A Study on the Characteristics of Electro-discharge Texturing for Temper Mill Work Roll

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This paper investigates the correlation between strip surface roughness and the surface of a temper mill work roll. As the actual temper mill is used, this data will be adopted to another actual temper mill for the application and operation of this experiment. The conclusions are as follows: The electro-discharge texturing(EDT) roll has a homogeneous roughness distribution and shape, and also a sinuous peak surface, and the life time is 2 times longer than that of the shot blast texturing(SBT) method. The higher the surface roughness of the work roll, the more time is necessary for the electro-discharge texturing method. But the shot blast texturing cannot control peak counts and produces irregular surface quality. The roughness of the shot blasting texturing roll is less uniform compared to that of the electro-discharge texturing roll because the work roll roughness is transferred to the temper rolled strip. It also produces a more desirable image and greater clarity to the color painted steel sheet.

Key Words : Electro-Discharge Texturing, Shot Blast Texturing, Peak Count, Surface Roughness, Temper Rolling.

1. Introduction

It is commonly accepted that the surface roughness of cold rolled steel influences the cold rolled strip, coated strip and prepainted products. Therefore, to the give appropriate surface roughness, the shape of the work roll for the temper mill is most important. The strip has greater peak counts and homogeneous roughness. This makes the prepainted surface smooth and excellent in appearance with good image clarity. The surface of the strip with high peak counts prevents sticking during high temperature annealing. Therefore the surface roughness of the work roll is very important. The reason that surface roughness of the work roll is transferred to the strip surface is the rolling force and tension at the temper rolling or cold rolling.

Generally conventional texturing of the work roll for cold rolling or temper rolling is made by a small and rigid grit shot blast at high velocity from the texturing machine. The resultant surface is nonuniform with small peaks & craters.

The shot blast texturing method is very difficult to obtain optimum conditions due to the hardness, speed, size and shooting angle of the grit, and of the work roll. Therefore, reproducibility is difficult to achieve using this process. However, nonuniformity of surface roughness can be compensated with several paint coatings, but this also makes the quality deteriorate and increases manufacturing costs. This study is to resolve these problems. Our research involves the use of electro-discharge texturing and laser beam texturing methods to get good quality steel. Many countries are adopting this process increasingly.

The purpose is to get accurate and homogeneous roughness in this study. There are few papers published because its importance is not known and the proper operation of the machine is not generally well known.

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This paper investigates the correlation between strip surface roughness and the surface of the work roll. After studing the surface roughness and shape according to the texturing method used for the work roll surface at temper rolling, the findings are as follows.

As the actual rolling mill is used, this data will be adopted to another actual rolling mill for the application and operation of this experiment.

2. Experimental Apparatus and Method

2.1 Apparatus

Work rolls textured by two types of texturing machine were used in this experiment and the results were compared. The shot blast texturing machine and its operating principle is very simple. This machine consists of a dust collector equipment to remove the steel powder and small grit outside from the sieve, selecting the proper size grit and the impeller which sprays grit on the work roll surface, and a rail car which is moving and rotating the rolls with constant speed. The proper surface roughness of the work roll can be obtained by rotating the speed of the impeller.

The electro-discharge texturing machine, consists of the head stock of the machine main body, the tail stock, the neck rest hydraulic system for the hydraulic cylinder, and a filter for removing impurities in the dielectric oil. In the case of electro-discharge texturing, if the workpiece is placed on the nest, the distance between the head stock and tail stock is set and controlled automatically, and the hydraulic cylinder of the tail stock secures the end of the work piece. The servo-cylinder controls the distance between the electrode and work piece to meet the diameter and length of the work piece by the input data to the computer. At this point electro-discharge texturing begins.

The gap between the electrode and work roll is controlled by 0.02～0.2 mm. There are 2 of 5 modes used largely to control peak counts under the same roughness. Determination of peak counts is controlled by varying the voltage and by changing the polarity of the generator. The voltage is generally controlled within the 30～50 V range, and roughness is determined by the frequency of the current and interval of the pulse.

Table 1 Chemical compositions of work roll (wt. %).

C	Si	Mn	P	S	Cr
0.95	1.00	0.60	0.02	0.02	3.00

Table 2 Mechanical properties of sample at temper rolled.

Material	Tensile strength (N/mm^2)	Hardness (H_RB)	Elongation (%)
SCP-1	314.58	42.7	44.40

Table 3 Chemical compositions of sample at temper rolled (wt. %).

