The Gneuss Online Viscometer

A Case Example

1. Introduction

In order to ensure product quality and operating efficiency when processing sensitive polymers, it is crucial to monitor certain key processing parameters.

For polymers which degrade due to hydrolysis, shear stress, or due to thermal and/or oxidization, it is extremely useful to monitor the polymer viscosity online.

The case example described here is the processing of PET to sheet for thermoforming. Under temperature and in the presence of moisture, the molecular weight chain will decrease. The influence of moisture on the molecular weight of viscosity on PET (which is measured in IV – the intrinsic viscosity) with difference moisture levels over the same time and at the same temperature is shown in figure 1.

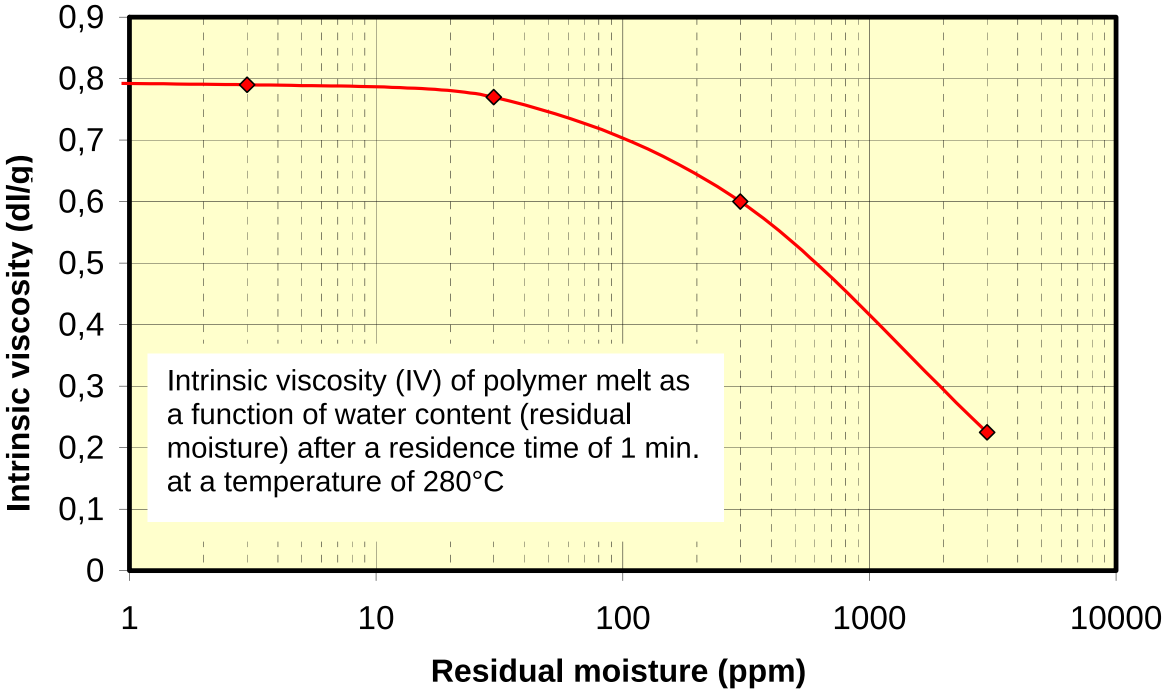


Illustration 1: Polyester degradation by hydrolysis - IV of polymer melt as function of water content (at 280°C, residence time 1 min)

The graph makes it clear that when processing PET to sheet for thermoforming, the residual moisture – or drying efficiency (in addition to temperature, residence time, shear stress and pressure) have a significant effect on the properties of the polymer melt.

If the viscosity of the polymer drops, this has a serious, negative effect on the mechanical properties of the final product. The lower molecular weight will lead to a reduced tensile strength and when the sheet is (in a subsequent production process) thermoformed to deep, thin walled containers, the thin wall of the container is prone to splitting. A further problem is maintaining uniform sheet thickness tolerances if the polymer viscosity fluctuates as the material flows differently through the die depending on the viscosity.

