“NSblade™”/ Application of Advanced Air Knife to Hot Dip Continuous Galvanizing Line
— Improvement of operational stability at high speed production —

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Abstract

Zinc coating weight of galvanizing steel strip is accurately controlled by Air knife located at both sides of strip. Recently, quality and productivity improvement as to hot dip galvanized steel sheet has been highly required. We, Nippon Steel & Sumikin Engineering Co., Ltd., has developed advanced air knife “NSblade™” through computational fluid dynamics, water model test, pilot line test and commercial line test. As a feature of NSblade™, wiping air width matched with strip width leads avoidance of air collision from top and bottom side at outside of strip edge. As a result, this device can reduce edge over coating and edge splash at higher speed operation. In this paper, the detail of development and the performance result after commercialization are described.

1 Introduction

Hot dip galvanized steel sheets with excellent corrosion resistance and workability have a wide variety of applications, such as construction materials, home appliances and automobiles. The hot dip continuous galvanizing line (CGL) produces hot dip galvanized steel sheets as shown in Fig. 1. In the galvanizing process, a material steel strip after heating in an annealing furnace is dipped into a molten zinc bath as shown in Fig. 2 to coat the surface of the steel strip with zinc. An air knife arranged on both sides of the strip is used to control the zinc coating weight accurately.

Recently, with the increasing number of hot dip galvanized steel sheet manufacturers, the demand for better quality (beautiful surface appearance and uniform zinc coating weight) and improvement in productivity through high speed processing of the strip has increased among companies to differentiate themselves from one another.[1-3] The process using an air knife is important because it affects the quality and productivity of hot dip galvanized steel strips, and therefore, improvement in the air knife has been demanded. To improve the air knife, however, two difficulties of air wiping impair the quality and productivity: (1) Splashing from the strip edge (edge splash) (phenomenon in which zinc is splashed at the steel strip edge) and

(2) over coating at the steel strip edge (edge over coating) (phenomenon in which the coating weight at both the steel strip edges is larger than that at the center). An ordinary air knife shown in Fig. 3 discharges air flow even to areas where there is no steel strip, so the jets from the top and bottom side collide with each other, which disturbs the flow near the strip edge. This turbulence causes zinc splash from the steel strip edge and that splash clogs the air knife nozzle tip, making stable operation impossible. In addition, the collision of the jets described above reduces the pressure to wipe the excess zinc at the strip edge, which causes edge over coating.[4)]

To prevent the collision of jets outside the steel strip edge, edge baffle plates (dummy plates) beside the steel strip edge were adapted. Such edge baffle plates located within 5 mm of the steel strip edge are effective for addressing the problem.[5)] However, the clearance between the steel strip edge and the edge baffle plate is too narrow; in the case that the steel strip bends suddenly, the steel strip edge may hit the edge baffle plates. As a result, if the bending amount is large, the clearance has to be kept larger, so the targeted effect cannot be obtained. In addition, if the steel strip and edge baffle plate become misaligned in the thickness direction as shown in Fig. 4, air flows in the formed clearance and the jets collide with each other, thus negating the effect of the edge baffle plates. Due to the problem of edge baffle plates from the aspect of operational stability, Nippon Steel & Sumikin Engineering Co., Ltd. has developed a new type of air knife NSblade™. and succeeded in commercializing it. This technology has led to the improvement of operational stability during high speed operation. This report describes the Research & Development details of NSblade™ and performance records since the commercialization.

