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Development of Precision Rolling Process Technology in Coil Bar and Rod

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Taiwan's fastener industry is heading towards the application of automobile and motorcycle security parts. In the meantime, the complexity of cold forming has increased gradually. Even material with slight seam defects will cause processing failure and lead to cracks. Due to the increasingly stringent material quality requirements, China Steel Corporation (CSC) started with precision rolling technology. First, the shape of the billet was adjusted to improve wrinkle defects. Second, the design of the descaling nozzle configuration was optimized to enhance descaling ability. Eventually, a wear factor was introduced to optimize the management of roll grooves. Through the above improvements, CSC has developed a precision rolling process technology for Seam Free products. After introducing Seam Free technology to manufacture SCM435RCH, widely used in making car bolts and engine fasteners, customers have responded with positive feedback in the following cold-heading process, where the improvements have been remarkable. Through developing Seam Free process technology and premium products, CSC helps the supply chain to achieve the goal of high quality and high-value development.

Keywords: Fastener Industry, Wrinkle, Seam Free, Cold Heading

1. INTRODUCTION

In the production process of the bar in coil, the heated billet will go through a sequence of multi-pass rolling. There, the original square billet is gradually reduced and formed into the desired circular shape, as shown in Figure 1. Most of the products used for cold-heading are screws and nuts, and almost 100% of the entire coil is fully used. Consequently, when a coil extends as long as several kilometers with partial seam defects, cracks may occur during the following cold-heading process. In addition, the development of Taiwan's fastener industry tends to have the following characteristics. First, the products are mainly used in the manufacture of automobile and motorcycle security parts. Second, the complexity of cold forming increases. Third, the proportion of wire drawing reduces. To meet the above requirements, some steelmakers in Korea and Japan peel the as-rolled coil to further reduce surface defects, but this method is a subsequent solution and requires additional equipment and retreatment procedures, which increases manufacturing costs. Therefore,

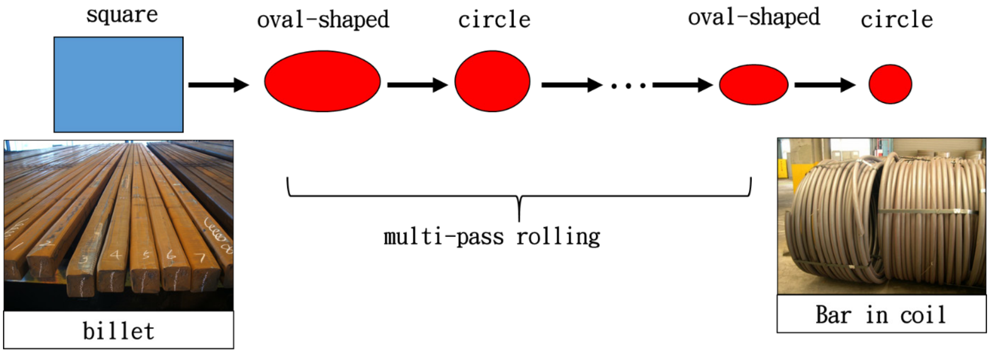


Fig.1. Process of billet rolling to coil.

CSC meditates to solve the problem from the source, develop Seam Free process technology, and improve product quality towards being Seam Free.

The cold-heading crack is caused by the presence of flaws in the material. The main reasons are as follows: poor forming behavior of rolling billet to the coil, scale on the billet surface isn't removed completely, material overfills stock during rolling and then continues to be rolled and lapped, as shown in Figure 2.

Analyzing the cold-heading cracked sample, the wrinkle defect is distributed symmetrically at 90°, as shown in Figure 3, and it is judged that the corner of the billet is occasionally poorly formed during rolling to the coil. According to the literature*1, the appearance of wrinkle appears dense and is mostly distributed symmetrically at 90° or 180°, which originates from the phenomenon of wrinkling and roughness on the surface at the initial stage of rolling. It is because when the billet corners come into contact with the roller, the force from the roller causes excessive compression on both sides of the billet, resulting in surface wrinkles.

When there is a layer of scale on the surface whose properties are different from the matrix material, the above wrinkle phenomenon is more aggravated during the plastic buckling process. In addition, when the surface of the rolling groove is excessively worn, it will also lead to excessive filling of the passed billet, which will be covered by subsequent rolling and become seam defects. Summarizing the above causes, CSC considers adapting the shape of the billet, to enhance the ability of descaling and management of the roll groove quality.

