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Coating Layer Behavior Analysis of Al-Si Coated Boron Steel in Hot Bending Process

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Abstract

Nowadays, the usage of high strength steel has been growing in automobile industry mainly as structural parts since for its lightweight and high strength properties the oil crisis happened. Owing to poor formability, complex-shaped hig h-strength steel components are invariably produced through hot press forming. The high-strength steel sheets are in so me instances used with an Al–Si-coating with a view to prevent scaling of components during hot press forming. How ever, friction and fracture characteristics of Al–Si-coated high-strength steel during hot press forming process have not yet been investigated. In this paper, the formed parts which were formed in hot bending process were investigated by u sing EDS、 SEM and nano indenter in order to analysis the coating layer behavior.

Key Words: Friction; High temperature; High-strength steel; Al–Si coating; SEM-EDS; Hot bending

1. Introduction

The emphasis on passenger safety and fuel efficiency has led to a significant increase in the usage of high-strength steels (HSS) in automobile applications due to their high-strength-to-weight ratio [1]. The most common applications of high-strength steels in vehicles are as structural reinforcements and energy absorbing systems. These components usually have complex geometries and are manufactured from sheet metal by means of various metal forming processes. There are, however, problems during forming of these steels owing to their poor formability, increased spring back and their tendency to work-harden. The forming of high-strength steel components is, therefore, done at elevated temperatures. The hot-metal forming of high-strength steels also leads to several problems such as oxidation of tool and workpiece surfaces, increased wear of the tools and scaling of the work piece. The high-strength steel sheets are in some instances used with an Al–Si coating in order to prevent scaling of the components during hot-metal forming [2]. In this study, we checked the coating layer variation during experiment which would be a reference about finding the optimal forming method of hot forming.

2. Experimental

In this study, the Al-Si-coated high-strength steel has the mechanical properties shown in Table. The size of the boron steel sheet used is 200mmX50mmX1.2mm. Fig. 1(a) shows the bending experiment die set. The sheets were first heat to 800°C and 950°C and last totally for 5 min in order to make them completely austenitizing [3-6], and then transferred on the bending die, the blank sheets were quenched by the room temperature die and punch at the same time when bending. Fig. 1(b) shows the bending process, the circles represent the fracture positions.

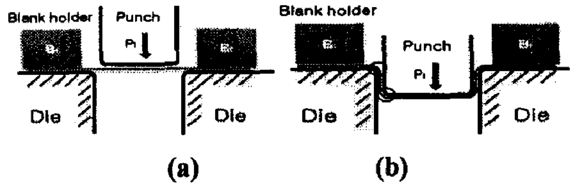

Fig.1 Blank cracking sketch map

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Table.1 Chemical composition and mechanical properties of tested material

Material	Chemical composition (mass %)					Mechanical properties		
	C	Si	Mn	Cr	B	YS(MPa)	TS(MPa)	EI(%)
BCJ239	0.2123	0.0806	1.484	0.4063	0.0016	469	659	20

3. Results analysis

In Fig. 2 we can see the original sheet coating layer microstructure taken by optical microscope. The thickness of the coating layer is about 27μm. Obviously, there are two layers on the sheet metal, to make it clear, EDS was introduced.

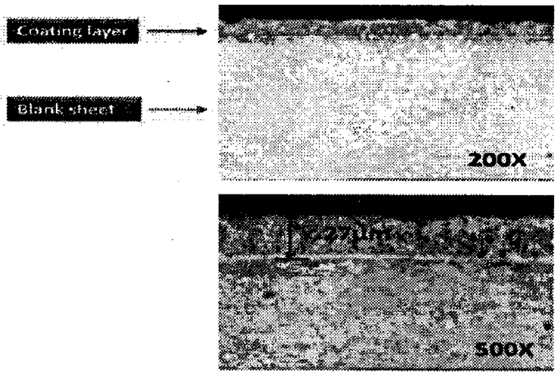
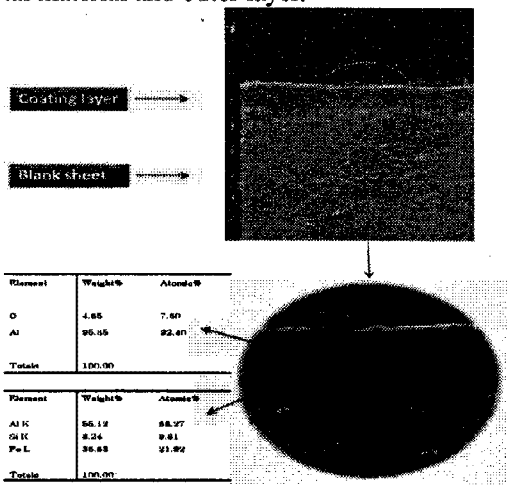
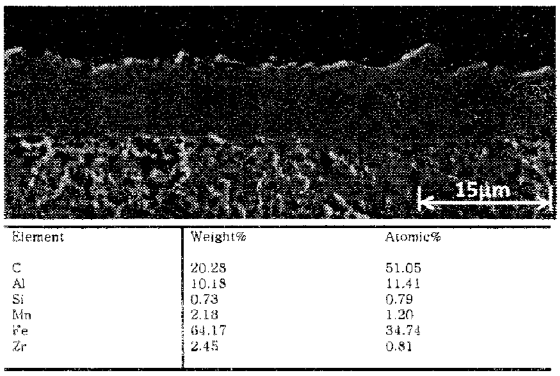


