Master's Thesis Engineering Technology

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Development and evaluation of an acrylic lubricant for PVC formulations

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Introduction

Kaneka Belgium is a subsidiary company of Kaneka Corporation. The modifier unit of Kaneka Belgium produces and develops additives for PVC in order to improve its properties. One major problem with PVC formulations is its **high melt viscosity**, making the processing difficult. As a consequence high **heat and power consumption** is necessary in order to process the polymer. Another disadvantage of the high viscous melt is that PVC can **stick to the metal parts** of the processing unit. To avoid these problems, **lubricants** are added to PVC formulations.

The function of the lubricants can be expressed in two different ways. On one hand, they lower the friction and adhesion during processing on the working surface. This is known as **external lubrication** and is displayed by the green stripes in figure 1. On the other hand, they can reduce friction by easing the movement of the polymer chains in relation to the components in the formulation during processing. This has a positive influence on the viscosity of the melt and heat build-up. This is known as **internal lubrication** and is displayed by the red stripes in Figure 1 [1][2].

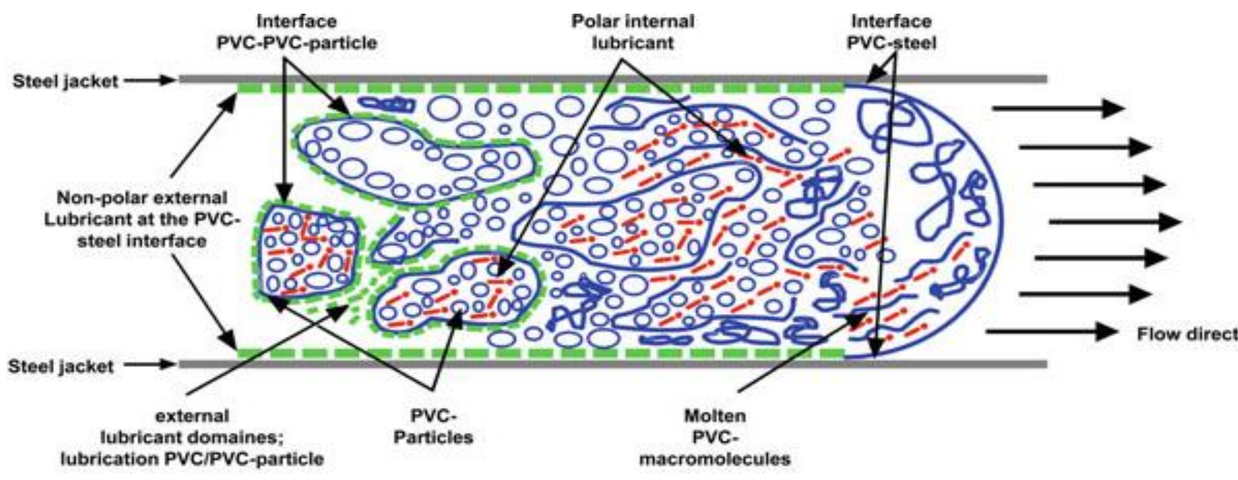


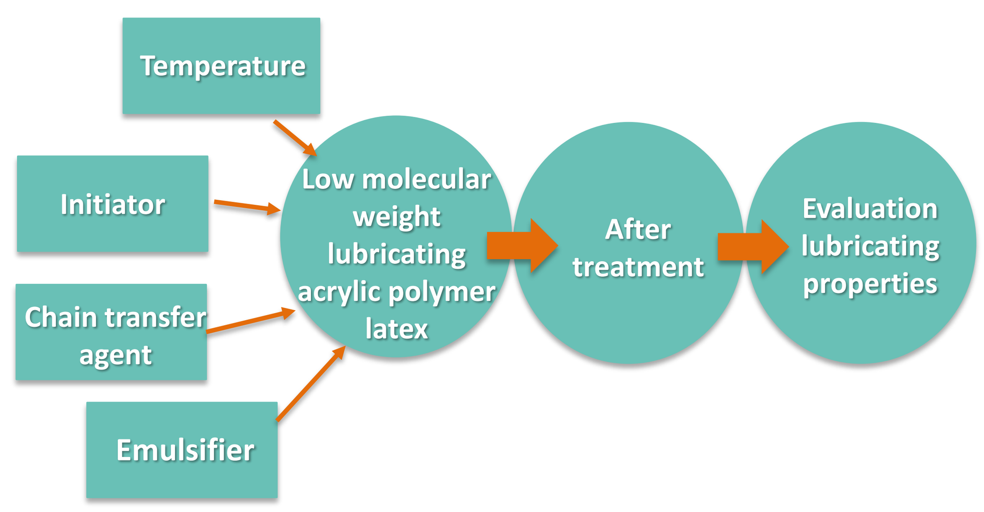
Figure 1: Schematic representation of the cross-section of the flow during PVC processing in the presence of lubricants [1]

