DEVELOPMENT AND APPLICATION OF WATER-IN-OIL EMULSIONS FOR ZINC HOT ROLLING[①]

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ABSTRACT Zinc hot rolling emulsions based on water-in-oil have been developed, those are more flame resistant than oil and better lubricant than oil-in-water emulsions. It was likely that the EHL inlet region provides an effective filter against water particles, so that the elastohydrodynamic lubricant(EHL) film consists of oil only, which is important for the zinc product quality.

Key words: emulsion oil-in-water water-in-oil zinc hot rolling lubricant agueous lubricant

1 INTRODUCTION

Oil-in-water(O/W) emulsions for modern hot rolling technology have been used depending on demands for fire resistance, health and environmental safety. But they show significantly poorer lubricantion and adhesion protection than oils. It is necessary to search for a kind of suitable fluid used in zinc hot rolling, which is of more effective fire resistance than oil, and of better lubricating ability, lower cooling intensity than O/W emulsions.

For satisfying the requirement of specific technology for zinc hot rolling, the water-in-oil(W/O) emulsions has been studied and experimented in this study.

2 PREPARATION OF W/O EMULSION

W/O emulsion can be made with surfactant HLB value of 3～6. The laborary experiment emulsions were prepared by an emulsifier mixture of HLB 4.5 consisting of 70% sorbitan trioleate (span85) and 30% polyoxyethylene sorbitan trioleate(Tween85).

Emulsions were prepared from distilled water liquidized paraffin (or mineral oil) and emulsifiers, 10wt.-% of emulsifier was used. The emulsifier mixtures and liquidized paraffin were blended at 75 ℃ and water was added to the stirred blend at the same temperature.

3 PROPERTIES OF W/O EMULSION

3.1 *Influence Factors of* W/O *Emulsion Stability*

The HLB value of an emulsifier is an experimentally derived measure of its affinity for water as opposed to oil. Besides the HLB value of emulsifier the following factors are important for W/O emulsion stabilization.

(1) Phase volumetric ratio. If the dispersed spherical particles are uniformly arranged, the dispersion phase volume can reach 74.02%. It is said that W/O emulsion can be made up to 74.02vol.-% or 78wt.-%. Otherwise water becomes continuous phase producing an O/W emulsion.

(2) Material of emulsification container. O/W emulsion is easy to be obtained during preparation in case of the container wall has strong water affinity; on the contrary, W/O is easy to be obtained.

(3) Other factors. In the similitude of the

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surface solid film, if the emulsion is rich in emulsifier, the colloid film strength can be guaranteed. Polar organnic substances such as aliphatic acid, aliphatic alcohol, aliphatic ether, alkylamine etc. are advantageous to enhance the emulsifier actively and the film strength, increases emulsion stability. In addition, the smaller the disperse particle is, the higher the continous phase viscosity and the more stable the emulsion will be.

3.2 *Effect of Mixing Time*

For a W/O emulsion, mixing time has effect on the particle size distribution (Fig. 1). When mixing 1 min, the water particle size stretches from 0.5 μm to greater than 10 μm; 15 min from 0.5 μm to less than 5 μm, assembly average $d_P = 1.5$ μm; prolonging the mixing time further, the distribution curve keeps almost the same as mixing 15 min.

Fig. 2 shows the effect of mixing time on viscosity. With increasing mixing time, viscosity of emulsion reduced from quick to slow.

3.3 *Effect of Water Concentration*

Water concentration has decisive effect on the emulsion type (Fig. 3). W/O emulsion of the water concentration from 0 to 78%, the viscosity increase is tenfold. Fig. 4 and Fig. 5 show the effect of the water concentration on oil film thickness. Untill the water concentration is too high to make the emulsion tend to invert, the film thickness varies quite little.

