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The Flow of Thermoplastics in Calender

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When we make a film or sheet with thermoplastics using calender, it is desirabe to understand the force acting on the material, the velocity of the material and the thickness ratio of the film in order to control intelligently factors which influence quantities and patterns of the film.

Calendering process is illustrated as following; the material does not leave the roll at $x=0$, but it leaves the roll as solid sheet at the point $x=X=\lambda\sqrt{2RH_0}$, where there is no velocity gradient. Consequently the thickness of the film is greater than the minimum clearance ($2H_0$) of two rolls rotating in the opposite direction with equal speed. In this paper, first, we calculated the value of λ vs. ρ_0 or $K=\frac{H}{H_x}$ vs. ρ_0, according to the theory of R.E. Gaskell (1950): where $\rho_0\left(-\rho_0=\frac{x_0}{\sqrt{2RH_0}}\right)$ represents the point where the pressure is zero. The results of this calculation for the Newtonian fluid and Power-Lew fluid ($n=0.5$) are shown in a figure.

Secondly we experimented this calendering process in the basic manner by making the calender having equal 98.6 mm diameter rolls which rotate in the opposite direction with equal speed.

This calender was designed for two special objects, namely, to be able to observe the nip from the side of rolls and to have a wide range of change in nip clearance. As the materials that are calendered, polyvinyle acetate (number of polymerization 400, 780), with plasticizer (D.O.P., D.B.P.) and filler, are used from the point of view that they have the typical flow properties of thermoplastics generally calendered in the plastics industry.

The mechanical properties of the samples, measured by using Band viscometer. The samples have not only non-Newtonian flow properties but also viscoelastic property.

Using these samples we measured the ratio of film thickness and nip clearance $K=\frac{2H_0}{2H}$ as the function of H_0 with various ρ_e, where the sample begins to touch the rolls.

Next the velocity profiles of the fluid in the calender were measured by using a rotating shutter and still camera, inserting slender, long rigid needles in the sample parallel to the axes of the rolles. The velocity profiles obtained from this method show agreement each other in the region near the nip.

From the velocity profiles, we can predict the shear-stress distributions and pressure distributions assuming the samples to be Power-Law fluids.

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The value of λ can be obtained from various data of experiment, such as the thickness proportionality factor K, integration of the velocity at spontaneous point, and the values of maximum shear stress and maximum pressure.

In this experiment the values $\lambda=0.36\sim0.46$, independent of the value of ρ_e, were obtained, but the values of λ obtained from $K=\frac{H}{H_0}=1+\lambda^2$ were greater than that obtained from integration of velocity at the nip. This seems to be related with the elastic extract of the samples.