Development and Application of an Optimization Procedure for an Operating Point in Hot Melt Extrusion

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Introduction

Hot Melt Extrusion (HME) is a widely used manufacturing technique [1]. Also in the field of formulation science it is a topic of large interest. Especially as a manufacturing technique for amorphous solid dispersions (ASDs) it is a commonly used process. [2] The key variables in an extrusion process are the screw speed and the mass flow rate. These two variables can be selected by the operator in a wide range.

Requirements for an operating point are
- good processability
- minimization of degradation products
- efficiency of the process

In the following work a procedure is developed to find an optimal operating point for an HME process.

Figure 1. Extrusion setup.

Materials and Methods

Extrusion

For the extrusion experiments a ZSE 27 MAXX (Leistritz, Nuremberg, Germany) was used. The mass flow rate was dosed by a gravimetric feeding system (KT-20, K-Tron, Niederlenz, Switzerland). As material for the optimization procedure the polymer copovidon (Plasdone S-630, Ashland, Columbus, USA) was used.

Regime map for HME

For the development of the operating point, a regime map was used. The material temperature of the extrudate at the end of the extruder is depicted on the x-axis, the specific feed load (SFL) is on the y-axis. The specific feed load is a dimensionless number which represents the degree of filling in the extruder. It depends on the mass flow rate ṁ over the screw speed n and it is made dimensionless by the screw diameter d and the material density ρ. It is calculated by the following equation.

$$SFL = \frac{\dot{m}}{d^3 \cdot n \cdot \rho}$$

Within this regime map, an operating window of the extruder can be set by following limitations:

SFL_{min}	minimal amount of material to even cover the screws
SFL_{max}	maximal amount of material that can be fed into the screws
$T_{g,mix}$	glass transition temperature of the mixture
$T_{s,mix}$	solubility temperature of API in polymer
T_{deg}	degradation temperature
Torque limitation	power of extruder insufficient to rotate the screw

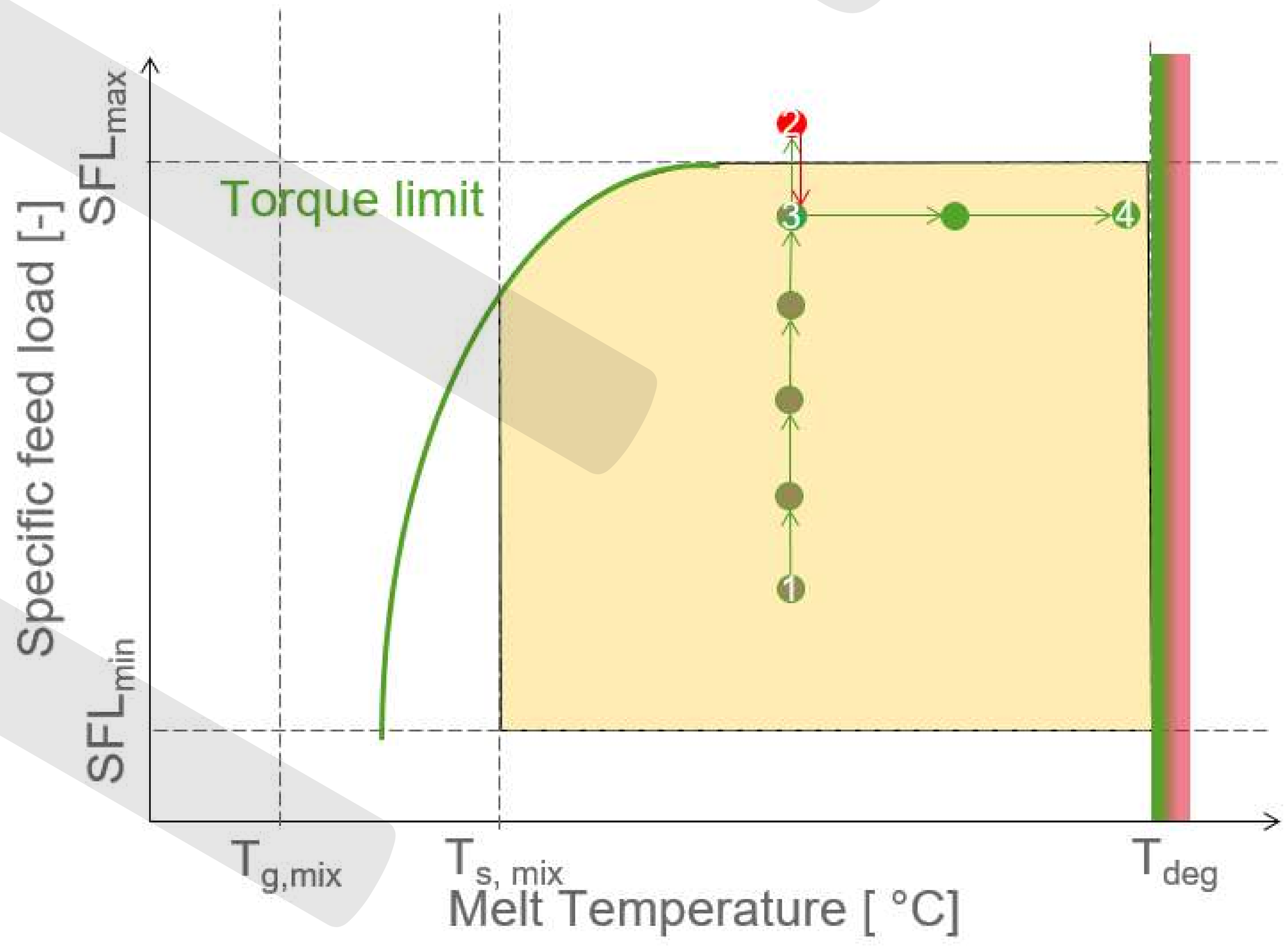

Figure 2. Optimization procedure in operating window for HME.