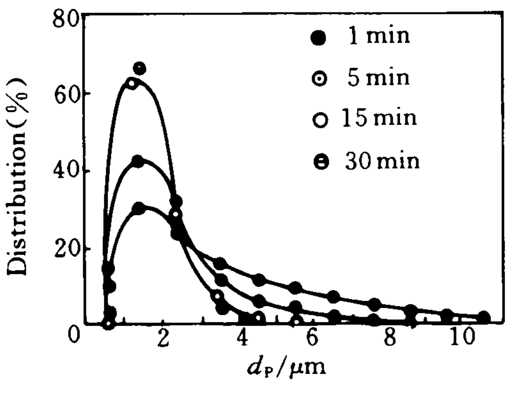

Fig. 1　Effect of mixing time (d_p) on particle size distribution

4 ROLLING TEST

4.1 *Zinc Strip Rolling Process*

The rolling mill composed of double rollers and roller cages was used to match with Hazelett zinc plate continuous casting equipment for the industry test. The ingot of the continuous casting equipment was 12.7 mm in thickness, 600~736 mm in width, and 5 m/min in pulling speed. The finished plate has the minimum thickness of 3.3 mm, strip coil diameter of 1 450 mm and coil weigth of

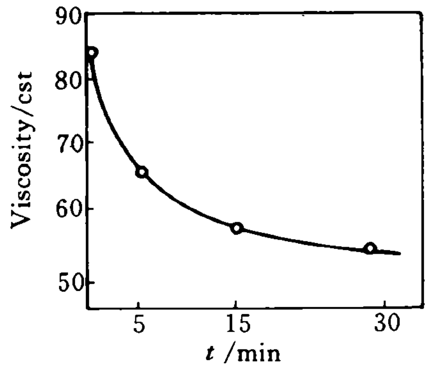

Fig. 2　Effect of mixing time (*t*) on the viscosity

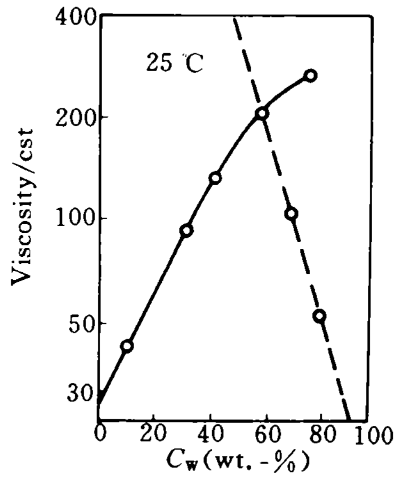

Fig. 3　The effect of water concentration (C_W) on the viscosity

full line　W/O emulsion;
dot line—O/W emulsion

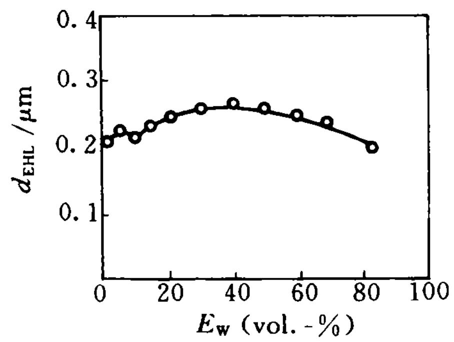

Fig. 4 The EHL film thickness(d_{EHL}) for an emulsion of water in liquid paraffin with different water content(E_W)

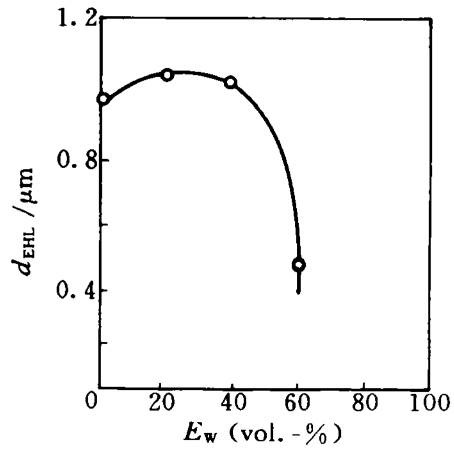

Fig. 5 The EHL film thickness(d_{EHL}) for an emulsion of water in mineral oil with different water content(E_W)