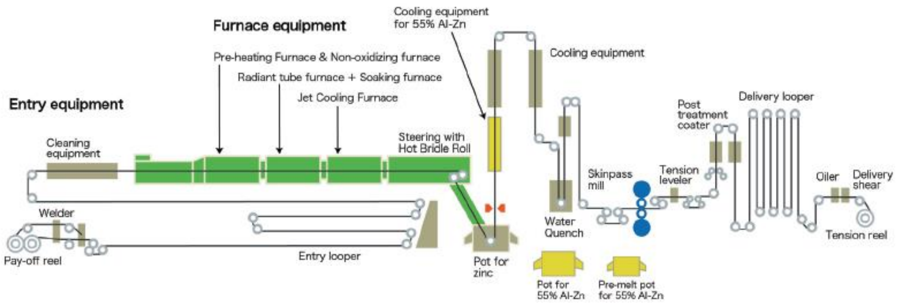


Fig. 1 Hot dip continuous galvanizing line

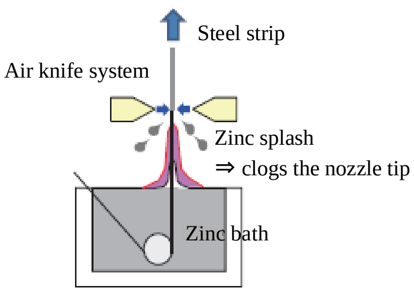


Fig. 2 Coating weight control

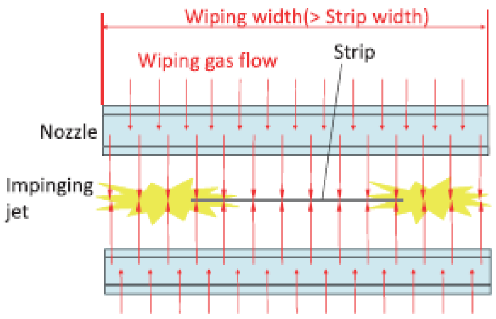


Fig. 3 Ordinary air knife

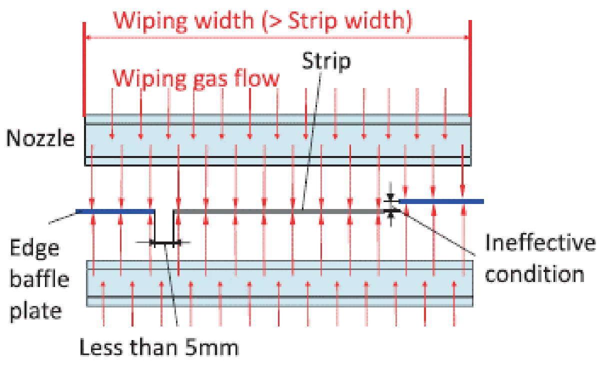


Fig. 4 Air knife with edge baffle strip

2 Development and Commercialization of NSblade™

2.1 Characteristics of NSblade™

Figure 5 illustrates the basic configuration of NSblade™. Individual air knife nozzles have blades to block the jet. This means that conventional edge baffle plates have been installed inside the air knife nozzles to avoid impinging on the jet outside of the strip edge. In addition, the position of the blades is controlled by non-contact sensors that detect the steel strip edge. As a result, the width of the wiping air always matches that of the steel strip, reducing turbulence outside of the steel strip edge and reducing zinc splash and edge over coating. Blades installed inside the air knife avoid physical contact with the steel strip edge or misalignment which were problems in conventional edge baffle plates.