Fig. 2 Original boron steel coat layer microstructure

Fig. 3 shows the detail chemical components tested by EDS. We can see that the main component of the outer layer is Al while the middle layer mainly contains Si and Fe, so we can conclude that the middle layer was made of alloy formed during deposition, and to some extent the middle is made to prevent the direct contact of metal material and outer layer.



(a) Original coating layer



Element	Weight%	Atomic%
C	20.28	51.05
Al	10.18	11.41
Si	0.73	0.79
Mn	2.18	1.20
Fe	64.17	34.74
Zr	2.45	0.81

(b) Formed part coating layer

Fig. 3 Original boron steel and formed part coat layer microstructures and components analyze by SEM—EDS

Due to the bending force, coating layer cracked mainly at the position of bending line. Fig. 4 shows the fracture detail. Fractures differ from different positions while also different bending conditions resulted in different damage degree on coating layer. Fig. 5 shows the measured positions of formed part for observation.

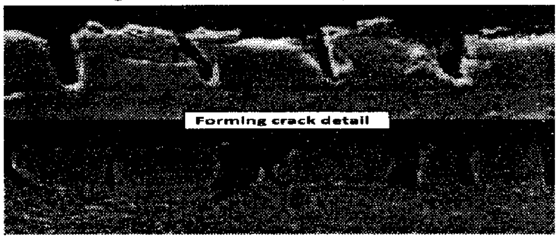


Fig.4 Forming crack detail

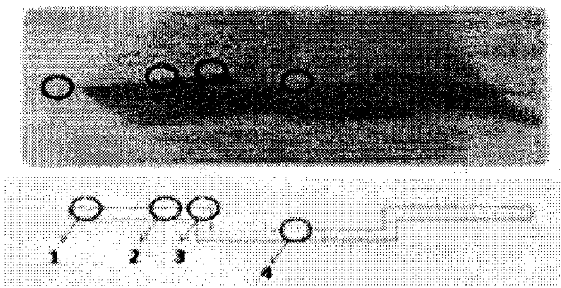


Fig.5 Positions for observation of crack detail and nano indentation experiment

Fig. 6 shows the scratch on the cross section of boron steel. Fig. 7 shows the detail of different parts' fracture according to different experiment (Blank holding force、heating temperature). We can see position 3 have the most serious fractures which even affect the function of coating layer. We also can conclude that the nearer to the bending line, the more cracks happened. By contrasting different heating temperature, the 950°C formed part have higher density crack and more narrow gaps while the 800°C formed parts have larger、more critical cracks and some cracks even extended to the metal material which would affect the anti-oxidation ability. It is concluded that blank holding force did not affect the coating layer behavior seriously in this experiment.