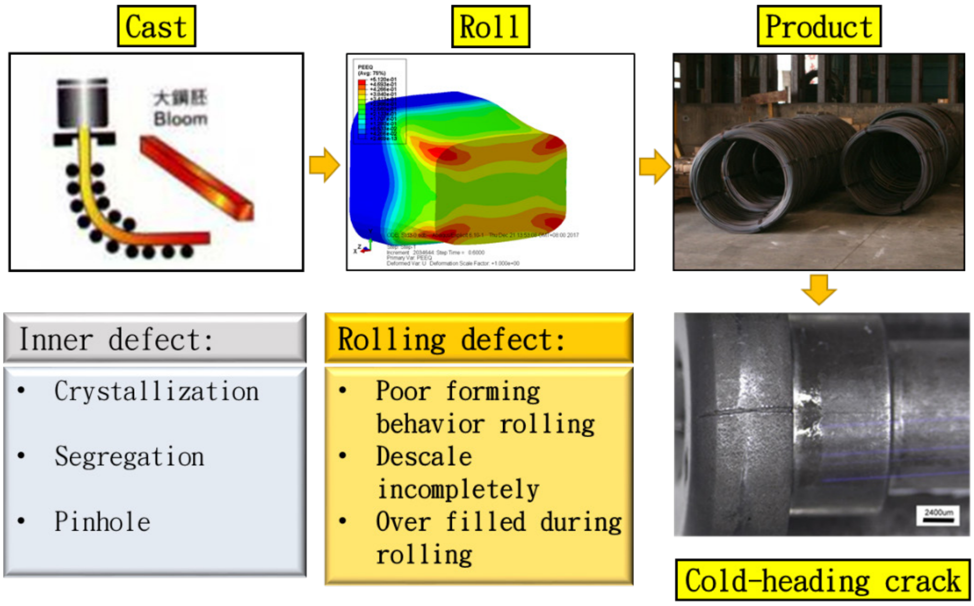
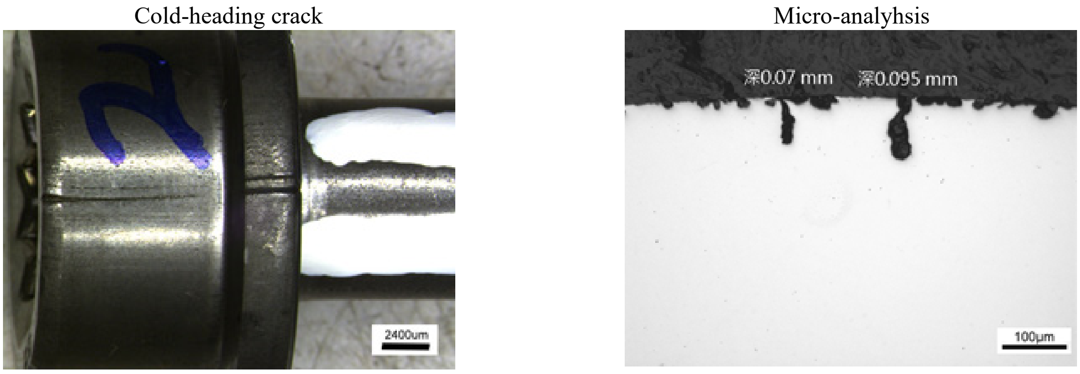


Fig.2. Causes of seam defects in the rolling process.


Cold-heading crack

Micro-analyhsis

Fig.3. Cold-heading crack and micro-analysis.

2. ADAPTING THE SHAPE OF THE BILLET

2.1 Concept of Design

According to the finite element simulation analysis, an increase in the billet corner radius can make the deformation of the billet corner smoother, as shown in Figure 4, which slows down the uneven buckling phenomenon at the corner. Figure 5 shows the difference in the cross-sectional profile more clearly. Therefore, minimizing the probability of wrinkle defects occurring during the roll-reducing period substantially. To meet the requirement of enlarging the corner radius of the billet, it is necessary to appropriately modify the groove shape of the billet roll.

2.2 Trial Rolling Evaluation

After modifying the following parameters: arc angle radius and bottom width of the billet finishing roller groove, the corner radius of the final billet can be effectively enlarged to an appropriate size, as shown in Figure 6.

