Water-Free Electrostatic Spray for High Pressure Die Casting

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Abstract:

Water- Based Die lubricants (WBD) are widely used in the world. A new generation of Water Free Releasing (WFR) agent containing no water overcame the disadvantages of WBD in 2004. Because of very small amount of spray (1/800 over WBD), LUBROLENE WFR provided technical, economical & environmental benefits. But due to small amount of spray, mists of WFR had a difficulty to reach all surface areas in the case of complicated cavity. In 2009, this difficulty was overcome by developments of “Electrostatic Charged spray gun” for die-casting use and “an innovative WFR agent for Electrostatic spray” so called LUBROLENE WFR-EC. With this innovative WFR-EC which has unique features for productivity, economics, and environment**,** we aim to change the die casting world. However, by simply changing die lubricant not everything goes well, we believe it is necessary for us to work together with die casters for our big leap forward.

1. Introduction

In die-casting process, Water-Based Die lubricant (WBD) has been used for about 40 years. It is good for mass production due to fire resistant feature and all die casting machines have been designed with the use of WBD. Because of this design, disadvantages of WBD lubricant were not discussed. Rather, all technical discussions were related to how to utilize WBD.

In 2004, those disadvantages were overcome by the introduction of a new generation die lubricant of Water Free Releasing (WFR) agent, which consisted of oily components without water. The major disadvantages of WBD were 1) narrow range of die temperature, 2) water residue on die surface and 3) short die life. In 2007, Mr. Izawa from Ryobi explained the advantages of WFR at WFO’s technical forum of GIFA. The remarkable benefit of WFR was just 1/800 of spray amount compared with that of WBD.

In 2009, an innovative system was added to this WFR series: Electrostatic Charged spray and a new WFR agent for this spray, so called WFR-EC. The feature of this system is “wrap around effect”. With an extremely small amount spray, sprayed mists can reach all surfaces of cavity. Releasing performance of WFR-EC is excellent.

This paper explains about technical features of WFR-EC and Electrostatic Charged (EC) spray unit over those of WBD.

2. Problems of WBD

The introduction of WFR consisting of oily components overcame the problems of WBD. As explained in 2007 at WFO technical forum, 3 major problems are re-explained below.

2.1 Narrow range of die temperature

WBD is an emulsion type fluid in which main oily active ingredients (0.2wt %) are mixed with by water (99.8wt %).

Rich water content of sprayed mists restrains applicable die temperature which affects the adhesion process and oil film formation on die surface. Roughly, 1/3 of sprayed mists do not reach to the die surface. 2/3 of them, reach the die surface. Out of this portion, 1/3 , is used for cooling. The rest of them, 1/3, is used for oil film formation.

The oil film formation is illustrated in Fig-1. A mist collides with the die, its water portion evaporates and oil portion adheres on the die surface to form oil film. Depending upon die temperature, the amount of adhesion changes.
1. At 150 C or lower, water does not evaporate so quickly. Due to this condition, oil portion goes down to a floor as an emulsion. Less efficient on oil formation.
2. At 250 C or higher, WBD mists rapidly boil, resulting in a rebound from the die surface. This is so called Leidenfrost phenomena (LF). The rebounding mists go down to a floor. It causes very low efficiency on oil formation.
3. Temperature between 150 to 250 C is efficient range. Generally, die surface

temperature is hotter than 250 C, WBD is used as a coolant at the early stage of spraying. So the applicable range is narrow. To fit to this range, excessive amount of WBD is sprayed for cooling.

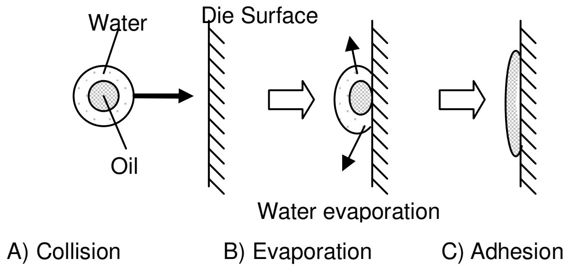


Fig-1: Adhesion process of WBD lubricant

2.2 Water residue on die surface

Even if oil film is successfully formed on the die surface, some amount of WBD remains in the die cavities. This causes a) porosity problem, b) water stain on the casting surface and c) explosion with hot molten metal. To dry water, air blow process is applied. This process wastes electric energy which is used to produce the CO2.

2.3 Short die life

Every shot, the die is cooled by water and heated by hot molten metal. When the die surface is cooled, tension stress decreases as shown in Fig-2. When it is heated, thermal stress increases (left side curve goes up). After thousands of shots, the repeated fluctuation on thermal stress breeds cracking of the die, resulting in short die life.

