Surface morphology evolution of Al-Si coated press hardening steel with different coating weight

Zitao Li[a,†], Shilong Zhou[b] and Lei Cui[c]

Technology Center, Ma'anshan Iron and Steel Company, Ma'anshan, China
E-mail: [a,†]lizitao@baowugroup.com, [b]zhoushilong@baowugroup.com, [c]cuilei_mg@baowugroup.com

The surface morphology of aluminum-silicon coated press hardening steel with different heating time was studied by scanning electron microscopy, and the AS150 and AS60 coatings were also compared. The results show that the dendrite phase can be formed when AS150 is heated for 3min, and the granular Al-Fe alloy grains can be formed when AS60 is heated for 2min. Both of these rough surface structures can provide good corrosion resistance after painting. Also, the surface morphology of the precoating was firstly found shows a significant influence on the surface morphology of aluminum-silicon coated press hardened steel part.

Keywords: Surface morphology; Al-Si coating; Press hardening steel; Hot stamping.

1. Introduction

In recent years, automotive lightweight technology has developed rapidly to meet increasingly stringent carbon emission regulations around the world. Ultra-high strength steels, especially hot-pressed hardened steels, are one of the effective ways to lightweight. Compared with cold forming technology, hot forming technology can avoid rebound effect to fully ensure the accuracy of parts. However, during the hot forming heating process of the steel sheet, even if there is a nitrogen atmosphere protection, an oxide layer is formed on the surface, then it needs to be shot blasting or pickling treatment to ensure the surface quality. So hot formed steel with coatings have been developed, such as, aluminum silicon (Al-Si) coating, hot dip plating pure zinc coating (GI), alloyed hot dip galvanizing coating (GA)[1-3].

However, hot formed Al-Si coating surfaces are non-reactive in phosphating solutions and no phosphate layer is formed on the surface.So the rough surface of the heat treated coating is must been insured to offer adequate paint adhesion without phosphate coating[4].It has been suggested that the alloyed layer has insufficient roughness when thicknesses of pre-coating is less than 20μm[5]. So far, there is a lack of research on the effect of coating thickness on the surface morphology of hot formed Al-Si coating. In this work, surface morphology evolution of Al-Si coated press hardening steel with different coating weight is studied.

Y. Zhang and M. Ma (eds.), *Proceedings of the 7th International Conference on Advanced High Strength Steel and Press Hardening (ICHSU 2024)*, Atlantis Highlights in Materials Science and Technology 3,
https://doi.org/10.2991/978-94-6463-581-2_50

2. Material and methods

Two steel substrate was a common boron alloyed carbon manganese steel 22MnB5 with a thickness of 1.4 mm. The coating weight was 75g/m2 and 30g/m2 on one side. The steel is annealing from 60 to 360 seconds at 930℃and cooled to room temperature by water cooled plate mold. The surface and cross-sections were analyzed by scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX).

3. Results and discussion

3.1. *AS150*

When the annealing time is 1 min, there is no obvious change on the surface of the coating compared with the initial one, EDS shows that the surface is Al-Si. When the annealing time is 2min, the surface of the coating changes and white fine linear structure appears. The EDS test shows that this phase is Fe_2SiAl_8 alloy phase. After the annealing time is 3min, the dendrite phase is formed on the surface. The phase structure transformation of AS150 has been extensively studied and will not be described here [6,7].

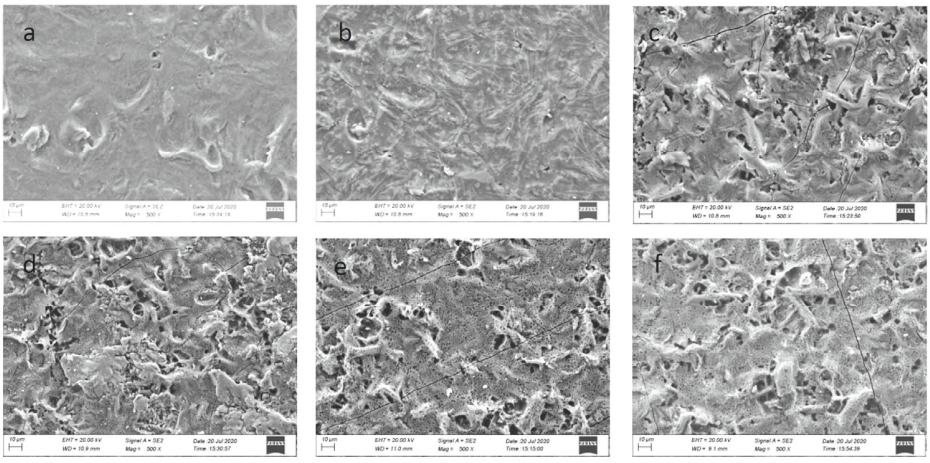

Fig. 1. Surface morphology of AS150 coating with varied annealing time (a-1min, b-2min, c-3min, d-4min, e-5min, f-6min).

3.2. *AS60*

When the annealing time is 1min, the coating surface shows no obvious change. When the annealing time was 2min, fine granular phase appeared on the surface of the coating, and EDS showed that it was Fe_2SiAl_7. When the annealing time is 3min, the surface morphology did not continue to change, and EDS showed that the granular phase was Fe_2Al_5.In Fig.2b and Fig.2c, traces of the skin pass process were still clearly visible after hot formed. This indicates that the morphology of the original surface of the precoating has a great influence on the morphology after hot forming. High surface roughness Ra maybe also easily obtained even if the precoating is less than 20μm.