To confirm whether the quality has improved before and after modification, the test method used is as follows. Samples from the coils rolled by the experimental group (major radius of the corner) and the current group (minor radius of the corner) were taken. First, magnetic particle testing was used to confirm the position of the seam, as shown in Figure 7. Then, use the upset test to

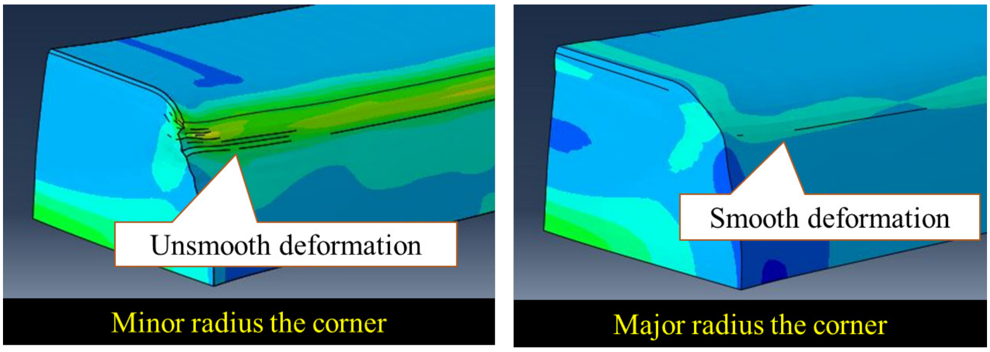


Fig.4. Simulation of corner deformation with different radii in the corner of a billet after rolling.

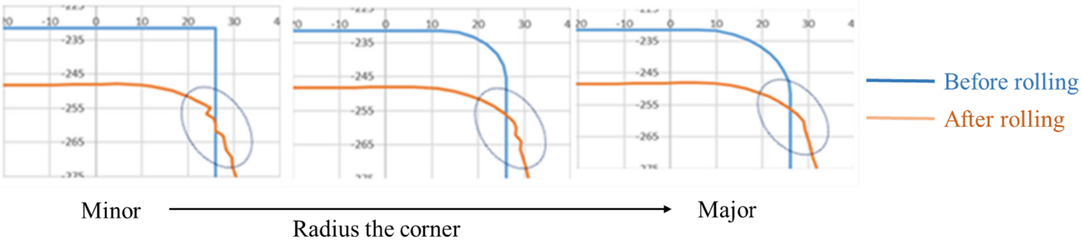
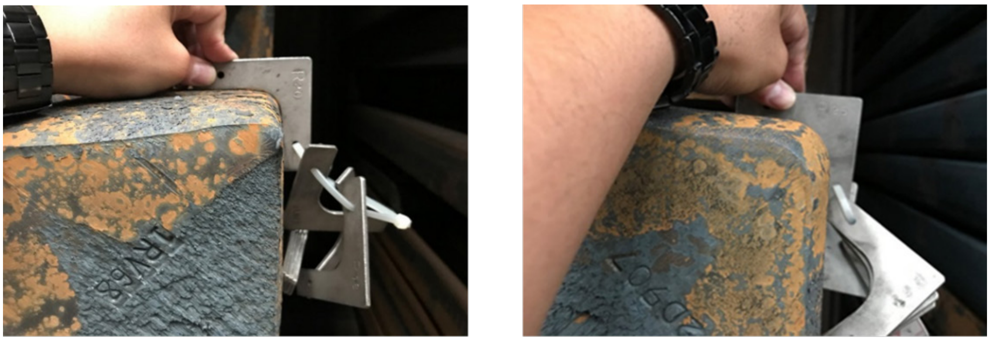


Fig.5. Simulation of cross-sectional profile with different radii in the corner of a billet before and after rolling.



Minor radius the corner Major radius the corner

Fig.6. Measurement of billets with different corner radius.

simulate the deformation of the customer's cold-heading process to detect the position of the defect, as shown in Figure 8. In this evaluation, SCM453RCH, which is widely used to manufacture high-tensile bolts, was chosen for this test. The crushing crack rate before and after modification was 1.27% and 0.41%, which showed an improvement of 68%.

