Research on thermochemical erosion of conveying rollers in the roller bottom heating furnace of hot stamping production line

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In this study, the thermochemical erosion of the heating roller hearth furnace conveying roller in the hot stamping production line was studied. Firstly, the application of hot stamping forming technology for high strength steel and the key position of roller hearth furnace in this technology are introduced. Then the possible thermochemical erosion mechanism between the aluminum oxide roll and the metal plate with AlSi coating is discussed. The experimental results show that the interface diffusion and chemical reaction between alumina roll and AlSi coating occur at high temperature, leading to adhesion and erosion. In addition, the erosion degree of furnace rolls in different furnace temperature ranges was also studied through experiments, and the relationship between furnace body length and furnace roll consumption was discussed. Although the use of furnace roll coating material can partly alleviate the problem of thermochemical erosion, the consumption of furnace roll and the improvement of effective energy consumption utilization are still challenging. Finally, this paper discusses the possibility of the combination of multi-layer box furnace and roller hearth furnace to form a mixed heating production line.

Keywords: High strength steel; Hot stamping; Heating roller hearth furnace; Conveying roller; Thermochemical erosion.

1. Introduction

Lightweight technology is one of the key technologies to achieve automotive energy conservation and emission reduction, while high-strength steel hot stamping technology can significantly achieve lightweight while ensuring automotive safety [1]. The advantages of hot stamping forming technology of high strength steel make it develop rapidly and rapidly once it is introduced [2]. In the application of hot stamping of high strength steel, more than 80% of the heating system is roller hearth furnace. This type of furnace can operate with or without shielding gas. In the hot stamping production line, the heating roller hearth furnace and the conveying roller play an important role. In the heating roller hearth furnace, the roller body needs to withstand the environment of high temperature and chemical corrosion, while the conveying roller needs to resist the friction and wear of materials. The aluminum oxide roll of roller hearth furnace and the metal plate with AlSi coating may have thermochemical corrosion. Thermochemical erosion refers to the erosion process in which both chemical corrosion and thermal action exist in high temperature environment.

Hot stamping technology has a wide range of applications in modern manufacturing industry, in which the heating roller hearth furnace is a critical equipment for heat treatment and heating of workpiece. In this process, as one of the key components, the conveying

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roller is subject to the erosion of high temperature and chemical medium. Thermochemical erosion is one of the main reasons for the performance degradation and life shortening of conveying rollers. Therefore, it is of great significance to study the thermochemical erosion of the conveying roller in high temperature environment. In a typical direct hot stamping process, boron alloy steel billets are first heated to austenitizing temperature in a continuous roller hearth furnace and kept warm (called soaking) to transform the pearlite ferrite microstructure received into a fully austenitic state. Then the heated blank is transferred to the cold die, and formed and quenched in the die to ensure that the part is transformed into a complete martensitic microstructure. The most common hot stamping steel grade is 22MnB5, in which the carbon content is about 0.22wt%, and the forming tensile strength is about 1500 MPa, even 1800-2000mpa. Al2O3 is formed on the surface of high-strength steel AlSi coated plate when heated at high temperature. The dense Al2O3 layer acts as an external protective barrier and effectively prevents further oxidation of the coating. This layer can also improve the corrosion resistance of the coating at room temperature, as shown in Figure 1.

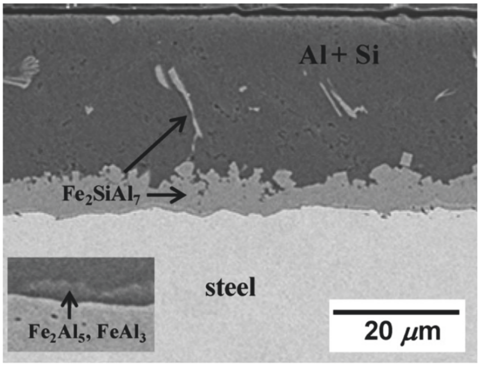


Fig. 1 Cross section scanning electron microscope (SEM) micrograph of aluminum silicon coating [3].

