“NS blade” / ADVANCED AIR KNIFE FOR HOT DIP CONTINUOUS GALVANIZING LINE

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SYNOPSIS:

Nippon Steel& Sumikin Engineering (hereinafter referred to as “NSENGI”) and its subsidiary CN Steel Plant Engineering Co., Ltd. (hereinafter referred to as “CNSE”) have supplied fifty-six Hot Dip Continuous Galvanizing Lines (hereinafter referred to as “CGL”) all over the world and also NSENGI has been developing the Air knife for Coating machine, it’s the key technology of CGL, and improving a product quality and productivity over forty years.

This paper presents newly developed Air knife technology which is called “NS blade”. In order to clarify the mechanism of zinc splash of strip edge and edge over coating (hereinafter referred to as “EOC”) which harm the high speed and thin coating operation, for the first time, experiment with high speed operation has been carried out with the use of several types of Air knife for above harmful phenomenon. As a result, “NS blade” was the most effective as a countermeasure for zinc splash and EOC compared to the results of ordinary type of Air knife. Moreover, the effect is studied with the comparison of the results analysed by numerical simulation. “NS blade” has the position-variable blades inside the acute angle Air knife. The blade inside Air knife interrupts air jet so that air wiping width coincidences with strip width. The position of these blades is controlled suitable to the strip width by Edge Position Controller. As a result, “NS blade” allows air jet to scrape molten zinc off with air consumption reduction, to protect EOC and to reduce zinc splash even at high speed operation and thin coating operation. In addition, air jet noise level and zinc consumption are reduced dramatically because there is no impinging jet except strip area. Therefore, “NS blade” enables environment-friendly operation in CGL.

Keywords: CGL, “NS blade”, Splash, EOC, Noise

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1. Introduction

The coating thickness of a hot-dip galvanized steel strip is adjusted in microns with a good accuracy by immersing the strip into molten zinc to cause the molten metal to attach to the strip surface, and then by air jet out from a pair of wiping nozzles. However, during thin coating operation at high speed particularly, it is necessary to increase the flow speed of air jet, which has posed problems, such as zinc splash at the strip edge and edge over coating (EOC) caused by wiped zinc. NSENGI has developed the new air knife/wiping nozzles (hereinafter referred to as NS blade) to respond to the needs of high speed lines and thin coating operations in recent years. This paper describes the structure of the NS blade and introduces the performance comparison experiments and analysis made between our conventional nozzles and NS blade. In addition, the paper discusses the effects achieved by commercial line tests.

2. Features of “NS blade”

In the conventional nozzles, jet flows collide each other directly in areas where there is no strip, causing the strip edge to be subject to this effects especially, which prevents normal wiping (Fig.1). As a result, zinc splash at the strip edge and EOC are caused by the influence of impinging jet. As an existing countermeasure, edge baffle plate is used for the phenomenon mentioned above (Fig.2). The insertion of the edge baffle plate between the nozzles prevents the collision of jet flows each other in the areas where there is no strip. As a result, the occurrence of zinc splash at the strip edge and EOC can be reduced. However, the effects are deteriorated due to the influence of collision of jet flows if a clearance between the edge baffle plate and the strip becomes 5mm or greater. On the contrary, if the edge baffle plate is positioned too closer to the strip, wiped zinc and irregular zinc mass on strip edge attaches to the edge baffle plate, and builds up there gradually.

In addition, if the strip vibrates, or C camber is generated, preventing the strip from being set in the same plane as that of the edge baffle plate, air jets of the front and back nozzles become out of balance, which causes the effects of the edge baffle plate to be deteriorated.

On the other hand, NS blade incorporates two sets of blade and chamber partition in a nozzle, causing uniform pressure air to flow out in the width direction between the right and left blades. Moreover, an interval between the blades is automatically controlled by the non-contact strip edge detecting sensor in accordance with the strip width. As a result, it is established that the strip width is always equal to wiping width, making the disturbance at the strip edge which occurred conventionally smaller, and making zinc splash at the strip edge or EOC less likely to occur. As the blades are installed in the nozzle, the blades do not come in contact with the strip even if the blades come closer to the strip according to the strip width, therefore, zinc splash does not attach to blades so much as the edge baffle plate. Consequently, this has enabled thin coating operations at a high speed. Further, the collision of jet flows is prevented in the areas where there is no strip, which has lead to a reduction in the noise sufficiently, and has improved the noise environment of the operators. The features and effects achieved from NS blade experiments, analysis and commercial line test are described below.

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[Diagram of NS blade and conventional nozzle showing differences in jet flow and wiping effectiveness.]