Recipe Development

❖ **Free radical polymerization:**

- Initiation: $I \xrightarrow{k_d} 2R\cdot$
  $R\cdot + M \xrightarrow{k_i} RM\cdot$
- Propagation: $RM\cdot + nM \xrightarrow{k_p} \sim M_{n+1}\cdot$
- Termination: $P_n\cdot + P_m\cdot \xrightarrow{k_{tc}} P_{n+m}$
  $P_n\cdot + P_m\cdot \xrightarrow{k_{td}} P_n + P_m$
- Chain transfer: $\sim P_n\cdot + CTA \xrightarrow{k_{tr}} P_n + CTA\cdot$
  $CTA\cdot + nM \rightarrow CTAM_n\cdot$

❖ **Approach:**



❖ **Suspension polymerization :**

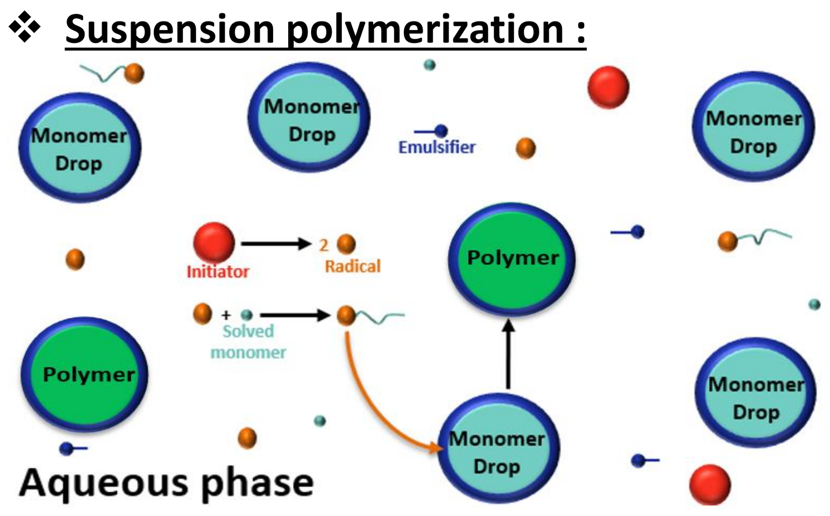


Figure 3: Schematic representation of suspension polymerization

❖ **Results :**

Table 1: the adapted parameters with the their result

Parameter	Results
Temperature	90 °C
Initiator	P4: S PHR A81: Q PHR
Chain transfer agent	M1: U PHR
Emulsifier	EM15: 0.6 PHR

Problem statement

The problem with current (external) lubricants, such as polyethylene and propylene waxes, is that they can display some undesirable properties, such as (die) **plate-out** (Figure 2). Plate-out is the phenomenon that causes **uncontrolled deposition on parts of the processing unit**. The current lubricants, dissolve inorganic additives and stabilizers in the PVC melt and act as a carrier for these additives. This complex of lubricant and inorganic compounds can adsorb easily to parts of the processing unit and cause deposition. As consequence, final products will display striping and scoring after some processing time, making them less appealing and strong [3].

Figure 2: Example of a die with plate-out (left) and without plate-out (right)

Evaluation

Final acrylic polymers were evaluated based on their lubricating power. This was tested via Brabender gelation and shear viscosity measurements. The results of these measurements are given in figure 4 and 5.

❖ **Brabender gelation:**

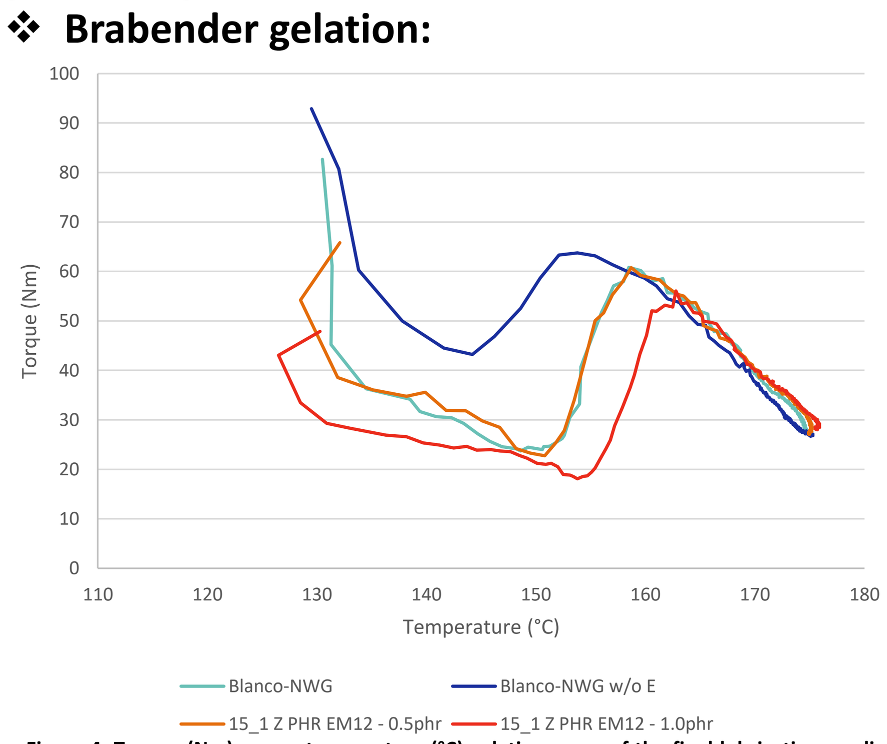


Figure 4: Torque (Nm) versus temperature (°C) gelation curve of the final lubricating acrylic polymer in a NWG formulation without Licowax E