2. Thermochemical erosion of roller hearth furnace conveying roller in high temperature environment

The transfer roller of roller hearth furnace is made of alumina (hollow) or quartz (solid core) materials. At high temperature, interfacial diffusion is a common mechanism of adhesion. The atoms between the surface of alumina ceramic roller and aluminum silicon coating will diffuse to form an interface layer. The diffusion atoms in the interface layer can form chemical bonds between the two materials and increase the contact area between them, so as to achieve bonding. The chemical reaction between the surface of alumina ceramic roller and aluminum silicon coating may also lead to bonding. At high temperature, the alumina on the surface of the alumina ceramic roll may react with the aluminum in the aluminum silicon coating to form an aluminum oxide interface layer. This chemical reaction forms a chemical bond in the interface layer to bond the two materials together. It is found that during the heating process, when the AlSi coated metal sheet is in direct contact with the ceramic conveyor roll, a very strong thermochemical reaction will occur.

This effect requires relatively frequent drum replacement, which may affect the availability of the plant, as shown in Figure 2.

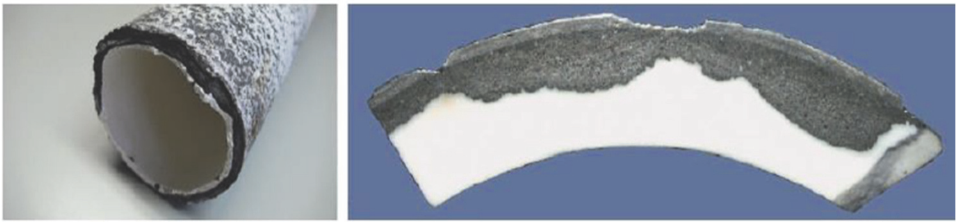


Fig. 2 Adhesion and erosion of ceramic conveying roller and AlSi coated plate [4]

At present, coating the roller of the heating furnace with materials that can reduce this affinity helps to reduce the accidents that the conveyor deviates from the direction of the main shaft movement caused by this adhesion, or because of the binding tumor (causing the position of the sheet after heating to deviate), bending and fracture. Based on the sol-gel process, a suspension was developed for spraying the conveying roller, which can prolong the service time by 50%.

3. Thermochemical erosion distribution of conveying rollers in different heating zones

During the process of transporting the aluminum silicon coated sheet from the furnace inlet side to the furnace outlet side through the roller bars of the roller hearth furnace, the aluminum silicon coating on the surface of the coated sheet undergoes a process of temperature rise, melting and alloying. The melting point temperature of the aluminum silicon coating is about 680 ° C, which is far lower than the austenitizing temperature of the steel plate. Therefore, when the coating plate is heated to this temperature range during the heating process, the coating is in the melting state, and the alloying reaction has not yet been carried out. The aluminum silicon coating on the back of the sheet at the contact with the roller bar in the furnace will adhere to the surface of the furnace roller. Friction and adhesion between the aluminum silicon coating and the ceramic roller bar will occur during the movement of the sheet, which will accumulate and increase over a long period of time, gradually increase and form nodules. The nodulation will erode the surface of the furnace roll. Due to the low thermal conductivity of the aluminum silicon coating and the difference between the thermal expansion coefficient of the aluminum silicon nodulation and the ceramic roll, the temperature difference between the surface and the interior of the ceramic roll will increase, resulting in peeling pits, and finally the roll will be broken, or the parts will be offset and unable to be produced continuously.

In this study, the experimental method of continuous batch production validation was used to analyze the adhesion condition. The length of the experimental roller hearth furnace is 16m, and the actual verification of the chemical erosion of the roller bars in the furnace during the continuous operation of the roller hearth furnace with aluminum silicon coating high-strength plate is explored.

Before the production of this batch of parts and components, shut down the maintenance roller hearth furnace, open the furnace top cover, extract all the roller bars with serious pollution and nodulation at the furnace side, polish and clean the surface of adhesion and nodulation, remove the defective broken roller bars, and replace the new furnace roller bars. From the start of production to the completion of the production of this batch of parts, the furnace temperature is set at 850 ° C in the first zone, 900 ° C in the second zone, 930 ° C in the third, fourth and fifth zones (a total of five zones of heating), the furnace roller speed is 42mm/s, and about 13000 pieces of parts are produced in total (two pieces in one mold, the length of the flat plate of the parts is 600mm, and the thickness of the material is 1.0), that is, about 6500 pieces of material pass through the surface of one side furnace roller in the furnace.

