 9 g/10min

The following graph illustrates a comparison between the apparent viscosity measured with a high-pressure Capillary Rheometer (RG20) equipped with a die L/D=30/1 mm compared with Melt Flow Indexer (Plastometer) mi40 with integrated viscosity option equipped with a die L/D=10/1 mm. The results of eight viscosity measurements carried out by mi40 visco are drawn over each other and show a great reproducibility. The results of mi40 closely demonstrates the results of Capillary Rheometer RG20.
The maximum shear rate is limited by the maximum pressure of 110 bar and the minimum piston speed of 0.1 mm/s. This correlates to a minimum apparent shear rate of 72 1/s with the L/D=10/1 mm die.



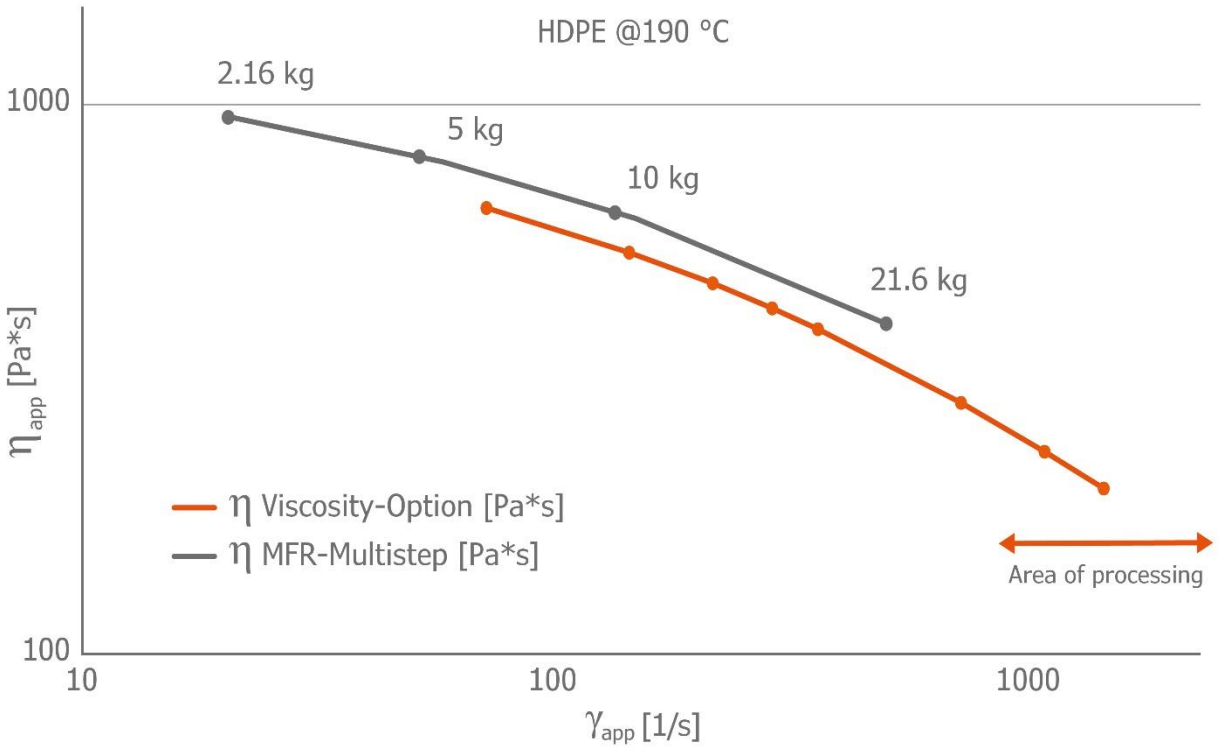
mi40 visco vs. MFR-multi-weight measurements with HDPE, Melt Flow Rate (190 °C/2.16 kg) = 9 g/10min

The following graphic shows a comparison between apparent viscosity recorded with multiple MVR-Multistep tests with a L/D=8/2.095 mm MFR-die in gray and data recorded with the Melt Flow Indexer (Plastometer) mi40 visco using a L/D=10/1 mm viscosity-die in orange.