One of the main causes for fluctuating residual moisture content is a varying residence time of the material in the drying equipment, the drying temperature, the dew point temperature of the drying gas and the impact of contact with the ambient air. Even if all the above factors are kept stable, the residual moisture content of the input material can vary (for example seasonally) which will result in the melt viscosity and molecular weight of the film. It is well known that problems for example occur, when switching from one drying unit to another.

In order to reduce the impact of viscosity variations, the manufactures of PET sheet for thermoforming typically produce the sheet thicker than necessary, thereby using more material than necessary.

By monitoring the viscosity, it is possible for the producer to take corrective measures. Measurement of the molecular weight or intrinsic viscosity are typically only possible with complicated laboratory equipment and not in real time.

For this reason, a simple and reliable real- time viscosity measurement (with the possibility of correlating to the intrinsic viscosity) offers valuable possibilities to the manufacturer of PET sheet.

2. The Gneuss Online Viscometer:

Gneuss has developed an Online Viscometer which permits continuous monitoring of the melt viscosity and the corresponding processing conditions.

The of the design briefs for this unit was to provide a device which is compact and therefore easy to retrofit without negatively affecting the process (no measurable increase in residence time) simple to use, able to withstand rough production conditions and which provides reliable results (after exact calibration) comparable in their accuracy to laboratory results.

Typically, the Online Viscometer is flanged in between for example a screen changer and melt pump in the extrusion line. The melt channel diameter can be matched to the customer’s existing equipment (between 20 and 110 mm diameter – see illustration 2) and – within certain constraints – the hole pattern for the connections can be varied to permit the most compact installation. The equipment includes a melt (metering) pump with drive motor, reduction gearbox and the necessary melt pressure and temperature sensors together with the visualization and control hard and software.

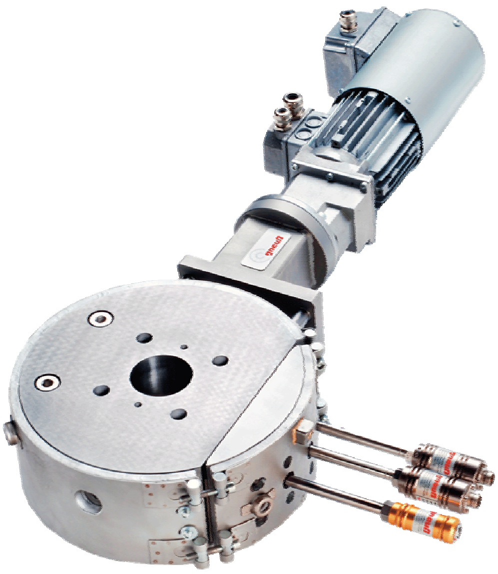


Illustration 2: Gneuss Online Viscometer

3. Operating Principle

The precision melt (metering) pump diverts a small proportion of the melt flow (max. 3 kg/h.) in bypass via a precision capillary slot. The elastic properties of the melt which could potentially disturb the measurement are filtered out by means of length – optimized inlet and outlet sections in the capillary slot, to even out the laminar flow (illustration 3).