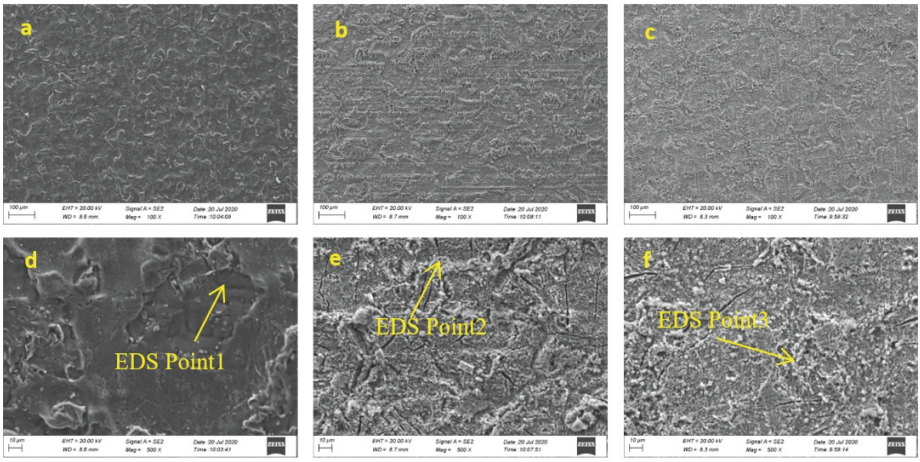

Fig. 2. Surface morphology of AS60 coating with varied annealing time
(a-1min-100X, b-2min-100X, c-3min-100X, d-1min-500X, e-2min-500X, f-3min-500X).

Table 1. EDS test.

	Fe（wt%）	Al（wt%）	Si（wt%）	Phase
Point 1	28.9	63.5	7.5	Fe_2SiAl_8
Point 2	32.3	55.9	11.8	Fe_2SiAl_7
Point 3	47.4	50.8	1.8	Fe_2Al_5

3.3. *Discussion*

During the annealing process, the liquefaction and alloying of the coating occur simultaneously. When the precoating is thick enough to liquefy, the liquefy coating level, causing the original valley caused by skin passed to disappear, then alloying continues until the dendrite Fe_2Al_5 phase forms on the surface. When the thickness of the precoating is thin, there is not enough coating to liquefy, and the liquefied coating cannot make original valley disappear, and the original roughness of the precoating is retained. Therefore, the morphology of hot formed Al-Si coating depends not only on the thickness of the precoating, but also on the original morphology of the precoating. According to this mechanism, when the roughness of the precoating is high, even if the thickness of the precoating is thick, the roughness after hot forming will decrease, because the liquefied coating needs to fill a deeper valley, which causes the roughness after hot forming to be lower than that of the precoating.

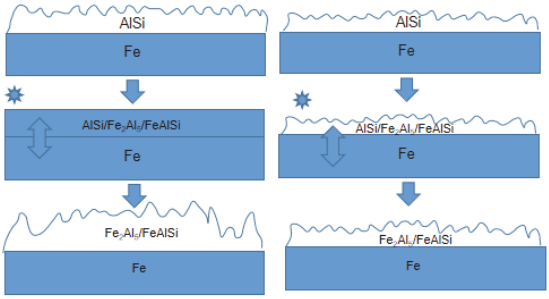

Fig. 3. Surface morphology evolution of Al-Si coated press hardening steel with different coating weight

4. Summary

The surface morphology of aluminum-silicon coated press hardening steel with different heating time was studied by scanning electron microscopy. The results shows：

The dendrite phase can be formed when AS150 is heated for 3min, and the granular Al-Fe alloy grains can be formed when AS60 is heated for 2min.

The surface morphology of the precoating was found shows a significant influence on the surface morphology of press hardened aluminum-silicon coating.

The surface of AS coating after hot forming is the result of the combined effect of the precoating thickness and surface morphology.

References

1. H. Karbasian and A. E. Tekkaya, A review on hot stamping, J. Mater. Process.Tech. 210, 2103 (2010).
2. H. Sun, H. U. Ping, M. A. Ning, G. Shen and B. Liu, Application of hot forming high strength steel parts on car body in side impact, Chin. J. Mech. Eng. 2, 252(2010).
3. Gui, W. Liang and Y. Zhang, Formability of aluminum-silicon coated boron steel in hot stamping process, T. Nonferr. Metal. Soc. China 6, 1750 (2014).B. W. Bestbury, R-matrices and the magic square, J. Phys. A 36, 1947 (2003).
4. D. W. Fan and B. C. D. Cooman, State of the knowledge on coating systems for hot stamped parts, Steel Res. Int. 5, 412 (2012)
5. CN101583486B-coated steel strip, its preparation method, its use method, stamping blanks prepared by it, stamping products prepared by it and products containing such stamping products
6. Rttger, A., Windmann, M. , & Theisen, W. . (2013). Phase formation at the interface between a boron alloyed steel substrate and an al-rich coating. Surface and Coatings Technology, 226(14), 130 – 139.
7. A, W. Y., B, E. H., A, H. K., C, S. A., B, S. K., & D, H. C. (2019). A study of annealing time to surface characteristics and hydrogen embrittlement on AlSi coated 22mnb5 during hot stamping process. Surface and Coatings Technology, 378, 124911.