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3. Coating Test
3.1 Experimental apparatus and procedures

Fig. 4 shows the schematic figure of the hot-dip galvanizing experiment apparatus. The steel strip (Width: 280mm wide, Thickness: 0.71mm) was pre-heated in the annealing furnace and immersed into the zinc bath kept at 460°C at the strip temperature of 550°C, and then surplus zinc was wiped off by the wiping nozzles. The line speeds were 160mpm and 180mpm. A sound meter was installed at a place 1.5 m away from the nozzles, and a noise from the wiping nozzles was measured, and 1/3 octave analysis was conducted. In addition, the cameras were installed in the front and side of the nozzle lower part to visualize zinc splash conditions. Also, samples after coating were collected, and coating weight was measured. The coating test was conducted using two types of nozzles, such as ordinary type and NS blade.

![Figure 4: Schematic of experiment apparatus](image)

3.2 Experimental results and discussion

(1) Test results of edge splash

Fig. 5 shows the photographs taken from the front and side of the nozzles (at the line speed of 180mpm). From Fig. 5, it is found that amount of zinc splash from the edge is apparently less in the case of NS blade than that in the case of the ordinary type.

![Figure 5: Edge splash (Front view and Side view)](image)
In order to clarify the air flow in the neighborhood of the strip edge for the ordinary type and NS blade, 3D non-stationary fluid analysis was conducted. In the analysis, the general-purpose thermal fluid analysis software Fluent v6.3 was used, and LES was adopted as a turbulent model. As the boundary conditions at the inlet, the stagnation pressure and stagnation temperature were determined to be 40kPa 300K respectively. As the outlet boundary conditions, atmospheric pressure was adopted. Meanwhile, the analysis was conducted under the conditions that no zinc coating would attach on the strip surface, and the strip would be static. Fig.6 shows the vector of flow speed on the plane 1mm away from the strip surface. From Fig.6, it can be thought that the NS blade was able to reduce zinc splash because the flow speed from the strip edge to outside was smaller than that of the ordinary nozzle.

![Flow velocity vector](image)

*Figure 6: Flow velocity vector*
(2) Test results of edge over coating

Fig. 7 shows the distribution of coating weight. The horizontal axis shows the distance from the strip edge, while the vertical axis indicates the relative coating thickness. From Fig. 7, it is found that EOC is caused up to a point 10 mm from the strip edge in the case of the ordinary type, however, no EOC is caused in the case of the NS blade.

The reasons for this are that there is no attenuation of wiping jet due to collision of jet flow in the neighborhood of the strip edge which was analyzed in Fig. 6 which is assumed to have effectively restrained zinc flow toward the strip edge after zinc wiping.

(3) Test results of noise

Fig. 8 shows the noise levels generated from the nozzles during the test. From Fig. 8, it is found that the noise levels of NS blade are smaller than those of the ordinary type. As described above, NS blade causes no collision of jet flow in the areas where there is no strip, therefore the noise level of NS blade can be reduced more than that of the ordinary type. As a result, it is thought that the NS blade can contribute to the improvement of on-site noise environment.

![Figure 7: Coating weight distribution](image1)

![Figure 8: Noise level](image2)
4.1 Galvanizing line

NS blade was installed in the continuous hot-dip galvanizing line. The strip edge was detected by the sensor to control the blade position. The strip width was 914mm and 1219mm, and the maximum line speed was 160mpm. The coating weight was Z08 to Z27. Fig.9 shows the distribution of coating weight in the strip width direction. From Fig.9, it is found that NS blade has achieved more uniform coating in the width direction than the ordinary nozzle, and a reduction in EOC was confirmed also in the commercial line.

In addition, NS blade achieved the operation of Z08 (40g/m² per side with a variation 10% or less) at a line speed of 160mpm maximally, which hadn’t ever been achieved by the ordinary nozzles. The noise level at this operation was from 95 dB to 105 dB.

![Figure 9: Coating weight distribution](image)

4.2 55% Aluminum Zinc coating line

NS blade was also installed in the 55% Aluminum + Zinc coating line. The strip width was 914mm and 1250mm, and the line speed was 150mpm maximally. The coating weight was AZ30 to AZ165. The NS blade achieved the operation of an extremely thin coating weight of AZ30 (15g/m² per side, with a variation 10% or less) at a line speed of 150mpm maximally without any problem. In addition, the noise level at this time case was from 95 dB to 100 dB.
5. Conclusion
   In order to verify the effects of NS blade, zinc coating experiment was carried out at test line. Air flow behavior near strip edge was checked by numerical calculation to verify reduction in EOC, noise levels and amount of zinc splash generation. Further, we achieved the operation test in the commercial line, and also attained the maximum line speed and targeted minimum coating weight in each line in the actual operations, and we confirmed the superiorities of NS blade to the ordinary nozzles.

6. Acknowledgement
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