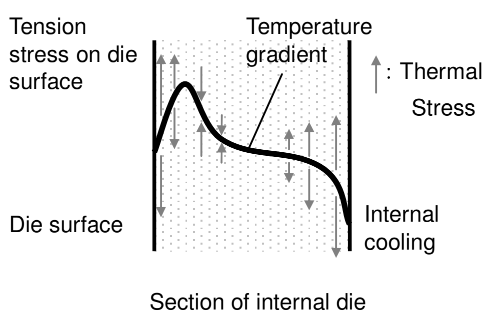


Fig-2: Thermal stress distribution of die

3. Development

Our developments involve following 2 stages.

1. First generation of WFR in 2004 to overcome the problems of WBD

2. Second generation of WFR-EC for Electrostatic spray in 2009 to further improve WFR for machines with a complicated cavity. This development involves a special spray unit.

3.1 First generation of WFR

In 2004, WFR was developed to overcome the problems of WBD. WFR's excellent features were introduced at WFO technical forum in 2007.

3.2 Second generation of WFR-EC

A) Needs

WFR had a minor difficulty in complicated cavities such as lubricating the back of the core pin. In 2009, "electrostatic charged WFR-EC" was developed to overcome this.

B) Addition of Electrostatic Charged feature

Since all of oil type lubricants including WFR are electrical insulators, electrostatic spray is not applicable to WFR. For giving an adequate electrical conductivity (20-800 Mohm), small amount of water was resolved in WFR with the assistance of surfactant. This is WFR-EC. (Electrostatic Charge is not applicable to WBD due to "too high electrical conductivity")

C) Formulation

WFR-EC consists of a) WFR formulation (mineral spirit carrier & oily ingredients for oil film formation) and b) of water/surfactant mixture for electrostatic charge. The Electrostatic Charged feature is just added onto WFR's feature. Since WFR-EC has a "wrap around effect" mentioned below, adhesion property & oil film formation capability of WFR are increased dramatically.

D) Electrostatic Charged Spray unit

For this WFR-EC, a special Electrostatic spray gun was also developed by Asahi Sunac Corporation. Compared with an ordinary electrostatic spray gun for painting, spray amount is about 1/50, and gun size is smaller.

4. Quality related features of WFR-EC

Excellent quality of WFR such as high Leidenfrost temperature, high adhesion efficiency, thicker oil film formation and low frictional property are explained below. In addition, the wrap around effect by electrostatic spray is also mentioned below.

4.1 High Leidenfrost temperature

WFR has a higher Leidenfrost (LF) temperature than WBD: 250 C of WBD vs 400 C of WFR. This feature was also kept for WFR-EC by selecting the same oily ingredients as mentioned above. Because of this high LF point, a rapid boiling does not occur at the die surface to 400 C plus. It can be said that WFR & WFR-EC have a broader application range (150 C to 400 C) on die temperature.

The high LF temperature provides two significant features of 1) no need of die cooling by lubricant, resulting in less amount of lubricant spray 2) more adhesion of oily ingredients or thicker oil film formation. These effects are mentioned in 4.3 of Adhesion level.

4.2 Wrap around effect

With the combination of WFR-EC and the spray gun, the sprayed mists will easily go around the back of the core pin as shown in Fig-3. It is called "Wrap around effect".

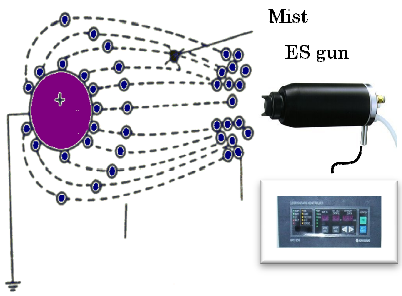


Fig-3. Electrostatic Charge System

This effect was visually demonstrated with a can which was coated with white powder (see Fig-4). WFR-EC was sprayed with & without electrostatic charge conditions. The surface of the can was steel colour (wet by WFR-EC) in the case of "with Electrostatic / back", while the can was completely white (not wet by WFR-EC) in the case of "without Electrostatic/back".

	front	side	back
With electrostatic			
Without electrostatic			

Fig-4: Wrap around effect

This feature greatly reduces soldering problem in the complicated cavity since mists go to the back of the cavity and core pins.