4. Test results and analysis

The temperature rise state and data of AISI coating sheet at the furnace side are shown in Figure 3. The number and measured temperature of each furnace roll are shown in Figure 4a). The running speed of the conveying roller of the furnace roller heating furnace is 42mm/s; The spacing of furnace rollers is 100mm. The observed phenomena are as follows:

1) The furnace rolls with coating adhesion are mainly between the 25th and 83rd (the range of access doors is between 35 and 63). The more serious knot slip occurs between the 50th and 65th heel;

2) The heating time and temperature of the sheets that began to adhere slightly were about 60s and 620 ° C, respectively;

3) The heating time of the material sheet with severe slip is about 120s-155s, and the heating temperature of the material sheet with severe slip is about 800 ° C to 850 ° C; (the heating zones are 1-38 rolls in the first zone, 39-70 rolls in the second zone, 71-102 rolls in the third zone, 103-126 rolls in the fourth zone, and 127-156 rolls in the fifth zone). The roll sticking phenomenon does occur during the sheet temperature rise process, and does not exist in the insulation stage.

4) The bonding state of 59 furnace rollers is inconsistent and gradually changes with the heating process of the sheet. With the increase of the sheet temperature, the adhesive bands change from less to more, and with the further increase of the temperature, the adhesive bands change from less to less, and finally disappear. It occupies a total length of 5900mm in this furnace, accounting for about 6/16=3/8 of the total length of the heating furnace.

From the analysis of the roll sticking process of the 16m long heating furnace in this experiment, the requirements for sticks of different lengths of furnaces can be calculated. If the furnace is 30m long, the easily polluted area is within the range of 120 furnace rolls from the 25th furnace roll. In the actual mass production, the roller bars in this seriously polluted area should be coated, which can reduce the impact of aluminum silicon coating on the service life of the roller bars, improve the stability of the production line, improve the yield and reduce the production cost.

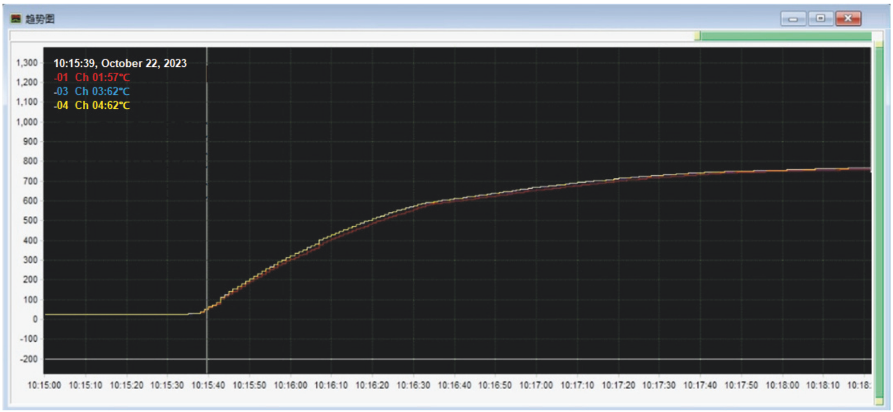
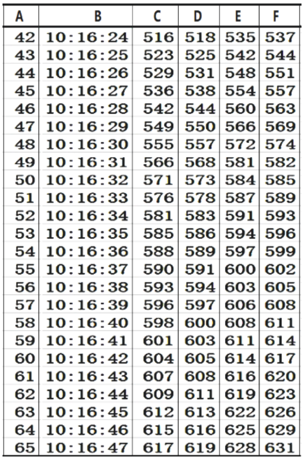
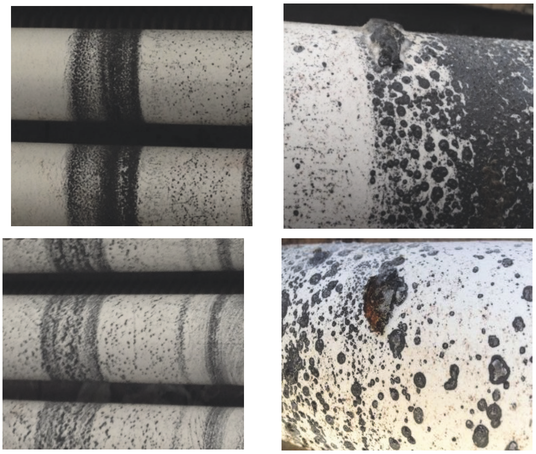