3. ESTABLISHMENT OF REFINED ROLL WEAR MANAGEMENT

3.1 Metallurgical Theorem

If the rolling groove is excessively worn during the rolling process, it will lead to excessive filling of the passing billet, resulting in uneven surfaces, which will be lapped by subsequent rolling and form seam defects, as shown in Figure 9. Since the bar and rod rolling factory takes the rolling count to manage the timing of roll replacement, it has happened once with a roll within the control range; however, due to excessive wear of the

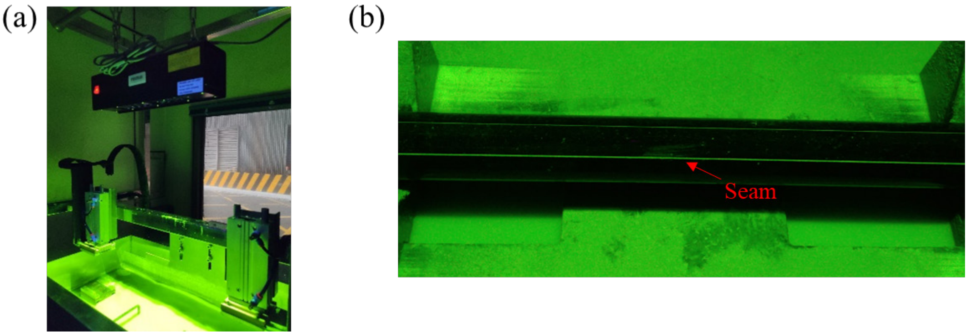


Fig.7. (a) Magnetic Particle Testing, (b) Schematic diagram of detecting seam defects.

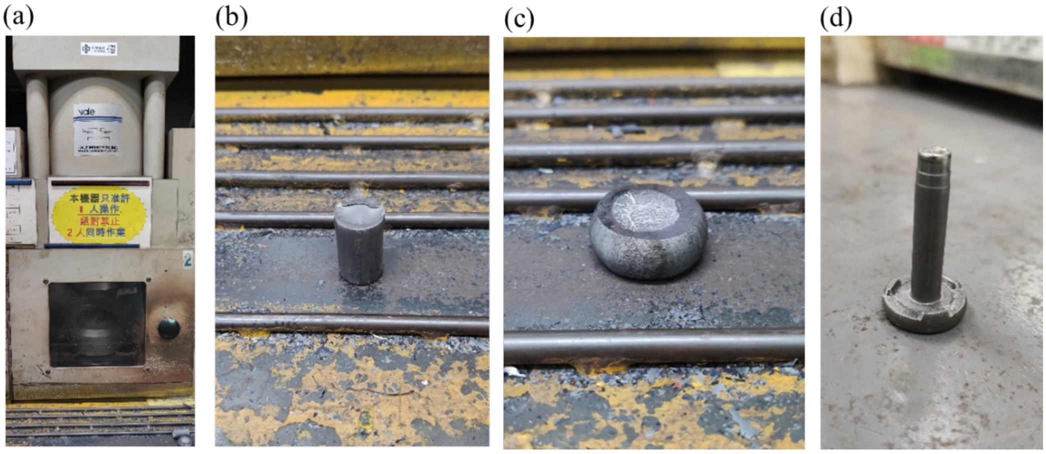


Fig.8. (a) upset tester, (b) test sample before compression, (c) test sample after compression, (d) customer cold-heading sample.

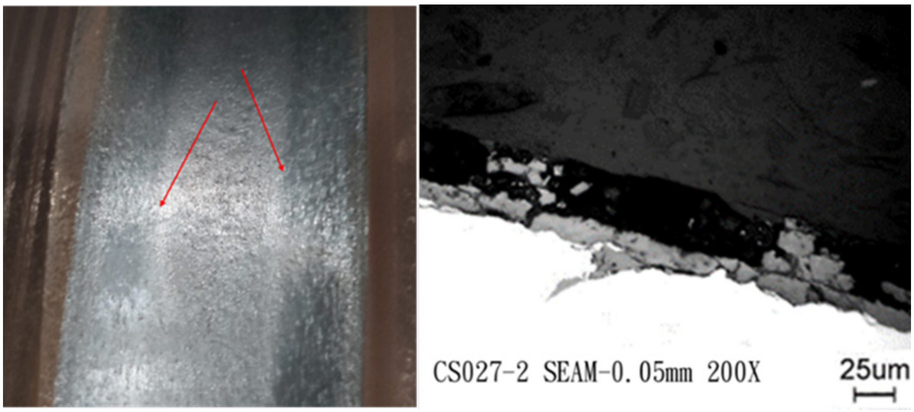


Fig.9. (a) Schematic diagram of roll groove wear, (b) seam defect formed by subsequent rolling.

rolling groove, seam defects were generated in the final coil. This is due to the variety of steel types in rolling combinations, such as low, medium, high-carbon, and various alloy steels. The high-temperature deformation resistance of each steel is different, and the degree of wear of the rolling groove is also different. To further manage the life of the roll carefully, the high-temperature deformation resistance factor is necessary to be introduced to intelligently manage the wear of the roll.