4.3 High adhesion efficiency

Adhesion efficiency was evaluated in an adhesion tester. The adhesion efficiency is the ratio of "adhered oil portion on steel test piece at 250 degrees C over total sprayed amount of oil ingredients". As shown in Fig-5, the adhesion efficiency values are 3% by WBD, 25% by WFR and 65% by WFR-EC, respectively.

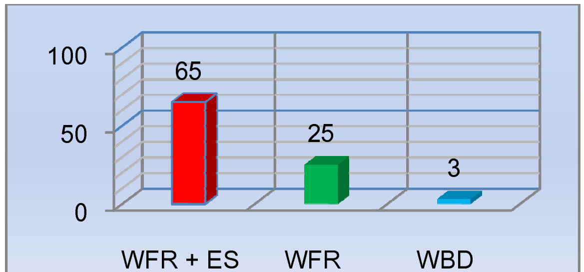


Fig-5. Adhesion Effieiency(%)

WFR's high efficiency (25% vs 3% of WBD) is delivered from 1) high LF temperature 2) excellent selection of oil ingredients and 3) excellent evaporation of mineral spirit carrier, which minimizes dripping down of adhered mists on iron plate surface.
WFR-EC's excellent efficiency (65% vs 25% of WFR) is delivered from the application of Electrostatic Charge.

4.4 Thicker oil film formation

The excellent adhesion efficiency is also observed in thickness tests: 0.5 micron by WBD, 3 by WFR and 5 by WFR-EC as shown in Fig-6. (The lower line represents the surface of steel plate and the upper line shows the oil surface level. The bigger the gap is, the thicker the oil film thickness).

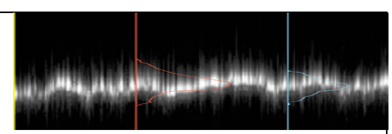
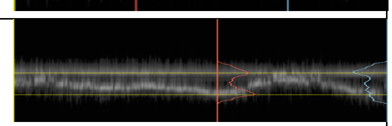
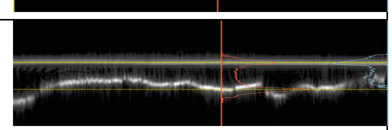
WBD 0.5 micron m	
WFR 3 micron m	
WFR -EC Electrostatic 5 micron m	

Fig-6. Comparison of Oil film thickness

4.5 Low friction property

As shown in Fig-7, WFR-EC has a lower frictional property than WBD. 10 Kgf friction level in labo tester is considered as a start of micro soldering in actual machines. Over 10 Kgf, micro soldering occurs. From this, it can be said that WBD is usable to 260 C, while WFR-EC is durable to 400 C. This excellent frictional property is resulted from 1) thicker oil film formation by electrostatic charge, high LF temperature & good evaporation of carrier, 2) appropriate selection of oil ingredients for high temperature use. In machines in the field, WFR-EC can avoid soldering up to 400 C.

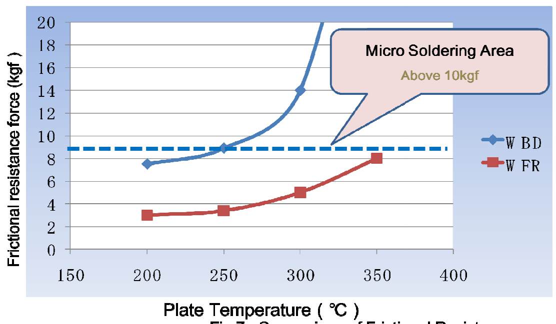


Fig.7. Comparison of Frictional Resistance

5. Performance related features of WFR-EC

Those excellent quality features of WFR-EC provide excellent performances in actual machines such as small amount of spray, countermeasures on WBD's problems, smaller size of porosity and other performances. Those features are explained below.

5.1 Very small amount of spray

In general, 2000 cc of WBD is sprayed to 2000 tons machine. In the case of WFR-EC, 2 cc is sprayed. 1/1000 of spray amount over WBD! This is delivered from 1) higher LF temperature, 2) very high adhesion efficiency of electrostatic charge, 3) good oil ingredient selection to adhere and 4) excellent evaporation of the mineral spirit carrier to form semi-solid oil film like a fast drying paint.

5.2 Broad range of die temperature

As mentioned in Section 2.1, WBD has the problem of "Narrow range of die temperature". This can be easily resolved by WFR & WFR-EC because WFR & WFR-EC have a high LF temperature. A <u>rapid boiling does not occur at the die surface to 400 C plus</u>. Compared with WBD, WFR-EC shows a broader application range (150 C to 400 C) on die temperature. This is confirmed by many die-cast machines. Considering frictional durability, 400C is the realistic maximum temperature.