The apparent viscosities recorded with the shorter MFR-die are slightly higher, because non viscous effects like entrance pressure loss are not corrected. Entrance pressure loss is even more important at shorter dies than longer viscosity-dies.

Additionally, the force of the motor added to the weight of MI-40 makes it possible to reach higher apparent shear rates compared to normal Melt Flow Rate measurements. This enables the opportunity to carry out measurements in the shear rate region that is actually used during production.

HDPE @ 190 °C	Max. apparent shear rate
MFR (2.16 kg) = 9 g/10min	[1/s]
MFR-multistep test	500
mi40 visco	1500



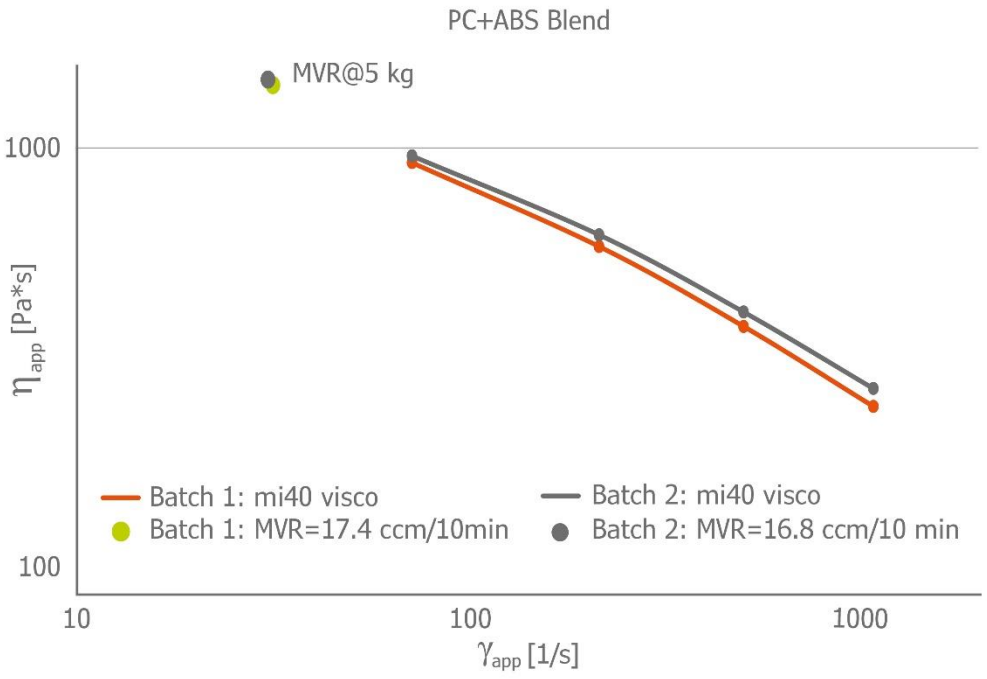
Using the mi40 visco with the L/D=10/1 mm die, is possible to measure materials with an apparent viscosity of 285 Pa*s at apparent shear rate of 1000 1/s. The viscosity at a shear rate of 1000 1/s is quite common quality control criterion and available on a number of spec sheets. For a wide variety of materials, the mi40 visco is able to test at these conditions.

Better selectivity: PC+ABS Blend, MVR (260 °C/5 kg) = 18 ccm/10min

A quite common problem during production is, that different batches of the same material show similar MFR/MVR values, but still behave differently in the actual production process. This can be caused by different shear thinning behavior. While the viscosity at the low shear rates during the MFR/MVR-test mostly correlates with the mean molecular weight, the viscosity at higher shear rates is also influenced by the broadness of the molecular weight distribution. With the mi40 visco it is possible to test materials close to the actual production conditions.