7 000 kg. Tandem rolling mills equipped an oil cooling system with a cooling pond of 60 m^3, a new type of emulsion spray nozzles of maximum spraying volume 3 000 L/min. Allowed maximum rolling force is 6 000 kN, rolling speed is 0. 1 ~ 0. 5 m/s. There are several standards for finished product inspection, i. e. the product surface should be clear, no air babbles, no scalings, no dirts, no water traces and no scratches, pits, rolling traces that deeper than allowed deviatin of finished plate thickness; Surface hardness must be lower than HB46 to eliminate or decrease wear of die and punch. There is no special lubricant for zinc hot rolling process at home and abroad, but prosol 67 form Mobil Co. and various emulsions of inland have been used, and they were not satisfactory with the technology. At first there were some white defects on product surface, secondly the surface hardness of product was too high. These unsolved quality problems have greatly affected on the competitive power of zinc products.

The start rolling temperature of casting plate is 250 ℃ properly. Since the deform ratio and deform speed are quite low, the coolants cooling intensity must not be too large.

4. 2 *Experiment Results*

The coolant pond used in the laboratory experiment is 2~3 m^3 in volume. The rolling speed, start rolling temperature, deformation rate, concentration of oil in W/O emulsions and some other parameters of rolling process had been changed. The major results are as follows:

(1) Raising the lubrication ability

When the rolling processes were quite alike, the rolling force of using W/O emulsions was 25% lower than that of using O/W emulsion. Since the W/O emulsions provided the capacity to build-up oil film, that is quite alike as oil. Deformation of the workpiece results in a very subtantial enlargement of surface areas, new fresh metal surface is exposed, the lubricat film protects not only the oil but also the new surface. The exsiting oil film decreases the metal flow resistance diminishes and elimiates the direct contact between the rolls and workpiece. The sliding took place within the oil film decreases the friction and the additional deformation force led by the friction.

(2) Controlling end rolling tempreature

End rolling temperature could be controlled to be over 165 ℃ due to using W/O emulsions during rolling process, so that the surface hardness of the rolling product was satisfied for the standard requivement. Table 1 listed the surface hardness from three rolling tests using W/O emulsions.

Table 1 The surface hardness of product by side to side arrangement

Test Order	Pull-out speed/m·min⁻¹	T_S/ C	T_E/ C	D_C/mm	D_R/mm	HB				
						P_1	P_2	P_3	P_4	P_5
Ⅰ	4.5	250	160	12.7	3.50	45.9	45.9	44.4	45.9	—
Ⅱ	4.5	250	174	12.7	3.61	45.9	45.9	45.1	45.9	45.9
Ⅲ	4.5	250	175	12.7	3.95	45.1	44.1	45.1	45.1	45.1

T_S —Start rolling temperature; T_E —End rolling tempenature; D_C —Casting plat thickness;
D_R —Rolling product thickness; $P_1 \sim P_2$ —Points for measuring hardness

5 CONCLUSIONS

Laboratory and industry test results show that it is preffered to use W/O emulsions instead of O/W emulsions. W/O emulsions possess the ability of forming EHL to protect their contact surface. It is likely that the EHL film inlet region provides an effective filter against water particles, so that the actural EHL film consists only of oil. Some EP (extreme pressure) agent, corrosion inhibitor in the W/O emulsions has active influence on the rolling process. The used emulsions have eliminated surface white defect. Their heat dispersion ability and flowability could be satisfied for the zinc hot rolling process.

It is worth to mention: if zinc plate pureness is higher, the recrystal temperature will be decreased. Increasing deformation ratio will produce more deformation heat. The coolant cooling effect can be increased.

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