Anton Paar

::: Intelligence in Rheometry

Tips and Tricks from Joe Flow – Normal force control: May the force be with you

A measuring gap control via normal force is of great advantage in the measurement of semisolids like gels as well as solid samples. A gap adjustment is also required for many curing reactions.

What is normal force?

The term normal force refers to a force perpendicular to a surface. In rheology, this force acts on a sample (sample surface between measuring plates or cross-section of a solid bar).

In old measuring methods, the axial load is often denoted as a mass. To calculate the normal force, this formula is applied:

Mass [kg] = NF [N] / 9.81 [m/s^2]

Example: The compression of a sample with a normal force of 10 N approximately equals a mass of 1 kg.

What to preset: normal force or gap?

The measuring gap is controlled
- either by normal force, based on a gap size measurement
- or by gap size, based on a measurement of the normal force.

Presetting both parameters makes no sense.

Important applications

We differentiate the following applications:

1. A soft elastomer or gel slides along a measuring plate and has to be re-pressed by setting a positive normal force. Ideally, plates with a profiled or sandblasted surface are used.

2. The sample between the two plates expands or shrinks in the course of the measurement. This is often the case during temperature-dependent tests or curing reactions. The occurring normal forces are compensated by setting a normal force of NF = 0 N.

Note: If the normal force is not adjusted, the sample may lose contact with the plate.

- At a preset normal force of NF = 0 N, the measuring gap size may slightly fluctuate due to heating or cooling of the measuring system. This change is proportional to the expansion coefficient of the material (steel). For a standard plate, the AGC coefficient is 0.65 µm per Kelvin of the temperature change (AGC = Automatic Gap Correction). The size change is therefore known and can be corrected assuming stationary conditions. In any case, the same rule applies here: In the case of NF control, the actual gap is calculated, not controlled.

3. A solid bar must be kept in an extended state. The sample is pulled by a preset negative normal force. The value of 0.03 N per mm^2 sample cross-section shall not be exceeded in this case (0.1 N per mm^2 for very rigid samples).

Note: Cones and normal force measurement are a bad match. If cone measuring systems are used, the measuring gap is defined by means of the cone's tip. A gap change can result in major measurement errors.

Also note: Cone-plate measuring systems require gap control; normal force control is not an option here.

Heat or control?

Hysteresis is a vital variable for presetting the normal force. I would like to demonstrate this using the example of an air conditioning unit with an adjustment hysteresis of ±1 °C. Imagine the room temperature is set to 23 °C. The heating only springs into action if the temperature drops down to 22 °C in the winter season. Then the valve opens and the room temperature rises up to the desired temperature of 23 °C. The valve closes once this temperature is reached. In the summer season, the cooling aggregate would switch itself on at 24 °C and cool until the desired temperature of 23 °C is reached.

The normal force control works in a similar fashion. The normal force is preset in the software's measuring window, e.g. to a constant normal force of 10 N. At a preset hysteresis of 1 N, the gap control would activate itself at 9 N and 11 N.

Moving profiles recommended by experts

While the normal force is preset directly in the measuring window, all framework conditions of the control (hysteresis, speed, normal force limit) are adjusted in the moving profile.

The RheoCompass™ software offers numerous standard profiles with useful presets. Like the App Manager, the profiles are based on the consistencies of samples. Individual settings can be made under "Setup" > "Moving profiles". To this end, an existing Anton Paar profile is duplicated and saved as "Copy of…". The name and the new settings can be adjusted in this profile.

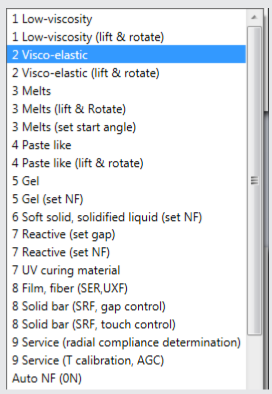


Fig. 1: Typical moving profiles in the RheoCompass™ software based on consistency and application

In the moving profile we differentiate the controls
- during the motion towards the measuring position (operation),
- during the motion towards the lift position (operation)
- and the settings throughout the measurement (measurement).

A separate tab with defined framework conditions is provided for each of these actions.

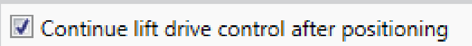
Operation: measuring position and lift position

- Users can define positions with according velocity. If the same velocity value is set for two positions, the velocity remains constant. In case two different values have been set, the velocity is changed from the first to the second value between position 1 and position 2 (linear adjustment). A few millimeters before the measuring position is reached, a velocity between 100 μm/s and 1000 μm/s makes sense. For faster motion in the upper positioning range, a velocity of 8000 μm/s is recommended.

- Normal force values are assigned to these positions as limits. Once the defined limit value and the hysteresis are exceeded, the measuring system stops moving until the sample has returned to its relaxed state.

- For axial positioning (lift drive) the modes “Set normal force” or “Set gap” are available.

- Users can optionally continue controlling the lift drive after the preset value has been reached. This means, for example, that the preset normal force can stay active until the test starts. In cases of active lift drive control, the instruments of the MCR xx2 series display “NF-Control” on their screen.



- As a further option, the measuring drive can be controlled, e.g. to penetrate the sample while rotating or to lock the measuring system until the test starts. Here the preset can also stay in effect after the position or normal force has been reached. “0” means “use maximum value of preset parameter”. In cases of active measuring drive control, the instruments of the MCR xx2 series display “M-Control” on their screen.

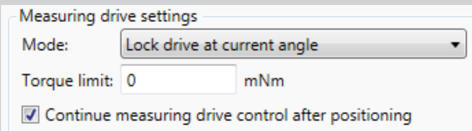


Fig. 2: Control of measuring drive

Online: During the measurement

The framework conditions of the measurement, i.e. the hysteresis for the NF preset in the measuring window and other conditions, are defined in “During measurement”.

- Several positions can be defined together with a velocity. The velocity values serve as limits for the presets in the test profile of the action “Measurement”. For precise control, a value of 10 μm/s is recommended. A value as low as this leads to a slow and precise adjustment of the normal force and is preferably used for tests on solids or measurements of curing behavior. In penetration or tack measurements, the priority is not on precision but on fast control. In these cases, the velocity should be pushed to the maximum (MCR xx1 series = 8000 μm/s, MCR xx2 = 16,000 μm/s).

- As a hysteresis value in measurements on solids, approximately 10 % of the NF preset have proven successful. This means, for example, that a preset of 10 N in the measuring profile would call for a hysteresis of approximately 1 N.

Note:
If the hysteresis is set too low, the lift motor is constantly adjusting.

If the hysteresis is set too high, the lift motor adjusts too late, meaning that considerable distances have to be readjusted in the gap. This can result in steps in the measurement.

At very low NF presets (<1 N) I recommend a hysteresis of 25 % of the preset value (e.g. preset 1 N, hysteresis 0.25 N).

- The minimum and maximum positions define the tolerance range of the control. The control is turned off outside these tolerances.

- This means, for example, that the measuring gap for a powder pressed by normal force can be given a limit for a lowest point. This has the advantage that the control is not continued after the powder is melted, and it stops at a minimum position of 0.5 mm, for example. This eliminates the possibility of the measuring plate moving all the way down until it touches the lower plate.

Conclusion

A reasonable normal force control is essential for a good measurement result, particularly with regard to semisolid, solid or reactive samples. The MCR rheometer series combined with the RheoCompass™ software allow for a precise adjustment of the normal force to the requirements of each application. Benefit from the pre-defined moving profiles that our experts have developed for you.