❖ **Shear viscosity:**

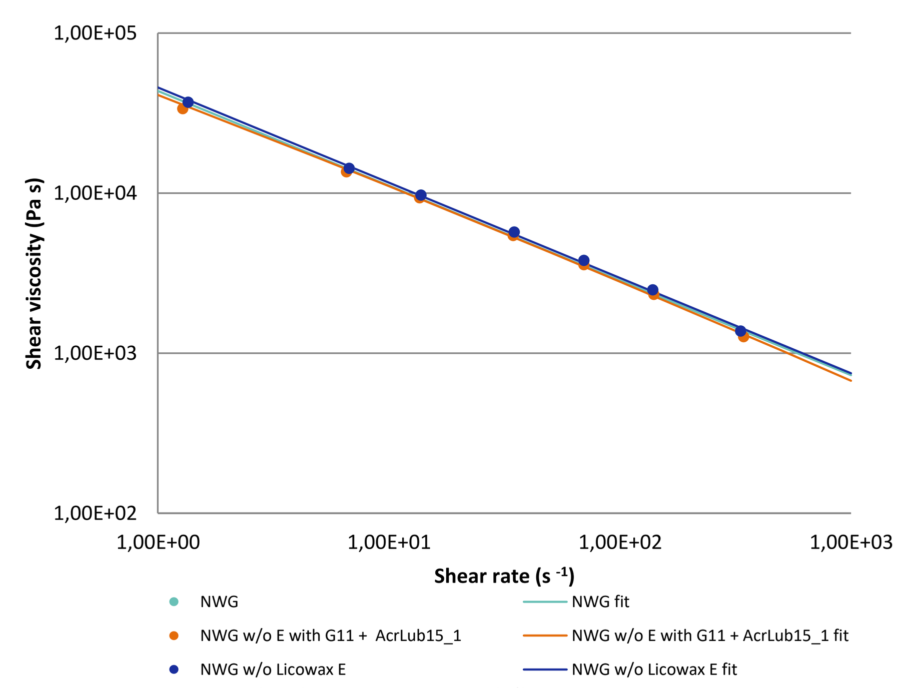


Figure 5: Shear viscosity (Pa.s) versus shear rate (s^{-1}) graph of the final lubricating acrylic polymer

Objective

The main goal of this research was to develop an acrylic external lubricant which solves the current plate-out issue and improves final product performance, such as gloss and surface finish. For lubricants to practice their external lubrication effect, they have to go to the outside of the PVC formulation. Because the polyethylene and propylene waxes have **low compatibility with PVC**, they will **completely separate** from the matrix and form a film between the metal surface and the PVC melt. This allows the melt to move smoothly along the metal surface of the processing unit [1]. But, due to the formation of the second layer, these lubricants tend to express plate-out more easily. The **proposed acrylic polymer** has a **low molecular weight and a higher compatibility** with PVC matrix. The low molecular weight polymer chains, on the on hand, cause the acrylic lubricant to go to the wall of the processing unit under the influence of shear. Because of the higher compatibility, due to the solubility of acrylic polymers in PVC, on the other hand, the acrylic polymer does separate completely from the PVC melt. As a result, the acrylic polymer lubricates the melt but does **not display the plate-out problem**. Therefore, standard polyethylene and propylene waxes can be omitted.

Conclusion

A recipe that is able to create an **acrylic polymer** with a **molecular weight** that meets the **target level** was **successfully developed**. The recipe produces an acrylic polymer which has a specific viscosity of X at a maximum conversion rate of 53.5 PHR/h. The remaining latex has a solid content of 29.05 % and the polymer particles in the latex have a D_{50} of approximately 0.542 µm.

In order to evaluate the lubricating properties of the acrylic polymer, a powder was obtained from the latex. Therefore, an after treatment process was developed. This process uses V PHR H8 and Z PHR EM12 at a temperature of T °C.

During the evaluation experiments, the acrylic polymer has proven to exert external lubricating properties. Out of Brabender gelation and shear viscosity measurements it was observed that the replacement of the standard external lubricant in the NWG II formulation with the acrylic polymer, in a one to one ratio, almost performed the same lubricating properties as the standard NWG formulation. Therefore, it can be concluded that the **acrylic polymer could potentially replace the external lubricant** in the NWG formulation.

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Bronnen:
[1] P. Eyerer, M. Weller, and C. Hübner, *Polymers – Opportunities and Risks II*, vol. 5, no. 2. 2008.
[2] W. V. Titow, *PVC Solutions and their Applications*. 1984.
[3] N. Varshney, M. Gilbert, M. Walon, and M. Schiller, "Plate-Out in PVC Extrusion. II. Lubricant Effects on the Formation of Die Plate-Out in Lead-Based Rigid PVC Formulations," *Soc. Plast. Eng.*, vol. 18, no. 2, pp. 209–215, 2012.

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