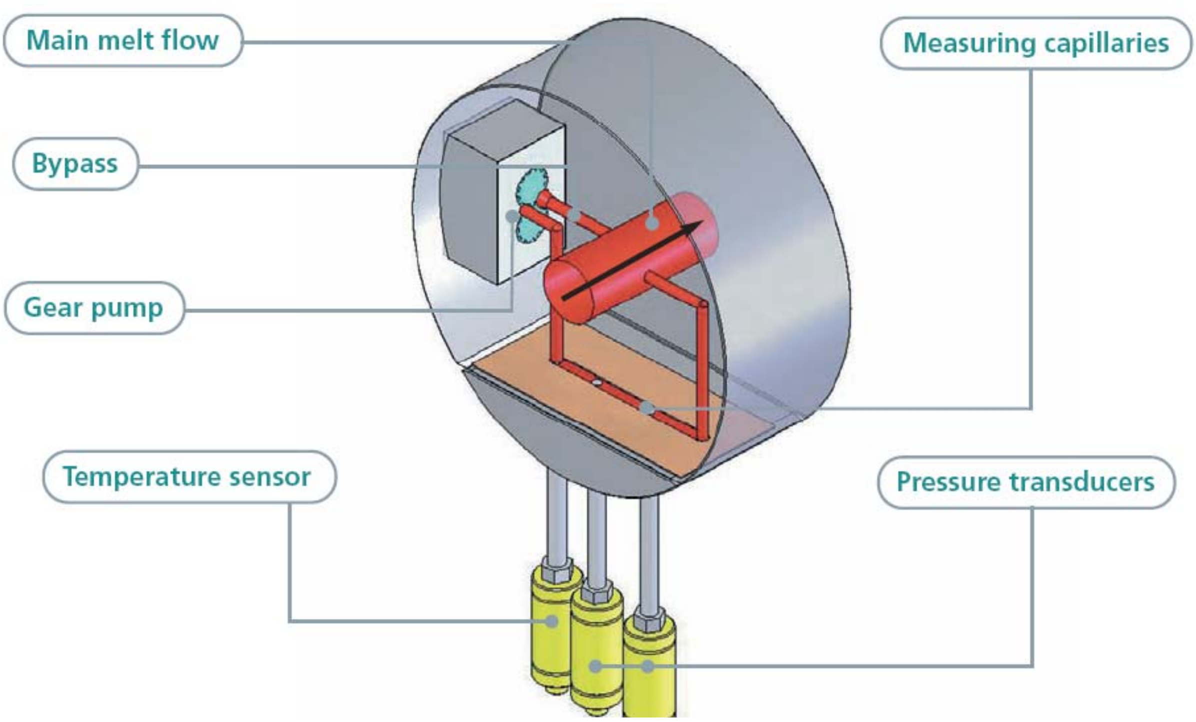


Illustration 3: Operating principle

From the volumetric flow through the capillary, the exact dimension of the capillary and the differential pressure in the capillary it is possible to calculate the shear stress and the dynamic viscosity.

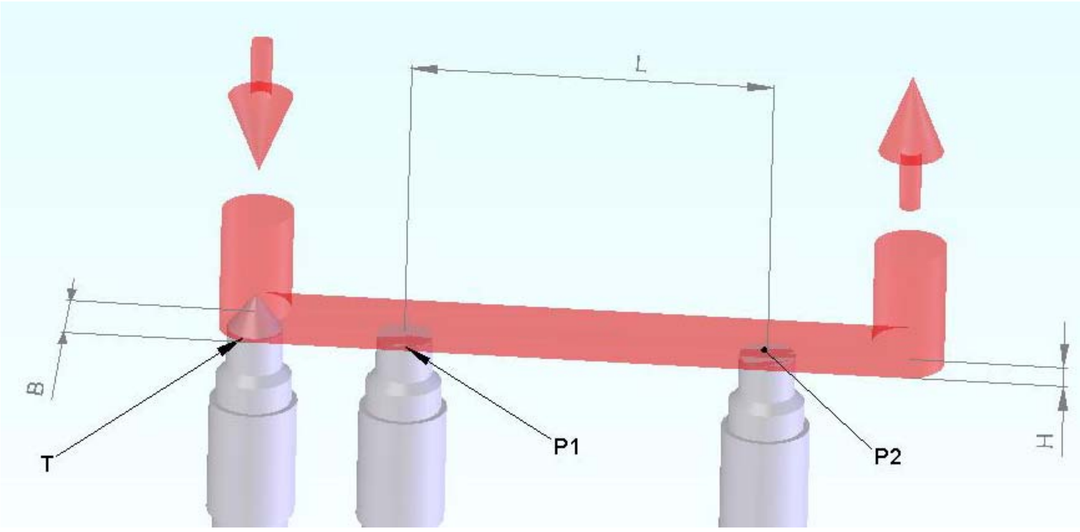


Illustration 4: Definition of Design Parameters

Design Parameters:

H capillary height

L capillary length

B capillary width

V_0 flow rate (volume) of the gear pump

Processing Parameters:

N speed of the gear pump

Q (n) volumetric flow through the capillary

Measurements:

P_1, P_2 Melt pressure in the capillary

T Melt temperature

representative shear stress:

$$\dot{\gamma}_{rep} = \frac{6 \cdot \sqrt{\frac{3}{5}} \cdot \pi \cdot n \cdot V_0}{B \cdot H^2}$$

representative viscosity:

$$\eta_{rep} = \frac{(P_1 - P_2) \cdot B \cdot H^3}{12 \cdot L \cdot n \cdot V_0}$$

The Online Viscometer measures the shear stress and the corresponding viscosity. By varying the speed (rpm) of the gear pump, it is possible to set different shear stresses and to measure the corresponding viscosities. With this data and with some correction factors (e.g. Weissenberg / Rabinowitsch, Schümmer, Dodge / Metzner or Reiner/Philipoff) a viscosity curve across a range of shear stresses can be measured and translated into real results.