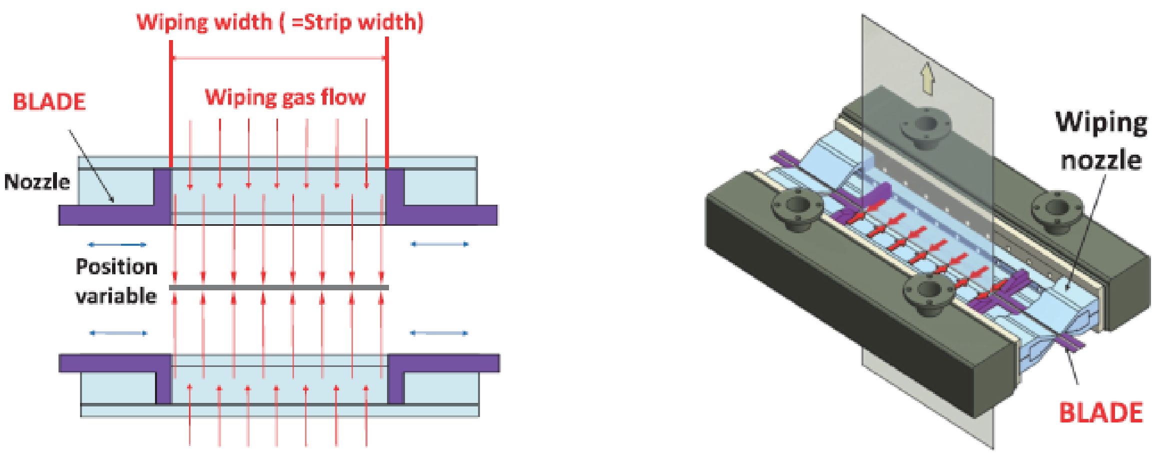


Fig. 5 Feature of NSblade™

2.2 NSblade™ development steps

NSblade™ was developed and commercialized using the following four steps. Details in each step and results are explained below.

Step 1: Computational fluid dynamics

Step 2: Water model test

Step 3: Pilot line test

Step 4: Commercial line test

Step 1: Computational fluid dynamics

The vorticity and flow velocity near the strip were compared between an ordinary air knife shown in Fig. 3 and NSblade™ in Fig. 5 by 3D nonstationary fluid analysis using the analysis software Fluent v6.3. Large Eddy Simulation (LES) was used as the turbulence model. Figure 6 shows the analysis model. Regarding the inflow boundary conditions in the air knife nozzle, the air pressure was 40 kPa and the air temperature was 300 K. To simplify the calculation, the steel strip was stationary, and only single fluid (air flow) was adapted. Zinc flow was disregarded. Figure 7 shows the flow near the steel strip edge. Regarding the ordinary air knife, the flow was disturbed due to the collision of the jets outside the steel strip edge. According to the numerical analysis results by Kim et al., the turbulence due to collision of the jets outside the steel strip edge as shown in the visualized result reduces the wiping pressure on the steel strip edge, which causes edge over coating.[4] On the other hand, because NSblade™ blocks jets outside the strip edge, the collision of jets can be avoided, which reduces turbulence. Therefore, NSblade™ is expected to be effective for preventing edge over coating. Figure 8 shows flow velocity vectors on a plane 1 mm away from the surface of the steel strip. In the case of NSblade™, the velocity of the flow from the steel strip edge toward the outside was smaller than that of the ordinary air knife; therefore, NSblade™ is expected to reduce zinc splash.