3.2 Experiment Planning

The material is kept heated to a specific temperature and deformed under a fixed strain and strain rate. The above yield stress measured by the compression test is called high-temperature deformation resistance. The higher the resistance, the greater the external force required to deform the material. During the rolling process, the billet is deformed by force and reduced to the final size. Because the surface of the roll groove directly sustains the force, the greater the resistance of the steel, the greater the reaction force applied to the roll surface. Hence, the roll surface wears more severely. Therefore, the high-temperature resistance with different steel was analyzed to understand the degree of influence of roll groove wear.

Since there is a significant change in the high-temperature resistance of the steel due to the varied types of alloy added, 12 steel grades with large production amounts and different compositions were selected as representatives for high-temperature resistance analysis. Gleeble testing shows that the resistance varies greatly with different steel types and temperatures, as shown in Figure 10. Therefore, high-temperature resistance can be accurately defined according to the actual rolling temperature, and the roll groove wear factor of each steel type can be calculated.

3.3 Roller Groove Wear Measurement and Verification

To confirm the relationship between rolling count and cumulative wear factor with the actual wear depth of the roll groove, we arranged actual measurements to verify the applicability of the wear factor. Using a laser rangefinder to scan and draw a cross-sectional profile, as shown in Figure 11, which represents the deepest wear

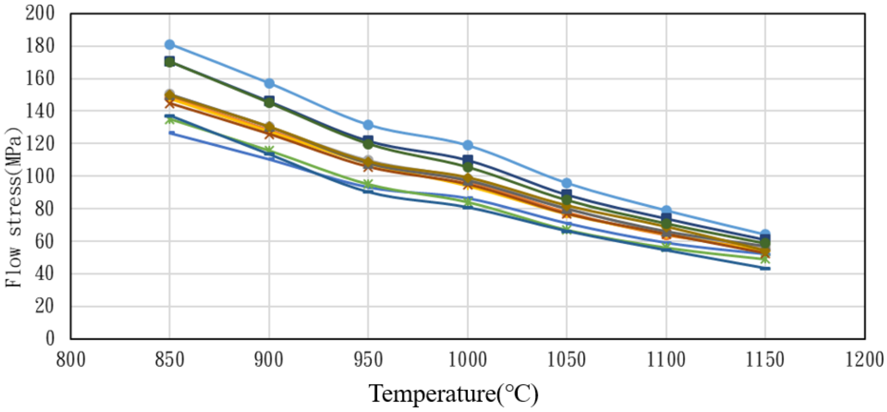


Fig.10. High-temperature deformation resistance variation of 12 steel types at different temperatures.

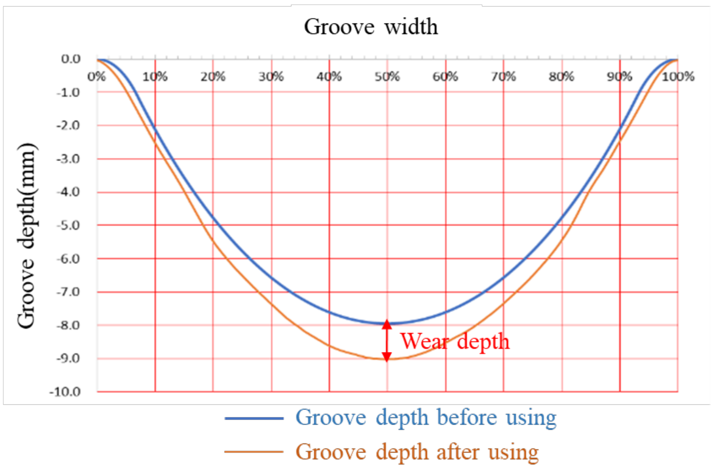


Fig.11. Roll groove profile scanned by laser rangefinder.

depth. Through regression analysis, the correlation coefficient between regression wear depth and cumulative wear factor is 0.99, which is higher than 0.90 of the rolling count, as shown in Figure 12. From these results after introduction, the roll groove wear factor is more in line with the actual wear of the groove.