Features:

The unit is heated electrically or by means of a liquid/vapour heat transfer medium. The user interface is by means of a touch panel display which shows all the running conditions and enables the operator to adjust the parameter settings via a clear and logical menu structure.

With the corresponding capillary slot depth (the capillary can be exchanged during production, viscosities within a range of 1 Pa.s. to 20.000 Pa.s. can be measured. The measurement range is also easily adjusted.

Great care was taken in the design of the unit to avoid dead spots or edges where shear- and temperature sensitive polymers could hang up or the flow could stagnate, the melt channels are manufactured to a high quality in order to ensure smooth flow. One innovative feature is the hinged design of the capillary which is easily removed and easily cleaned (and without stopping production).

4. Case example:

The following is a brief description of the experience of a customer operating the Gneuss Online Viscometer in a line for the production of A-PET sheet for thermoforming.

In this case, the customer runs a large number of different products, comprising of different proportions of bottle flake (reground PET bottles) and virgin material. The more virgin material is used, the higher the viscosity and vice versa.

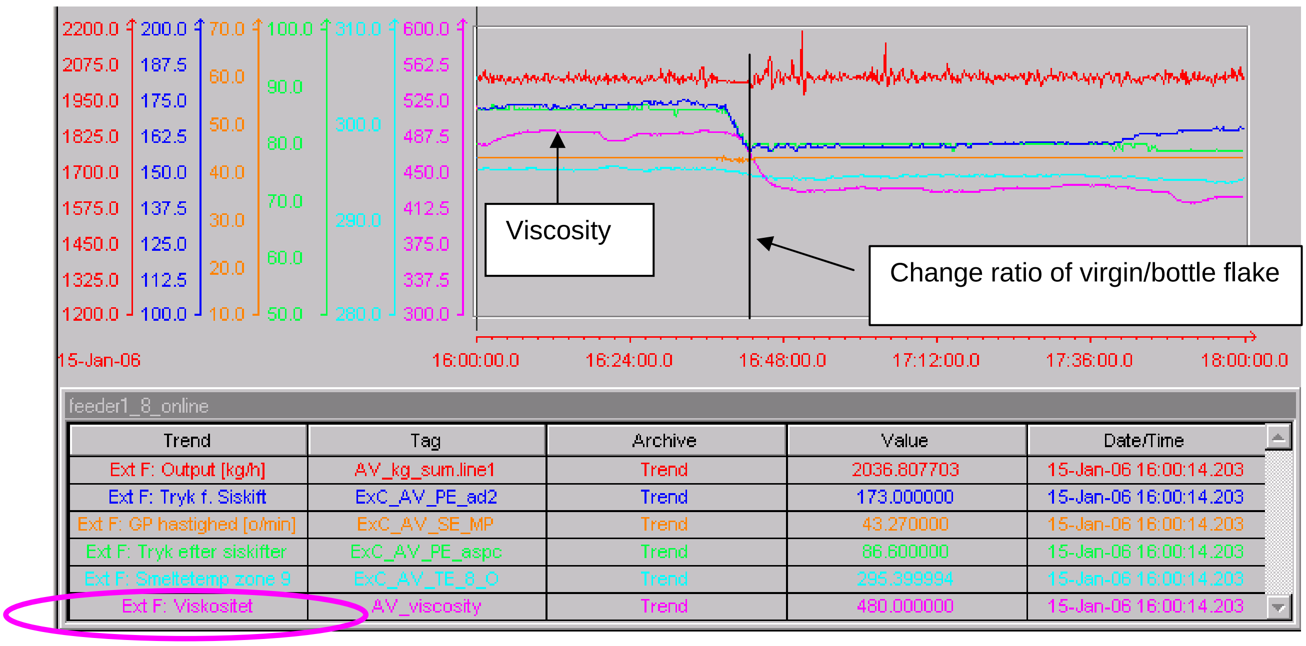
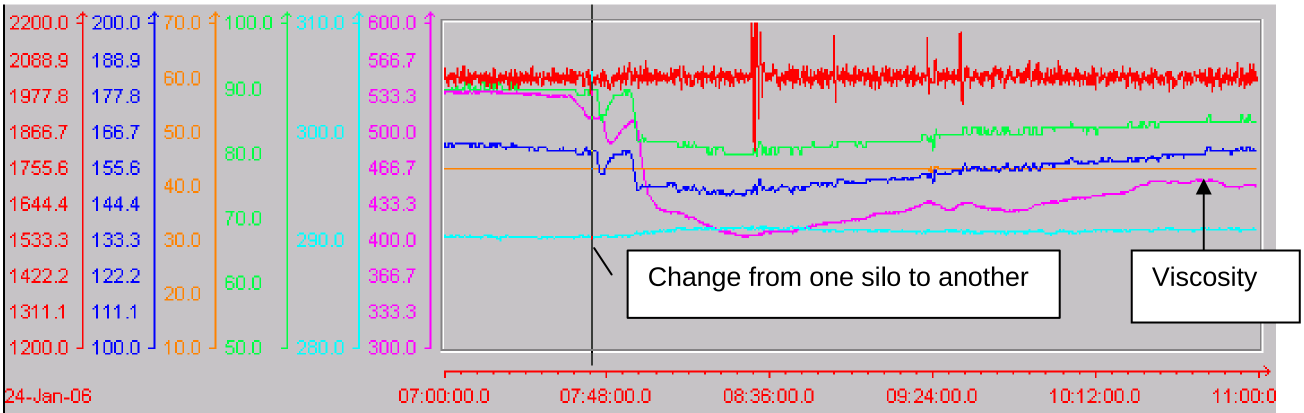