Fig. 3 Monitoring curve of heating rate of heating furnace



A	B	C	D	E	F
42	10:16:24	516	518	535	537
43	10:16:25	523	525	542	544
44	10:16:26	529	531	548	551
45	10:16:27	536	538	554	557
46	10:16:28	542	544	560	563
47	10:16:29	549	550	566	569
48	10:16:30	555	557	572	574
49	10:16:31	566	568	581	582
50	10:16:32	571	573	584	585
51	10:16:33	576	578	587	589
52	10:16:34	581	583	591	593
53	10:16:35	585	586	594	596
54	10:16:36	588	589	597	599
55	10:16:37	590	591	600	602
56	10:16:38	593	594	603	605
57	10:16:39	596	597	606	608
58	10:16:40	598	600	608	611
59	10:16:41	601	603	611	614
60	10:16:42	604	605	614	617
61	10:16:43	607	608	616	620
62	10:16:44	609	611	619	623
63	10:16:45	612	613	622	626
64	10:16:46	615	616	625	629
65	10:16:47	617	619	628	631

A)



B)

Fig. 4 Temperature and adhesion erosion; a) Furnace roll number and temperature; b) Adhesion and erosion of furnace roll.

A series of experiments were designed and carried out to simulate the thermochemical erosion process under actual operating conditions. In the experiment, the working samples that meet the actual production process conditions are selected, and the experimental observation is carried out for a long time under the predetermined temperature, pressure, chemical corrosion medium and other conditions, FIG. 4A). The experimental results show that mullite (the chemical formula of the material is 3Al2O3 · 2SiO2) conveying roller and high-strength steel aluminum silicon coated plate have different degrees of thermochemical corrosion at high temperature, as shown in Fig. 4b). Corrosion, oxidation and particle deposition occurred on the surface of the conveying roller, and the silicon aluminum alloy layer of the heated coating plate can improve the heat resistance and corrosion resistance of the mullite roller to a certain extent. According to the current technical means, there is no very effective technology to solve the corrosion resistance of furnace roll. The multi-layer box furnace has no moving machinery in the furnace [5] and has high effective energy consumption. It can be combined with the roller hearth furnace to form a mixed heating production line, so as to shorten the length of the roller hearth furnace, reduce the overall heat loss, reduce carbon emissions and reduce production costs.

5. Conclusion

In this study, the thermochemical erosion of the conveying roller in the heating roller hearth furnace of the hot stamping production line was experimentally studied

In the high temperature environment, it is found that the interface diffusion and chemical reaction may occur between the aluminum oxide roll and the metal plate with AlSi coating, leading to the phenomenon of bonding and erosion. This finding shows that thermochemical erosion is one of the main mechanisms leading to the performance degradation and life shortening of the conveying roller. In order to reduce the impact of thermochemical erosion and prolong the service life of the conveying roller, appropriate coating materials can be used.

The paper further discusses the combined use of multi-layer box furnace and roller hearth furnace. The experimental results show that the hybrid heating production line composed of multi-layer box furnace and roller hearth furnace can reduce the length and energy consumption of roller hearth furnace, so as to reduce the degree of thermochemical corrosion of furnace rollers. This provides a new idea and direction for improving production line efficiency and reducing furnace roll loss.

However, despite some progress, there are still some problems that need further study. For example, the performance of coating materials needs to be further improved to improve their resistance to high temperature and chemical corrosion. At the same time, it is necessary to optimize the design of roller hearth furnace to reduce the degree of thermochemical erosion. In addition, the research on the process parameters of the combined use of multi-layer box furnace and roller hearth furnace is also an important content of the next research.

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