5.3 No water residual on die surface

As mentioned in Section 2.2, WBD has the problem of "water residual on die surface". WFR-EC resolves this problem since its water content very small and spray amount is very small. It can be said that WFR-EC does not leave any water on the die surface. Because of this, WFR-EC has following merits:

a) No porosity which is related to remained water.
b) No need of "air blow process", resulting in shorter cycle time
c) No need of air blow to dry water, resulting in electric power saving or CO2 reduction.

On the items of b) and C), actual performances were evaluated using a typical Japanese size of 350 ton machine for 3 months.

b) Every shot, 3 seconds saving for air blow This corresponds to 8% shorter cycle.
c) Every shot, 0.34 KwH electric power saving. This corresponds to 0.12 Kg of CO2 saving. Since this size machine works about 500,000 shots per year, CO2 reduction reaches 60 tons /year/machine.

5.4 Longer die life

As mentioned in Section 2.3, WBD has the problem of "short die life". WBD causes the fluctuation of die surface temperature every shot, resulting in crack formation on die surface at around 20,000 shots. After repairing the die surface several times, the die is finally changed to a new one. Generally, the die life is 150,000 shots in the case of 350 tons machine.
WFR-EC prolong die life due to very small spray amount which leads to almost no cooling. Two customers checked crack formation: No crack was observed at 800,000 and 600,000 shots by WFR, respectively. Both of them said that a) they could not confirm the die life itself as the die outlived the number of parts to be made and b) they felt that the die would last forever.

Considering the maximum production number of die casting per machine, a smaller value of "6 times longer" is used for estimating die economics. In the case of 350 tons machine, the cost saving of each machine reaches €125k year. This is the biggest economic effect of WFR-EC.

5.5 Smaller size of porosity

At actual die-casting sites, a very low level rejection rates were visually observed with WFR-EC: almost zero of WFR-EC vs several % of WBD. This was supported by CT scan check of a die-casted product. Observed data were 1) porosity size: 0.1 mm or smaller of WFR-EC vs 1-2 mm by WBD and 2) homogeneous porosity formation of WFR-EC versus larger porosity near outside of the product by WBD.

The followings would be reasons why WFR-EC is better than WBD.

a) WFR-EC does not cool the cavity compared with WBD.
b) Molten metal is higher temperature
c) Molten metal flow is better.
d) Stronger turbulent flow of molten metal
e) Trapped gas becomes smaller

Limited number of data support that a die-cast product with WFR-EC has a slightly higher strength. This is probably due to homogeneous / small porosity.

5.6 Other features of WFR-EC
ENVIRONMENT-FRIENDLY

1. No waste water disposal, WFR requires small spray amount control, and this also contributes to reduction of Co2 generation thru reduction of electric power for water treatment device.
2. Non-flammable in liquid form in foundry environment, including in direct contact with molten aluminum.
Non flammable as a vapour off the hot die as the carrier component evaporates.
No human health or environmental hazards associated with WFR.
3. Other electric power saving can be achieved through a) reduction of re-melting of rejected product because of excellent releasing performance and b) reduction of air blow and c) reduction of molten metal temperature. In total, 180 tons with 500t DC/M of <u>CO_2</u> can be reduced per year.

6. Conclusion

In 2004, WFR agent was introduced. Because of no water, it lubricates die with 1/800 of amount as explained at WFO technical forum in 2007. Due to too small amount of spray, it has a minor difficulty in lubricating a complicated cavity, especially behind core pins. This difficulty was overcome by the developments of WFR-EC and the Electrostatic Charged spray gun in 2009. WFR-EC provides following merits over WBD.

Items	Merits
Performance Applicable temperature	Wider, 130 - 400 C
Releasing	Excellent Low rejection rate: 0-1%
Environment	No waste water CO_2 reduction : 180 tons /500t DCM / Year
Economics	Longer die life €125k / Year

7. Further development

Some die-casting machines show quite high die temperature like 430 C. For those machines, powder containing WFR-EC (with less oily ingredients) has been developed as the third generation WFR. It is called NPL. Its specific features are 1) no soldering even at an extremely high die temperature, 2) less gas formation or less porosity and 3) a smooth & beautiful casting surface even at lower die temperature like 200 C. Performance data is now being accumulated.

Finally, we would like to thank all WFR users involved in developing WFR-EC.
With this innovative WFR-EC which has unique productivity, economic, and environmental features, we aim to change the die casting world. However, by just changing die lubricant not everything goes well, we know it is necessary for us to work together with die casters for our big leap forward.

8. Reference

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