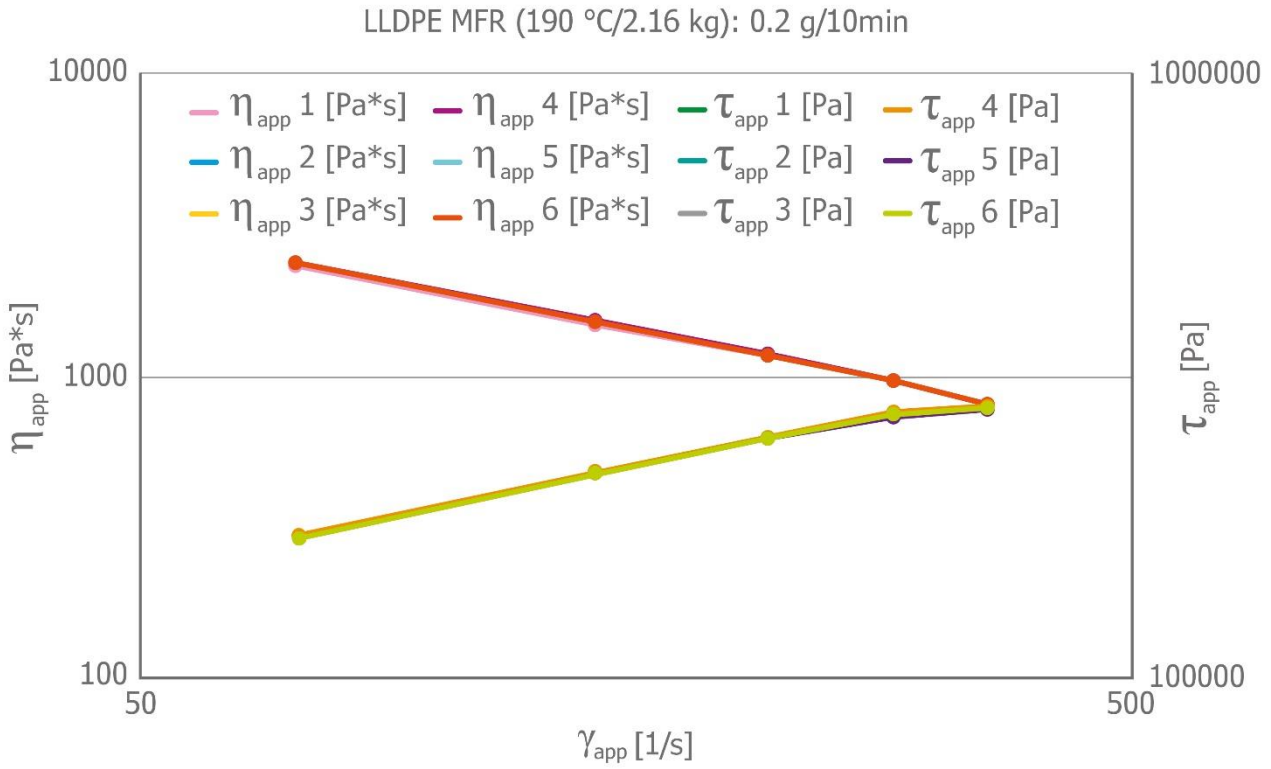
In the following example, batch 1 was fine, while batch 2 creates problems during injection molding. Both MVR values are in spec and only slightly different. With the mi40 visco it is possible to detect the different shear thinning behavior of both batches. The difference in viscosity is more pronounced at the actual shear rates used during the production process.

PC+ABS Blend	MVR (5 kg)	Apparent Viscosity @ app. Shear rate 1080 1/s
260 °C	[ccm/10min]	[Pa*s]
Batch 1	17.4	242
Batch 2	16.8	267
Difference	-3.4 %	+10.3 %