Material	C	Si	Mn	P	S
SHP-1	0.05	0.009	0.25	0.010	0.010

2.2 Experimental material

The hardness of the work roll used for this experiment is Hs 95, and the normal work roll involving a wt. of 3% Cr as shown in Table 1 is used.

Mechanical properties of the annealed strip used to determine the transference of surface roughness from the roll to the work are shown in Table 2, and the chemical compositions are shown in Table 3.

The thickness and width of the sample used here is 1.0 mm and 1219 mm, respectively, and it is representative of the standard in cold rolled strip processing.

2.3 Experimental method

The same roll was used here to examine the exact roughness, shape and change according to the texturing method used.

To compare the transference shape and type under the same conditions, the roll for the temper mill was textured with shot blast texturing, and electro-discharge texturing was used under the

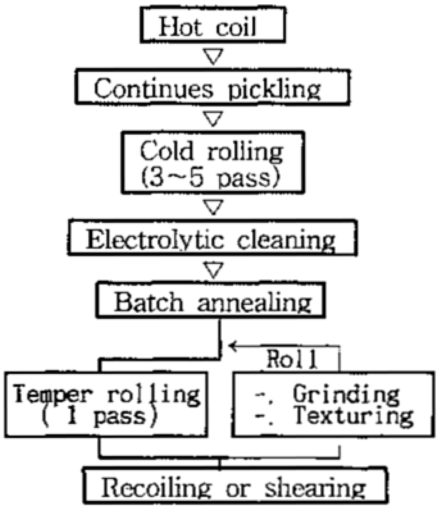


Fig. 1 Flow chart of cold rolling processing.

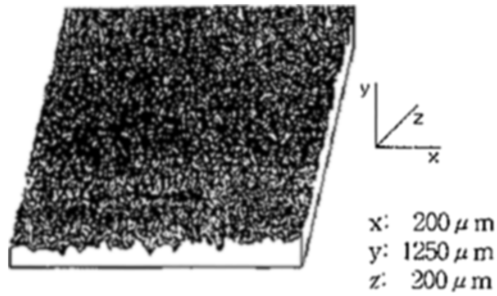
same temper rolling condition. Temper rolling used one pass for the experiment, and is shown in Fig. 1.

The work roll taken out of temper rolling was atmospherically cooled and a full fatigue layer of 0.025mm was ground at the roll grinder. The work roll surface roughness and peak counts were measured on all surfaces of the roll before being placed in the temper mill and after working. The surface condition of the strip was examined by SEM to observe in more detail the surface roughness by "Hommel tester-1000" of portable roughness test equipment. The surface roughness and peak counts of the work roll and strip are of average value, which is measured at 3 points along the direction of the roll body and direction of strip width respectively. The strip surface roughness cannot be measured at the temper mill, so it was measured during recoiling process after temper rolling. The work roll surface roughness was measured under vibration-free conditions before and after rolling.

3. Results and Discussion

3.1 Roughness shape by texturing method

The roughness shape of the work roll is very different using the texturing method as shown in Fig. 2. The electro-discharge texturing method has a homogeneous peak height and a large peak count, but the shot blast texturing method has a heterogeneous peak height and smaller peak counts. A partially untextured area can also be observed as shown in the shot blast texturing of Fig. 3, where the roll surface is magnified 175 X. The reason is that the grit size sprayed by the impeller is not uniform in size, and the grit is sprayed onto the surface of the roll irregularly.



(a) Electro-discharge texturing method

(b) Shot blast texturing method

Fig. 2 Shape of surface roughness according to texturing method.

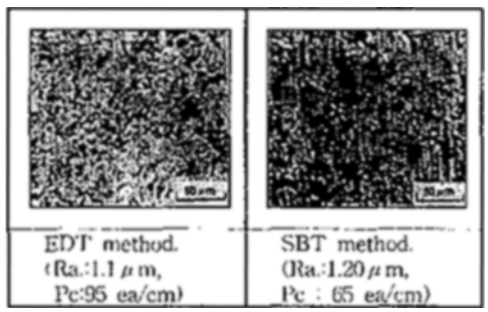


Fig. 3 Photo. of work roll surface roughness on the texturing method.

However, in the case of the electro-discharge texturing method, there is no untextured area due to the uniformity of the electric discharge. Peak shape and height is therefore uniform.

