Visualization study of liquid surface stability for full reverse 3-roll coater with rigid gravure roll

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Introduction

Roll coating systems are widely used to coat a thin liquid layer on steel sheets, and many publications discussing forward roll coating systems and reverse gap control coating systems are available[(1)(2)]. Recently, thinner and more uniform layers are required for use with the high performance solutions involved. A reverse gravure roll system can coat a thin layer film easily because the liquid is only transferred from the gravure cell. However, the existence of the gravure cell complicates the flow between the rolls. To our knowledge, no systematic study in the literature has explored this condition in depth.

In the present study, the flow between a reverse deformable roll and solid stainless steel gravure roll is visualized in order to determine how the uniformity of coating in the high roll speed region is affected by operating parameters, that is, the speed ratio between the rolls and liquid properties.

Experimental set-up

In order to visualize a continuous coating liquid film, experiments with coating equipment having a looped steel strip were performed. The experimental set-up is shown in Fig. 1. This coater has three rolls and a strip with a loop of about 10 meters. A high-speed camera was used to verify the appearance of the liquid film. (Fig. 2) The film thickness is calculated by measuring the volume of liquid after the blade. A rigid gravure roll was used as the pick-up roll (PR). Rubber-covered rolls were used in the applicator roll (AR) and metering roll (MR). The coating liquids used in this test were all Newtonian fluids.

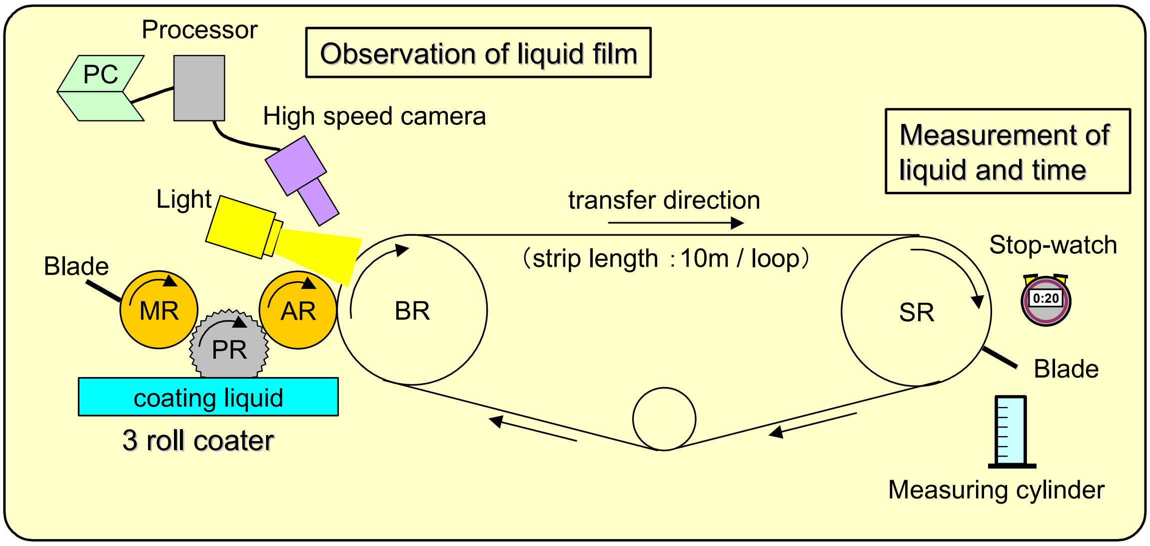

Fig. 1 Experimental set-up

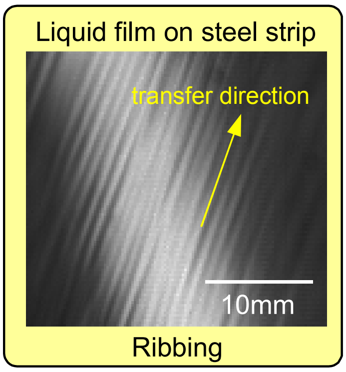

Fig. 2 Example of liquid film on steel strip

Results

The coating window and liquid surface on the strip are shown in Fig. 3. The viscosity of the coating liquid was 1.0 mPas, and surface tension was 45 mN/m. The liquid film thickness was kept constant at 8 μm. The coating condition for stable uniform coating depended on the ratio of the roll rotation speed. The stable region was extended when the applicator roll speed and pick-up roll speed were fast. When the PR speed was slow compared with the AR speed, ribbing occurred between the AR and PR. When the AR speed was lower than the strip speed, ribbing occurred between the AR and strip. When the AR speed was fast compared with the strip, stripe marks were generated on the strip surface because of the oscillation of the meniscus.