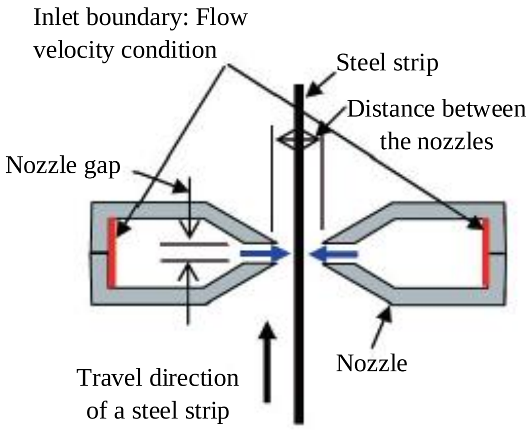
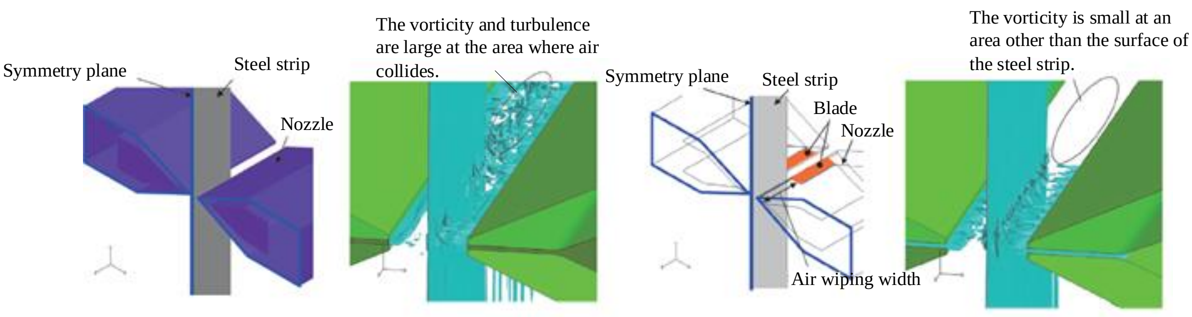
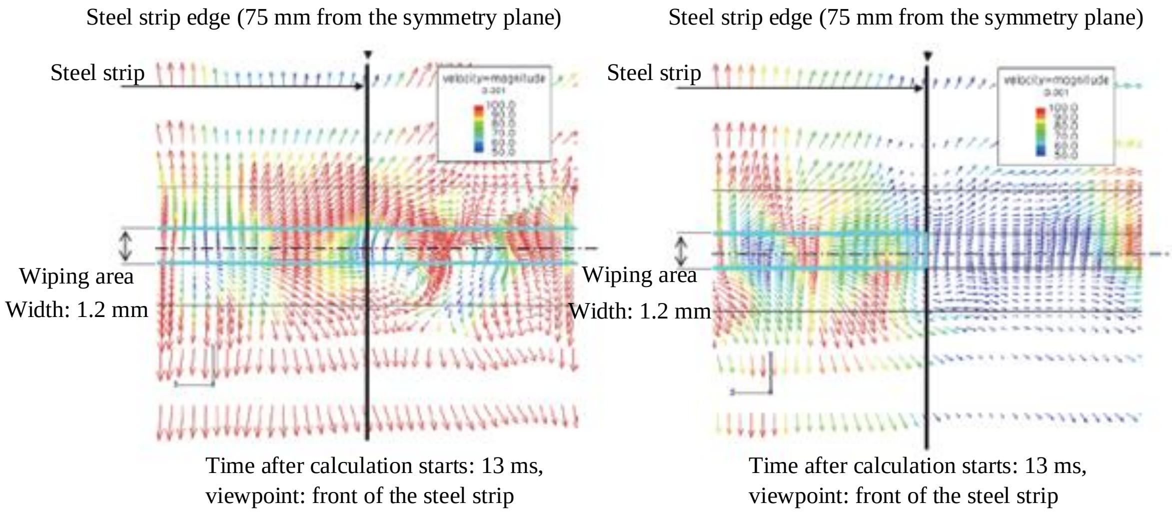


Fig. 6 Analysis model



(a) Regular nozzle (b) NSblade™

Fig. 7 Visualized turbulence at strip edge computed by CFD



(a) Regular nozzle (b) NSblade™

Fig. 8 Velocity vector of plane 1mm apart from strip surface

Step 2: Water model test

Water model test equipment was used to study the quantity of splash in order to demonstrate the computational fluid analysis results.

Figure 9 shows the water model test equipment. A stainless steel endless belt was processed in a water tank and then pulled up. Then an air knife was used to remove water. Water splash was collected 100 mm and 300 mm below the air knife and its weight was measured. The processing speed was from 160 to 215 m/min and the pressure of the air knife was 40 kPa. Figure 10 compared the weight of water splash between the ordinary air knife and NSblade™. Figure10 shows that the water splash was reduced thanks to the effect of NSblade™ for minimizing the turbulence near the steel strip edge that was confirmed in the computational fluid analysis.