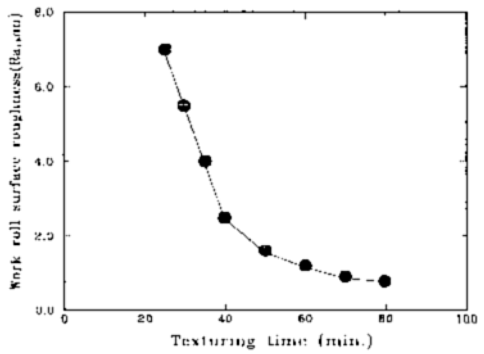


Fig. 4 Relationship between work roll surface roughness and texturing time on the electro-discharge texturing method.

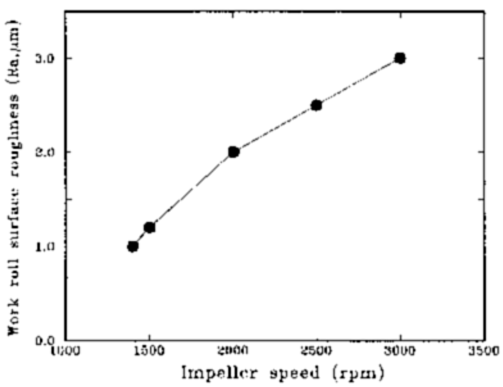


Fig. 5 Relationship between work roll surface roughness and impeller speed on the shot blast texturing method.

The electro-discharge texturing work roll has an almost uniform peak shape and peak counts after use, but in the case of shot blast texturing, the work roll has non-uniform texturing and rapid wearing because of several variable factors such as grit size, hardness, and rotation speed of the impeller.

Figure 4 shows the relationship between the work roll surface roughness and texturing time on the electro-discharge texturing. If the roughness is low, the texturing time is long, and the higher the roughness the shorter the texturing time. The reason is that when there are low peaks there is a large arc, and at this instant, the gap between the electrode and the roll becomes bigger. If the roughness is higher, the gap is smaller. Shot blast texturing time does not change according to the roughness; the roughness is determined by the impeller speed only. So, it takes 20 minutes for texturing one roll, which is equivalent to the rail car speed. The impeller speed is controlled according to the required roughness. The correlation between the roughness and impeller speed is shown in Fig. 5.

The work roll surface roughness obtained from electro-discharge texturing method is similar to a very homogeneous cratering shape, and there is a trace formed by the roll grinding stone. If the work roll surface that was textured by the shot blast texturing method is magnified, the nonuniform surface can be readily observed. The surface roughness of the work roll which is worked by electro-discharge texturing method is more uniform and homogeneous to peak shape and peak counts than that of shot blast texturing.

The surface roughness of the strip, which affect paintability and formability for cold rolled products, must be controlled properly because the surface roughness is determined by the roughness of the temper mill work roll.

3.2 The variation of roughness and peak count on the work roll surface

Figure 6 shows the relationship between the work roll surface roughness and temper rolling length on electro-discharge texturing. The correlation between the work roll surface roughness and temper rolling length on the shot blast texturing method is shown in Fig. 7 Work roll surface roughness by electro-discharge texturing is almost the same gradient to both rolls of the top and bottom work roll and has a linear trend. Roll surface roughness by shot blast texturing method deteriorates rapidly and becomes glassified quickly during temper rolling. Wearing of the work roll surface and deterioration of the work roll surface roughness creates Fe powder, which is attached to the work roll surface and leaves a trace on the strip surface, so that eventually the roll becomes disfunctional.

As shown in Fig. 6, in the case of electro-discharge texturing, the work roll surface roughness is 1.4 μm when the temper rolled length is 60 km. But in the case of shot blast texturing, the

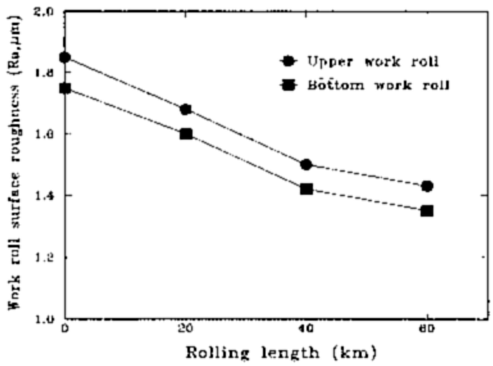


Fig. 6 Relationship between work roll surface roughness and temper rolling length on the electro-discharge texturing method.

