Manufacturing Process of Ultrawide Optical Films Used in Liquid Crystal Displays with Roll-to-Roll Transportation





Shnji Hikita[*1] (1965)
Daisuke Fujikura[*2] (1958)
Tadashi Sasaki[*2] (1946)
Takashi Nawano[*3] (1949)
Hiromu Hashimoto[*4] (1951)

1. Outline

Conventional cathode-ray tube (CRT) displays are being rapidly replaced by liquid crystal displays (LCDs) for televisions and computer monitors. The highly functional optical films used in LCDs are continuously produced in large quantities at a low cost by roll-to-roll transportation using guide rollers. Although wider optical films are now required owing to the increase in the size of LCDs, the inertia moment of guide rollers increases during the transport of such optical films; therefore, it is very difficult to stably transport wide optical films, on which even tiny scratches are not permitted, without causing defects. We systematically studied a web handling technology from a theoretical viewpoint in collaboration with a university, with the aim of producing ultrawide optical films. The technology introduced in this paper was developed as a means of producing high-quality and high-performance ultrawide optical films without web defects by applying the results of the theoretical research.

2. Description of Technology

Thin and flexible continuous materials, such as papers, films, and metallic thin films, are called webs. Web handling is the technology of transporting webs without decreasing their performance. Guide rollers are driven by traction due to the pressure generated by the tension of the web on the surface of the rollers. As the transport speed increases, the thickness of the air film between the roller and the web also increases, leading to a decrease in traction. Through the theoretical consideration of fluid dynamics, we developed a micro-grooved roller that can remove the air film. The depth of the grooves of the micro-grooved roller shown in Fig. 1 is of micrometer order and equivalent to the thickness of the air film formed between the roller and the web; therefore, the flow within the micro-grooves can be assumed to be viscous. By applying the concept of equivalent film thickness, we determined the thickness of the air film between the roller and the web and calculated the slip onset velocity.

Wrinkles are easily generated on thin optical films upon the application of excessive tension, resulting in the breaking of films. Wrinkles lead to film breakage when the buckling stress due to the bending moment generated as a result of the misalignment between two rollers, which causes deformation (a trough), exceeds the critical buckling stress of the cylindrical film owing to the traction between the roller and the web. Therefore, the critical tension for inducing wrinkling was determined.

In general, there is a trade-off relationship between slippage and wrinkling. Therefore, it is difficult to determine the optimum micro-groove size that ensures a safe operation region where neither slippage nor wrinkling occurs. To optimize the micro-groove size, we set the minimization of [(slip onset velocity)/(critical web tension for inducing wrinkling)] as our objective function and solved the optimization design problem using the following parameters as the design vector and constraint functions: groove width, groove depth, number of micro-grooves per unit width, and critical pressure for generating scratches. As a result, the optimum width, depth, and pitch of the micro-grooves were determined.

It was verified that the optimized micro-grooved roller can prevent films from both slippage between the roller and the film and wrinkling on the rollers. From Fig. 2, it was also verified that the optimized micro-grooved roller can maintain a high friction coefficient even at high transport speeds, compared with the non-optimized micro-grooved roller.

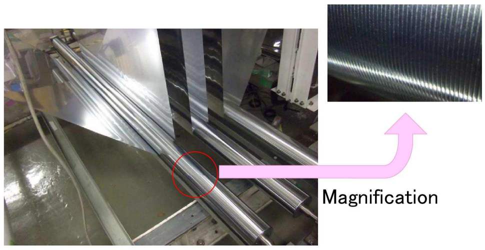

Fig.1 Micro-grooved roller

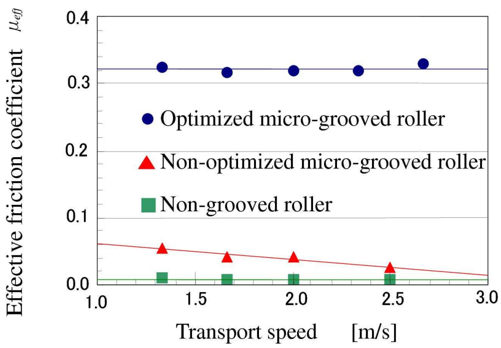

Fig.2 Conventional and micro-grooved rollers

Fig.3 Appearance of ultrawide optical film

3. Summary

It is possible to produce high-quality optical films with no defects, such as scratches and deformations, as shown in Fig. 3, by applying the developed micro-grooved rollers to production lines for ultrawide optical films.

[*1] Member, FUJIFILM Corporation (210,Nakanuma,Minamiashigara,Kanagawa,250-0193)
[*2] FUJIFILM Corporation (210,Nakanuma,Minamiashigara,Kanagawa,250-0193)
[*3] Member, FUJIFILM Opto Materials CO., LTD. (463-1,Ohata,Yoshida-cho,Haibara-gun, Shizuoka, 421-0305)
[*4] Fellow, Tokai University (4-1-1 Kitakaname, Hiratsuka, Kanagawa, 259-1292)