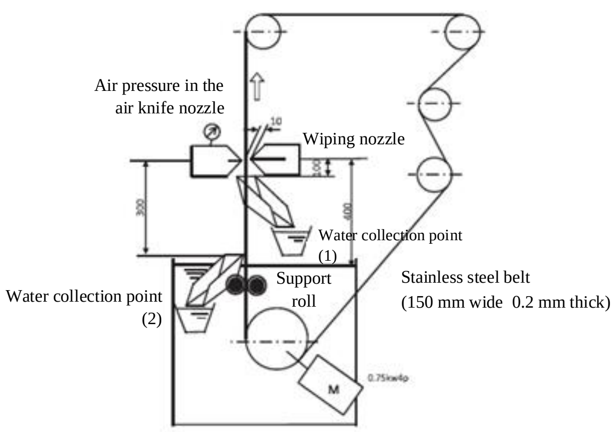


Fig. 9 Test equipment for water model

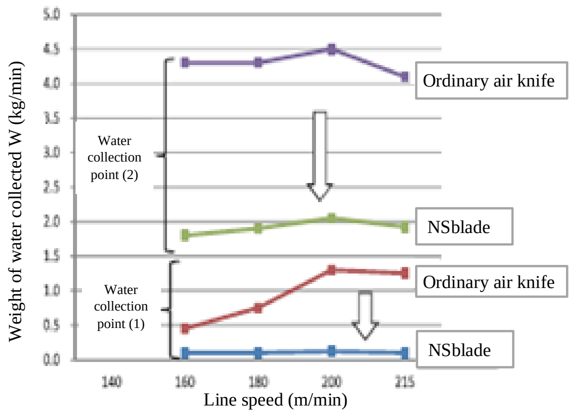


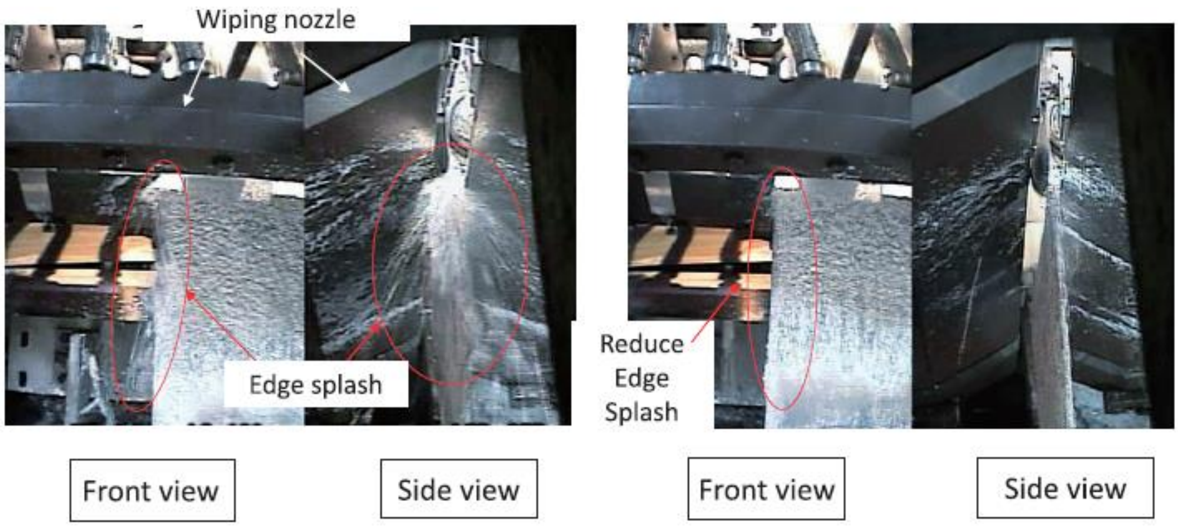
Fig. 10 Water splash weight measured by the water model