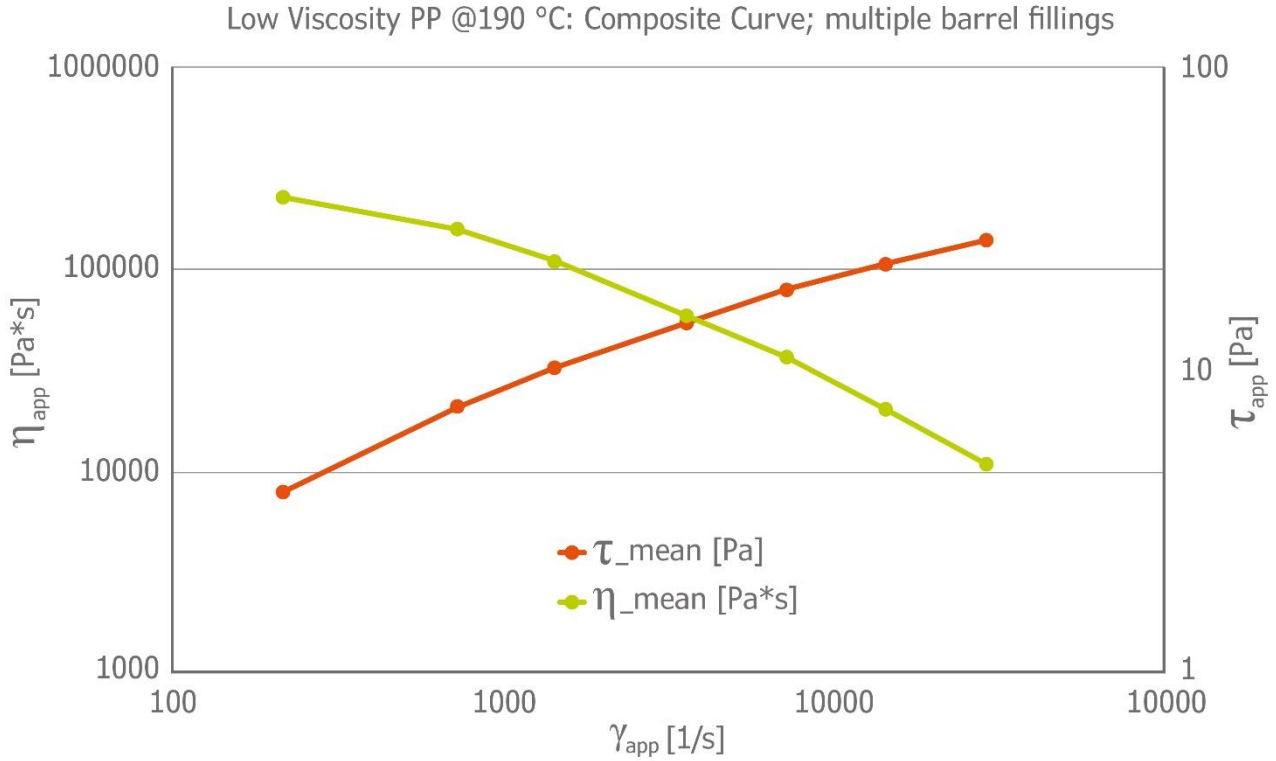
High viscosity material: LLDPE, MFR (190 °C/2.16 kg) = 0,2 g/10min

It is also possible to measure material with very high viscosity. The following LLDPE is usually characterized at the very low shear rates during a standard MFR test (MFR = 0,2 g/10 min correspondents with an apparent shear rate of 0,48 1/s). With the mi40 visco, it is possible to measure at shear rates in the shear thinning region. The maximum possible apparent shear rate with this material is 360 1/s limited by the maximum force of 800 N. The 6 displayed tests show a great reproducibility.



Low viscosity material: PP, MFR (230 °C/2.16 kg) = 800 g/10min

Low viscosity material can be measured over very broad shear rates. The maximum piston speed of 40mm/s results in an apparent shear rate of 28760 1/s using the L/D=10/1mm die. The mi40 visco is well suited to characterize materials like these.



Conclusions

With the new viscosity option, the mi40 visco is transformed into a testing device capable of MFR/MVR measurements according to ISO 1133-1, ISO 1133-2 and ASTM D1238 as well as viscosity measurements according to ISO 11443. The proven ease of operation of the melt-flow indexer is combined with the increased material characterization capabilities of a capillary rheometer. This new option makes it possible to test viscosity as a QC criterion, without a huge investment in time, training or money.