Optimization procedure

1	Starting point
1 → 2	Increase of SFL by decrease of screw speed
2	Upper limitation of the operating window is exceeded → Backlog
2 → 3	Screw speed set to previous value
3	Optimal SFL is reached
3 → 4	Increase of screw speed and mass flow rate simultaneously
4	Optimized operating point

Results and Discussion

From starting point (1.8 kg/h, 100 rpm, Figure 3 (1)) the specific feed load was increased until a backlog occured at 20 rpm (2).

Experiments have shown that when decreasing the screw speed, the resulting temperature of the polymer strand decreases, so that the movement from point (1) to point (2) runs not straight upwards but slightly to the left. This can be explained by the decreased screw speed and therewith less energy input by the rotation of the screws.

The step backwards was made to reach the maximal specific feed load of 0.0375. From this point (3) the mass flow rate was increased stepwise. The screw speed was increased by the same factor, to retain the maximal SFL.

The final operating point (4) for the used material is at a specific feed load of 0.0375, which results from a mass flow rate of 30 kg/h and a screw speed of 550 rpm.

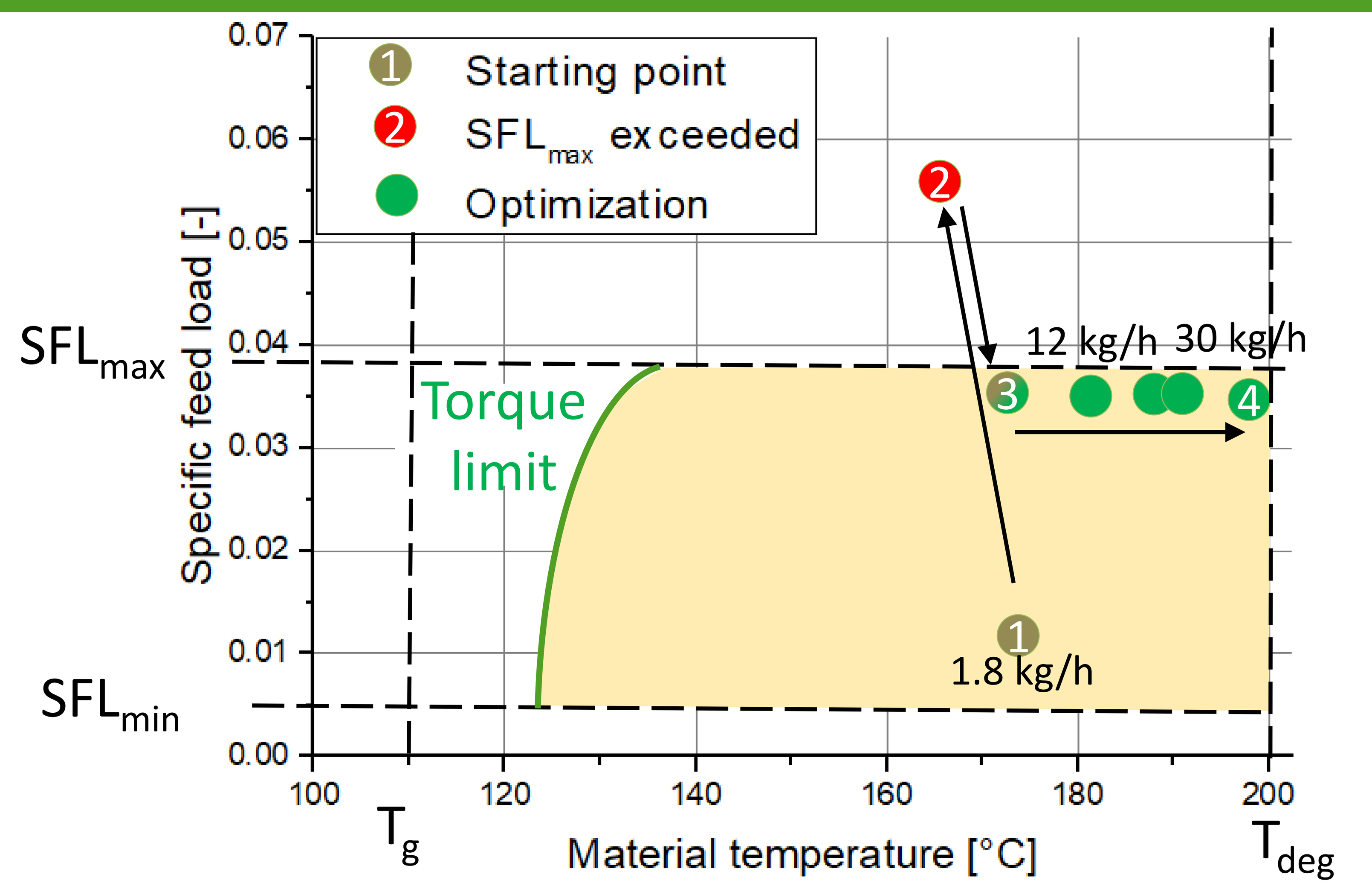

Figure 3. Application of Optimization procedure for HME with copovidon.

CONCLUSION

In the present work an optimization procedure for the operating point in a hot melt extrusion process was described. Its applicability was presented. Within the application it was shown, that an operating point with high throughput at a high specific feed load was reached.

References: [1] Kohlgrüber K, et al.. Co-rotating twin-screw extruders. Fundamentals, technology, and applications. Munich, Cincinnati, Ohio: Hanser; (2008)
[2] Repka, M. et al..Melt Extrusion.,New York, Springer, (2013).

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