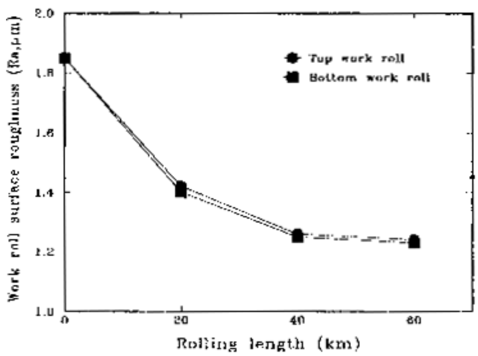


Fig. 7 Relationship between work roll surface roughness and temper rolling length on the shot blast.

temper rolled surface roughness deteriorates after 20 km of rolling length as shown Fig. 7. After temper rolling, this characteristic was transferred to the strip and produces inferior formability and paintability.

This is related to the roll life; therefore it is very important. The roughness by electro- discharge texturing is not triangular but sinusoid or harmonic wave. Experimental results by an actual temper mill shows a lifetime twice as long. This phenomenon can be seen in Fig. 8. Rmax is large in the case of the shot blast texturing method, and is divided into two parts of untextured and textured areas. Stress is accumulated on the textured parts of the work roll, so the peaks are worn rapidly by friction. In the case of electro-discharge texturing Rmax is low and little height

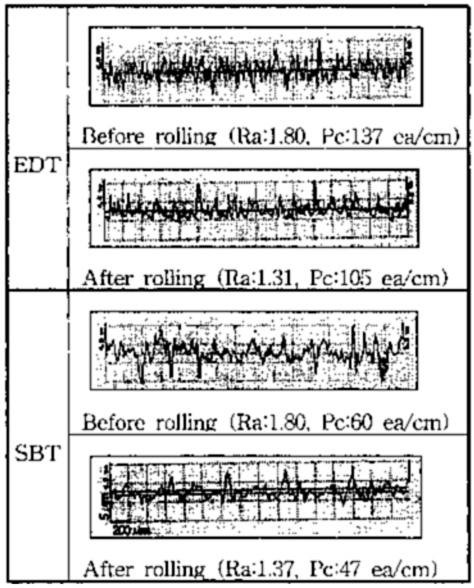


Fig. 8 Variation of work roll surface roughness and peak counts on the texturing method.

difference exists, so the wearing is slow and constant. Peak counts of the work roll surface in the case of electro- discharge texturing method decreases with a constant gradient. In the case of shot blast texturing method, peak counts of the work roll decreases rapidly at the beginning step and no change is observed after rolling approximately 1/3 the length of the electro-discharge texturing method process. As shown in Fig. 8, sharp and salient peaks wear quickly in the early stages of rolling. This is the reason that the peak counts value does not change at this time, because it is similar to that of the roll grinding surface. At the same time, wearing of the work roll is minimal.

3.3 The variation of roughness and peak count of strip surface

Surface roughness of the cold rolled strip is transferred and determined during the temper rolling and peak counts and roughness are also the same. But surface roughness of the strip is different due to elongation from temper rolling.

Figure 9 shows the results, of the electro-discharge texturing roll, Fig. 10 shows the results of the shot blast texturing roll. There is no change

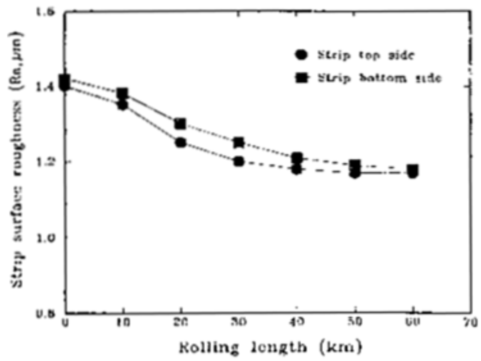


Fig. 9 Relationship between strip surface roughness and temper rolling length on the electro-discharge texturing method.

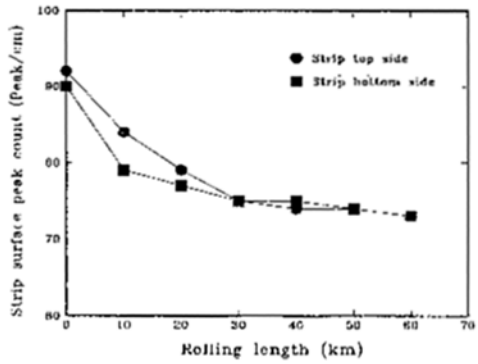


Fig. 11 Relationship between strip surface peak counts and temper rolling length on the electro-discharge texturing method.