Step 3: Pilot line test

On a pilot CGL line, molten zinc was actually used to study and test the splash and distribution of coating weight at the steel strip. Steel strips (width: 280 mm, Thickness: 0.71 mm) were heated in an annealing furnace up to 550°C at the processing speed of 160 m/min and then fed into a molten zinc bath (GI bath) at 460°C. After that, the air knife (air pressure was 50 kPa) was used to wipe excess zinc and then the strips were cooled. Finally, samples were taken from the finished coil to measure its coating weight. Figure 11 shows splash and Fig. 12 shows the distribution of the coating weight when the ordinary air knife and NSblade™ were compared. It was confirmed that NSblade™ reduced splash and improved edge over coating while high speed operation using molten zinc as shown in Figs. 11 and 12. In addition, the noise of the air knife was measured when air pressure was 100 kPa. Figure 13 shows the results. Thanks to the prevention of the collision of air jets by NSblade™, the noise was reduced 10 to 30 dB in the range of 1 kHz to 3 kHz. These results indicate that NSblade™ could be applied to actual operation.

Step 4: Commercial line test

With our customer’s cooperation, an actual operation test by using NSblade™ on a commercial line was conducted. Table 1 shows the operation conditions. NSblade™ was used for approximately two weeks in the GI pot that had been tested on the pilot CGL to verify the durability of the blade’s drive mechanism and coating quality. Through these steps, the development and commercialization of NSblade™ was completed



(a) Ordinary air knife

(b) NSblade™

Fig. 11 Comparison of zinc splash condition between ordinary air knife and NSblade™

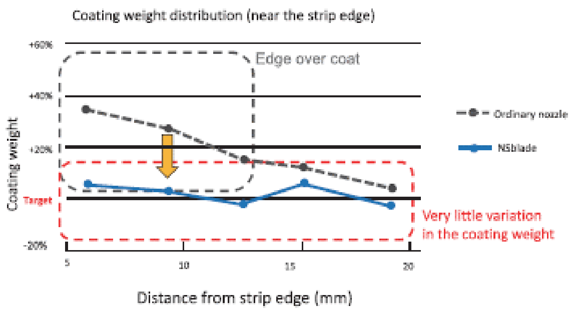


Fig. 12 Coating weight distribution at strip edge

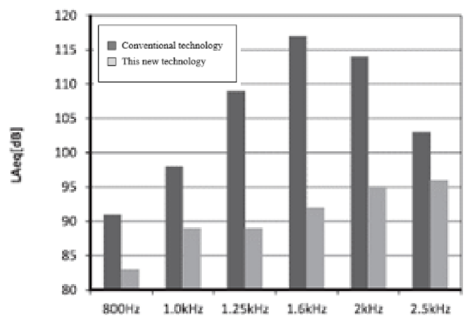


Fig. 13 Noise level of air knife

Table 1 Operation condition

Coating bath	GI
Temperature	460°C
Maximum processing speed	160m/min
Coating weight (both sides)	80—270g/m^2
Width of steel strip	914—1,219mm
Splash	None
Edge over coating	None

3 Delivered NSblade^{TM} and Effects by Introduction

The first commercial NSblade^{TM} was delivered to Ton Dong A Corporation (Vietnam) in 2013. Since then, seven NSblade^{TM} have been ordered (as of September 2017.) Figure 14 shows the appearance of the NSblade^{TM}. Table 2 shows the delivery records (as of May 2017). Three of them were revamping projects in which NSblade^{TM} was applied to other supplier’s CGL. The effects by the introduction are described below.

Fig. 14 Overview of NSblade^{TM} (Photo)

Table 2 Supply record list of NSblade^{TM}

No.	Customer	Products	Maximum Line speed	Coating weight range
1	Rachashima No. 3 CGL	GI	160mpm	80-270g/m^2
2	Ton Dong A No. 4 CGL	55%Al-Zn	150mpm	30-200g/m^2
3	“A” Company CGL	GI	160mpm	80-350g/m^2
4	Ton Dong A No. 3 CGL	55%Al-Zn	108mpm	30-200g/m^2
5	Tianjin Xinyu New CGL	55%Al-Zn	220mpm	50-200g/m^2
6	“B” Company CGL	55%Al-Zn	180mpm	40-200g/m^2
7	PT TATAMETAL No. 1 CGL	GI 55%Al-Zn	120mpm	GI : 80-300g/m^2 55%Al-Zn : 30-200g/m^2