4. ENHANCE DESCALING ABILITY

4.1 Optimization of Descaling Nozzle Configuration

When a heated billet comes out of the furnace, its surface will be covered in a layer of scale. However, if the scale on the billet surface isn't removed completely, it would roll into form seam defects during the subsequent rolling process, as shown in Figure 13. To confirm the existing descaling performance, we used high-pressure descaling nozzles to scour an aluminum plate and observe the erosion marks, as shown in Figure 14. It was found that the erosion marks in some areas were blurred and not concentrated, so it is speculated that the water columns interfere with each other, and the configuration of the descaling nozzles needs to be improved.

The configuration of the existing descaling nozzles and the jetting situation between the water columns of the upper, lower, left, and right nozzles were simulated, as shown in Figure 15(a). It can be observed that there will be interference between the water columns at the corners. Therefore, the configuration of the nozzles was redesigned. Upper and lower nozzles still maintain reverse jetting, but the left and right nozzles were changed to forward jetting to avoid interference between water columns, as shown in Figure 15(b). After the online setup of the new configuration of the nozzle and jetting for testing, it was found that the erosion marks on the four sides were clear and concentrated, as shown in Figure 16. There is no interference with each other, showing that the new configuration is a remarkable improvement.

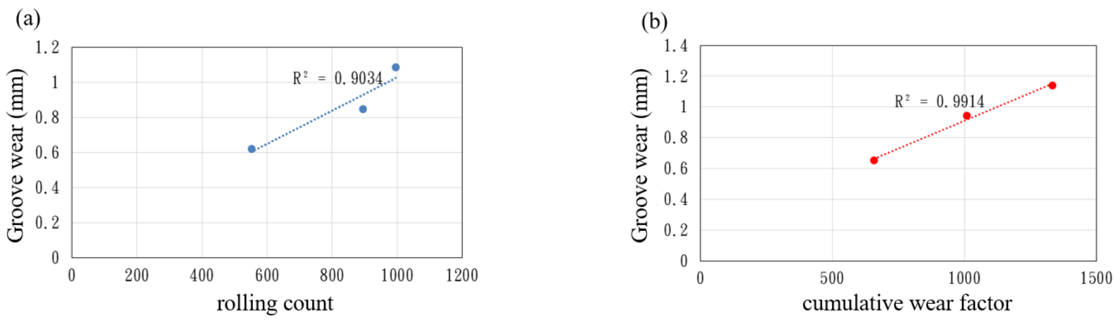


Fig.12. (a) Groove wear depth corresponds to rolling count (b) Groove wear depth corresponds to cumulative wear factor.

Fig.13. Incomplete descaling of billet and rolls to form seams.

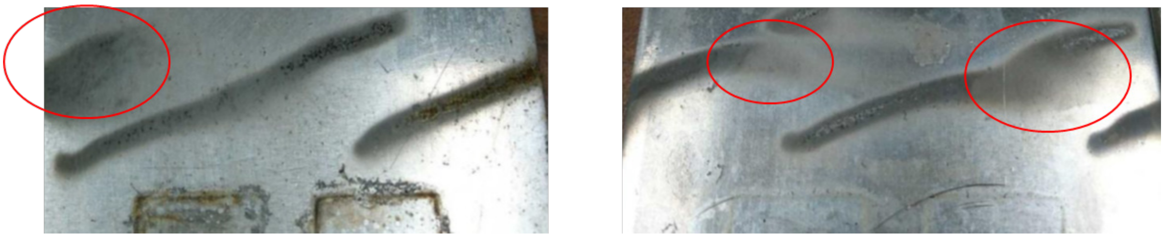


Fig.14. Descaling performance test.

4.2 Descaling Efficiency Improvement

To further improve the descaling efficiency, a newly designed high-efficiency nozzle was introduced to reduce the pressure loss of the water column. Compared with the former nozzle, the descaling efficiency increases by 7%. In addition, the descaling pressure was simultaneously increased, and the billet moving speed was reduced to enhance descaling performance. It was found that the erosion marks of the new nozzle were concentrated and clearer than the old nozzle, as shown in Figure 17.