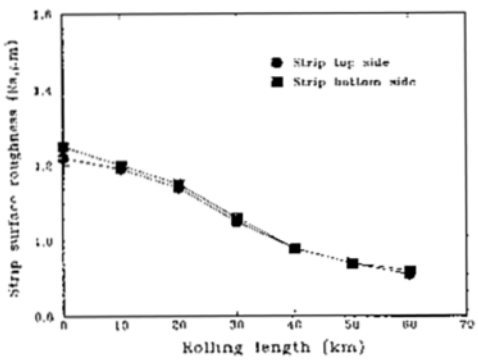


Fig. 10 Relationship between strip surface roughness and temper rolling length on the shot blast texturing method.

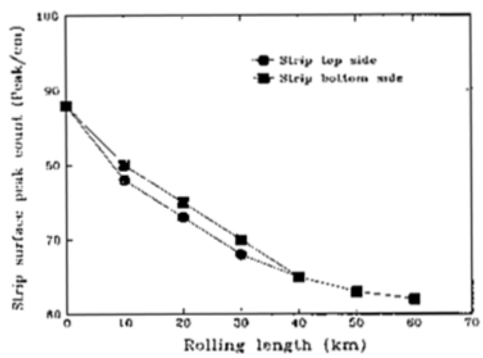


Fig. 12 Relationship between strip surface peak counts and temper rolling length on the shot blast texturing.

until 60 km of strip length in the case of electro-discharge texturing roll, while there is no roughness after 30 km of strip length in the case of shot blast texturing roll as shown in Fig. 10.

The peak count of strip the surface is determined by the roll surface roughness, but the higher total reduction ratio, the more peak counts.

As shown in Fig. 11 the peak count goes down rapidly in the first 10 km, and then it has stable values after 30 km. The bottom surface of the strip has more peak counts than the top surface of the strip, which is not touched by the neutral point of the roll bite, and the top and bottom roll are different from each other. This is the reason that there is a length difference from the contact length of the work roll and strip between the top and bottom work roll by the cross brake roll which is installed to prevent edge breakage of the strip.

The strip surface roughness is transferred by the shot blast texturing work roll as shown in Fig. 12. It is not as clear, and slower than the electro-discharge texturing work roll. This cannot be expressed because the exact trend of wear of the roll surface is irregular. So, electro-discharge texturing can control the proper roughness and peak counts to meet the customer's needs. But the shot blast texturing cannot control peak counts and produces irregular surface quality.

The peak can be seen with a magnified SEM image of the strip surface as shown Fig. 13. The strip surface which used electro-discharge texturing roll has a more homogeneous and smooth roughness, while the strip which used the shot

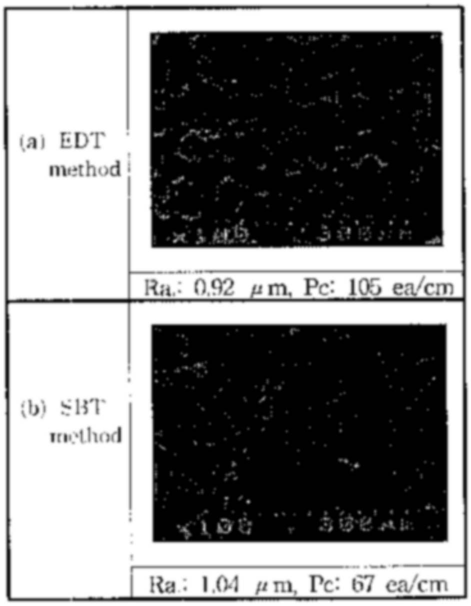


Fig. 13 Photo. of strip surface on the texturing method.

blast texturing roll has an unclear and heterogeneous roughness, with surface morphologies of the rolling direction. This produces a bad image clarity, and inferior clarity and formability in the case of painting.

4. Conclusion

This paper has investigated the character- istics of two of the texturing methods of the temper mill work roll. The results from the actual temper mill process were obtained as follows:

(1) Electro-discharge texturing roll has homogeneous roughness distribution and shape, and also a sinusoidal peak surface, and the lifetime is twice as long as that of the shot blast texturing method.

(2) The higher the roughness, the more greater the rolling time to electro-discharge texturing; peak counts decreases, while texturing time is constant. In the shot blast texturing method, there is not a correlation between texturing time and peak count.

(3) The roughness of the shot blast texturing roll is nonuniform compared to that of the electro -discharge textured roll because the work roll roughness is transferred to the strip which was temper rolled.

(4) The roughness and peak counts of the strip surface which used a electro-discharge texturing roll is more homogeneous than that of shot blast texturing, and it produces a more desirable image clarity and greater clarity to the color painted steel sheet.

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