Illustration 5: Viscosity trend when changing from 40% to 60% bottle flake.

In some cases, a viscosity drop could be observed when changing from one dryer silo to another. This is typically caused by moisture which has gathered at the base of the silo. After a few hours, the viscosity will return to normal as the moisture content is reduced down through the silo. It is also possible to see changes in the viscosity when changing from (virgin) raw material from one manufacturer to another.



feeder1_8_online

Trend	Tag	Archive	Value	Date/Time
Ext F: Output [kg/h]	AV_kg_sum.line1	Trend	2024.231531	24-Jan-06 07:43:24.203
Ext F: Tryk f. Siskift	ExC_AV_PE_ad2	Trend	161.000000	24-Jan-06 07:43:24.203
Ext F: GP hastighed [o/min]	ExC_AV_SE_MP	Trend	43.240000	24-Jan-06 07:43:24.203
Ext F: Tryk efter siskifter	ExC_AV_PE_aspc	Trend	89.000000	24-Jan-06 07:43:24.203
Ext F: Smeltetemp zone 9	ExC_AV_TE_8_O	Trend	290.240002	24-Jan-06 07:43:24.203
Ext F: Viskositet	AV_viscosity	Trend	513.900000	24-Jan-06 07:43:24.203

Illustration 6: The viscosity trend shows a material change from one dyer silo to another. The viscosity drops and after a few hours returns to the original level.

Due to the ability to monitor the viscosity, the customer was able to introduce countermeasures in order to keep the value within the optimum range. By doing this, it was possible to reduce the quantity of scrap produced by 50 %. At the same time, it was possible to reduce the average film thickness by approximately 10%. The investment in this technology was recovered in only 6 months.

5. Summary

- Gneuss Kunststofftechnik GmbH has developed a new Online Viscometer
- This new measurement device is extremely compact and designed specifically for retrofitting to existing extrusion lines
- The viscosity measurement is carried out in bypass: no polymer loss.
- The new viscosity meter is advantageous also for the processing of sensitive polymers such as polyester, polycarbonate, polyamide (nylon) etc.
- Material composition, drying efficiency, additive level or reaction progress are easily monitored by following the melt viscosity.

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