5. CONCLUSIONS

Following the introduction of the Seam Free process technology, the process capability has been effectively improved, successfully reducing the output

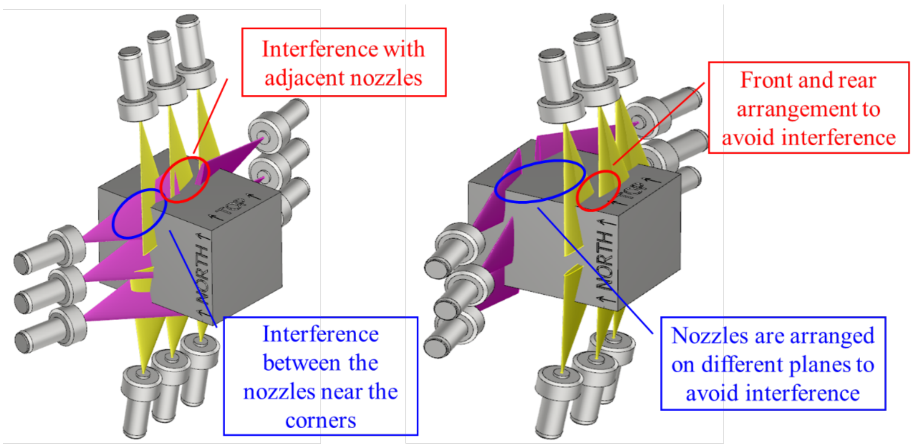


Fig.15. (a) Former descaling configuration, (b) New descaling configuration.

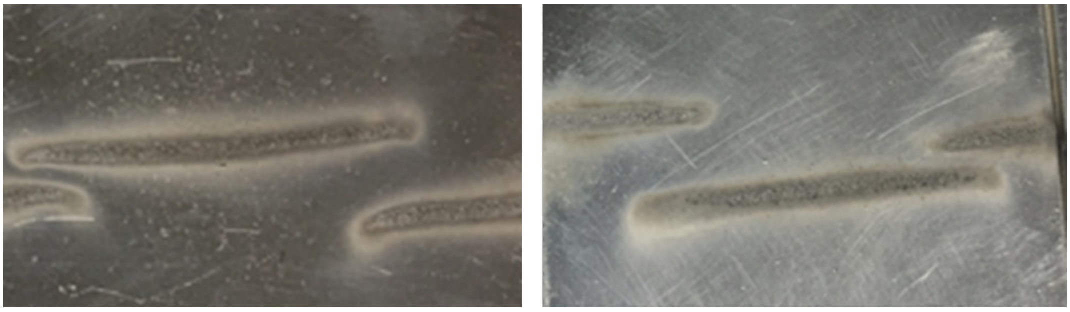


Fig.16. Descaling performance test of new nozzle configuration.

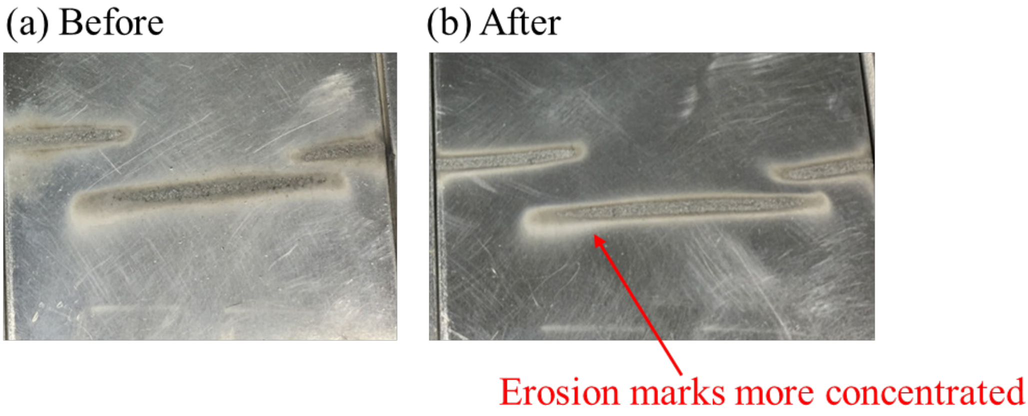


Fig.17. Descaling ability test of new nozzle configuration.

of defective products. SCM435RCH is used to manufacture car bolts and engine fasteners which customers reported had the occasional cold-heading crack in the past. After applying Seam Free technology to the production line, many customers responded that there was no more cold-heading crack issue, and the improvement effect was remarkable. Through enhancing product quality, CSC assists the supply chain to achieve the goal of high quality and high-value development.

6. REFERENCES

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