The key advantages of the mi40 visco are:

- Unimpeded functionality as Melt Flow Indexer (Plastometer)
- QC control for processability of plastics
- Fast and easy viscosity measurements according to ISO 11443
- Up to 10 apparent shear rates with one filling of the barrel
- Material characterization at higher, process relevant shear rates
- Viscosity test at the commonly specified apparent shear rate of 1000 1/s
- Lower cost and easier to use than normal capillary rheometers

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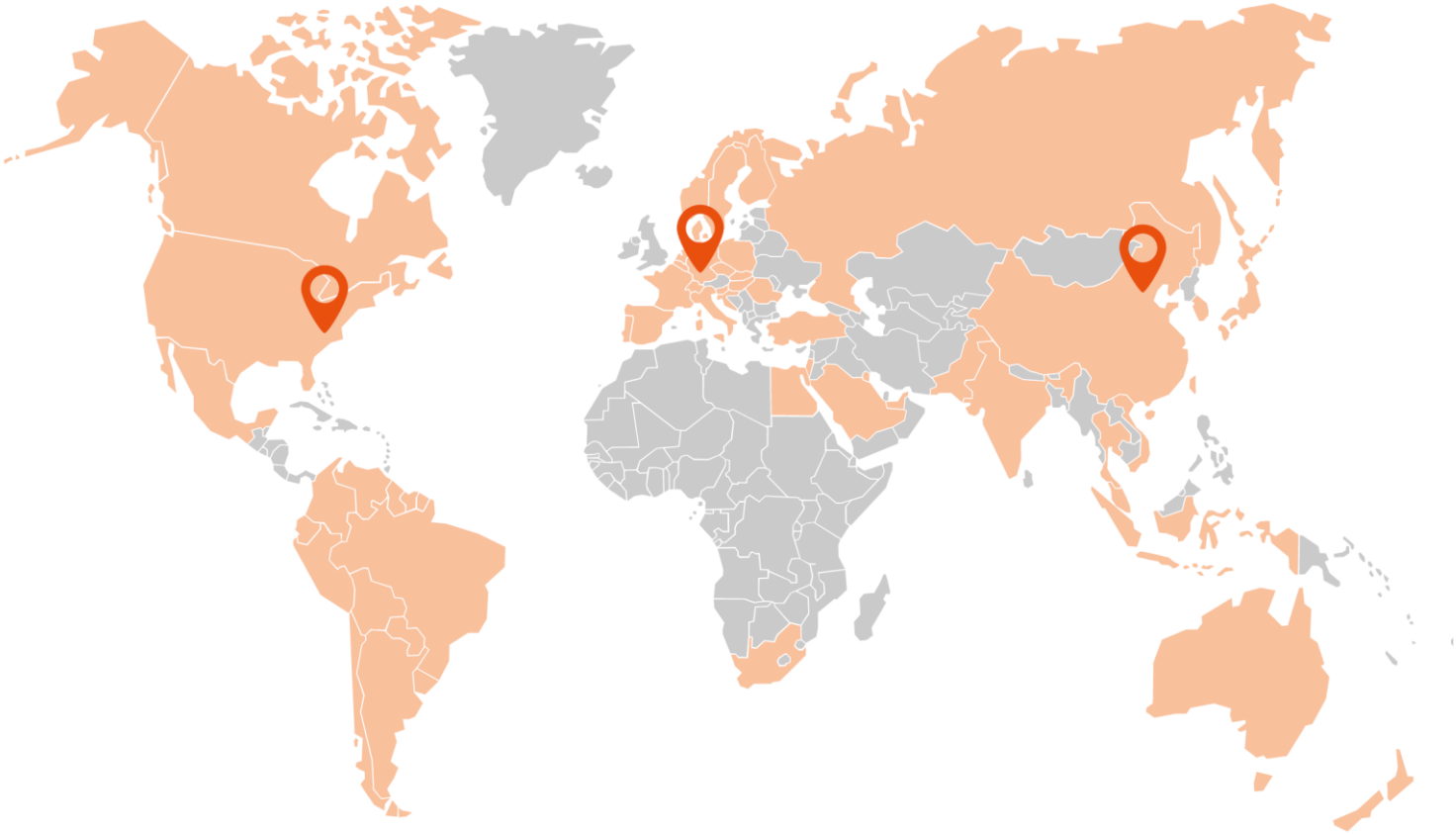

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