3.1 Reduced edge over coating and splash

Table 3 shows the results of the introduction of NSblade™ to the GI coating bath and 55%Al-Zn coating bath. The table shows that the occurrence of edge over coating and splash was reduced compared to the existing air knife. Figure 15 compares the coating weight distribution at the edge of the strip in a 55%Al-Zn coating bath as an example. Before NSblade™ was introduced, production by staggered winding (method for winding the strip while shifting the steel strip edge) due to edge over coating had been problematic. The introduction of NSblade™ eliminated edge over coating, which enabled production by flat winding.

Table 3 Comparison of Edge over coat and splash

Coating bath	GI	55%Al—Zn
Temperature	460°C	600°C
Edge over coating	Reduced	Reduced
Splash	None	None

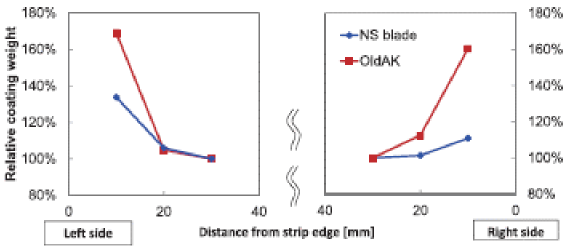


Fig. 15 Comparison of coating weight distribution

3.2 Reduced production of top dross

After another company replaced its air knife with NSblade™, the quantity of top dross decreased as shown in Fig. 16. Top dross refers to zinc oxides (ZnO) formed on the surface of a molten zinc bath. The air discharged from an air knife impinges on the steel strip and the downward jets reach the zinc bath surface, which oxidizes zinc to form top dross. Because these oxides are impurities, they reduce the yield of the zinc bath. In addition, top dross adhering to steel strip leads to a surface appearance defect, to prevent the issue operators use a spoon to scrape off top dross on the molten zinc bath periodically (approximately once an hour) for cleaning.

Table 4 compared the flow rate of discharge air. An ordinary air knife discharges air even to the outside of a steel strip. Such excessively discharged air leads to the formation of top dross. On the other hand, NSblade™ can match the wiping width to the strip width and can reduce the required flow rate of discharge air. As a result, NSblade™ can prevent excessive oxidization and can reduce the quantity of top dross produced.

The application of NSblade™ to nitrogen wiping nozzles for manufacturing high-grade coated steel strips and wide air knife for automobile steel sheets in the future is expected to further reduce running costs by minimizing the nitrogen consumption.

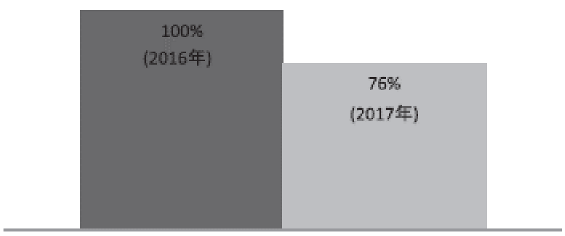


Fig. 16 Quantity of Top dross generation

Table 4 Comparison of discharge air flow rate

With of steel strip	Ordinary air knife (width of 1600 mm)	NSblade^{TM} (wiping width = steel strip width)
900mm	3,000Nm3/hr	1,500Nm3/hr (50% saving)
1200mm		2200Nm3/hr (27% saving)

4 Conclusion

This report describes details of the development of NSblade^{TM} and performance results after it was commercialized. NSblade^{TM} conducted fluid analysis, a water model test, pilot line test, and commercial line test to demonstrate its effects, which then led to its commercialization. In addition, NSblade^{TM} has overcome the existing problem with the operational stability of edge baffle plates and reduced the occurrence of edge over coating and splash, and is thus highly valued by customers. We will remain in close contact with customers to gauge customer opinions quickly in order to propose technologies that satisfy their needs.

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