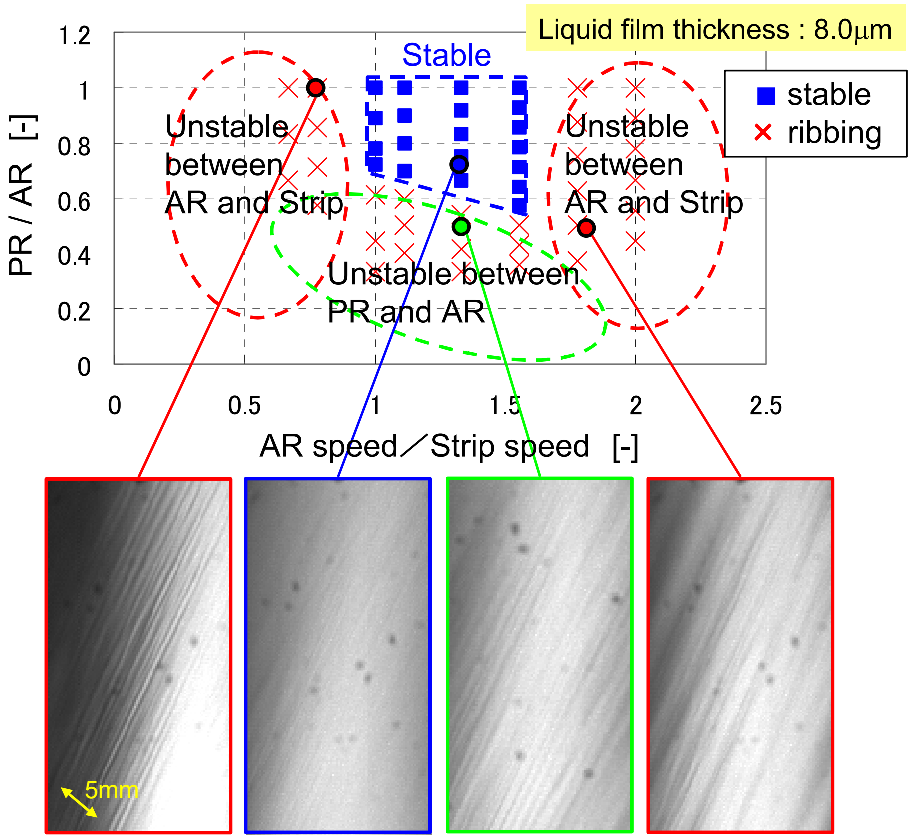

Fig. 3 Stability diagram and liquid surface on strip

The effect of the roll speed, viscosity, and surface tension on coating uniformity is shown in Fig. 4. Table 1 shows properties of coating liquids applied in this experiment. The stable region narrowed when the ratio of rotation speed (PR/AR) was lower and the capillary number increased. However, the stable region existed at a high ratio of speed (PR/AR).

Table 1 Coating liquid properties

Type	Non-volatile [%]	Viscosity [mPa・s]	Surface Tension [mN/m]	μ / σ [-]
Liquid①	5	1.4	43	1
Liquid②	6	1.9	36	1.6
Liquid③	7	2.7	31	2.7

Capillary Number: $Ca = \frac{\mu V}{\sigma}$

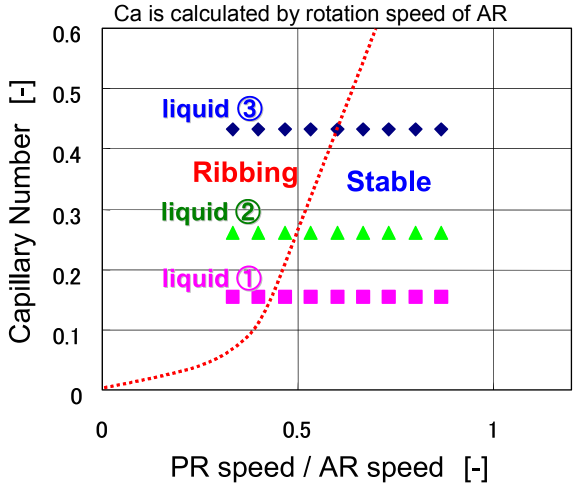

Fig. 4 Influence of Ca number on stable condition

Conclusion

The results of experiments show that a high applicator roll speed condition helps to expand the stable region of the roll speed ratio (AR/PR) in reverse 3-roll coating with deformable rolls, and a low capillary number also helps to expand the stable region. The range of coating uniformity is compared with the case of a gap control system[3]. The results show that the stable region can be extended by use of the reverse gravure roll system.

References

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