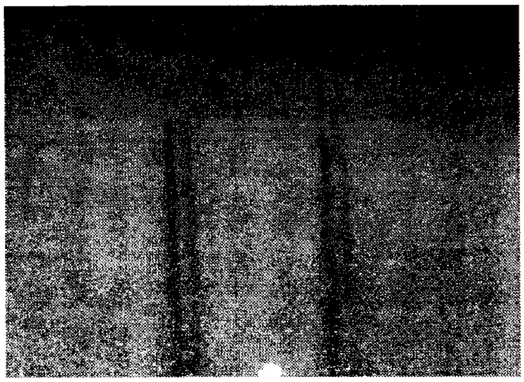
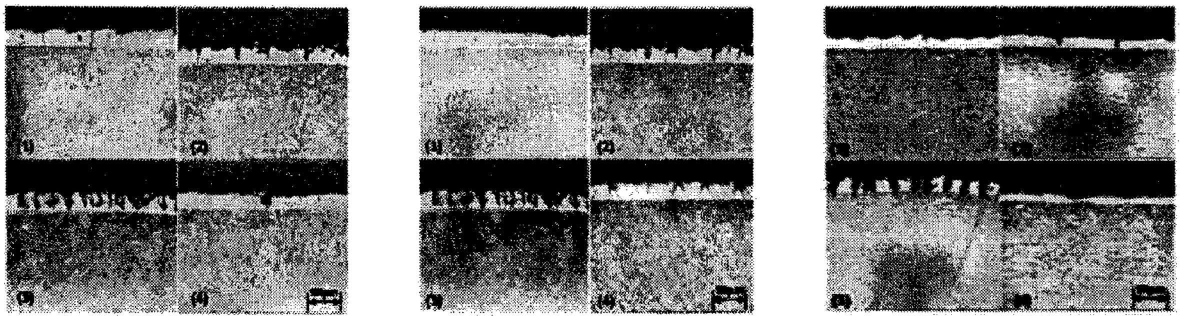


Fig.6 Scratch on the cross section of boron steel



T_s=950°C B_f=10KN **T_s=950°C B_f=19KN** **T_s=800°C B_f=19KN**

Fig. 7 Formed part coating layer microstructure at different condition

By using nano indenter, the hardness and friction coefficient of the coating layer were obtained. Fig. 8 shows the hardness of coating layer according to different experiment conditions. On the contrary, the hardness of coating layer decrease when the heating temperature increase while the hardness of sheet metal increase when the heating temperature increase [7]. It is obvious that different hardness results in different friction.

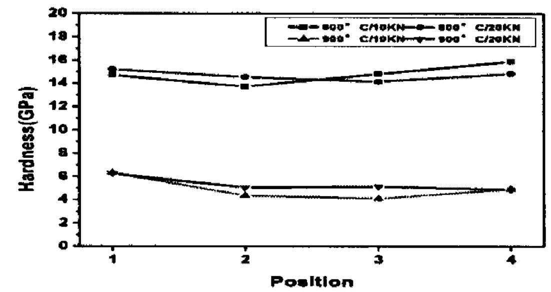
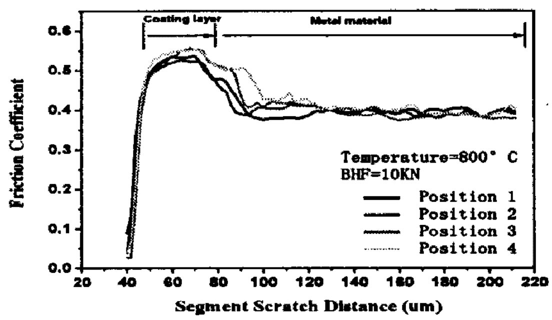
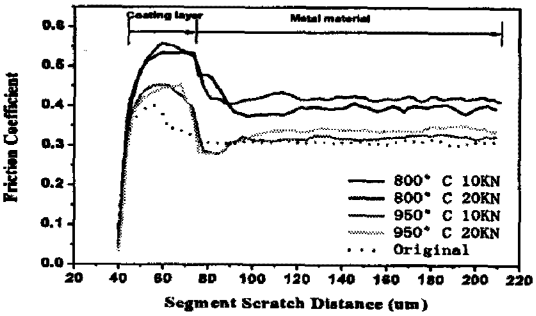


Fig. 8 Coating layer hardness of different experiment conditions

Fig. 9 show the friction coefficient variation of different experiment conditions. Fig. 9 (a) shows the friction comparison of different positions shown in Fig. 6. There is no obvious difference among different positions. Fig. 9 (b) shows the comparison of different experiment conditions. The highest friction coefficient can be seen at the condition of 800°C which is about 0.55, at the condition of 950° heating, the coating layer friction coefficient is about 0.45 while the original coating layer friction coefficient is about 0.4.



(a)



(b)

Fig. 9 Coating layer friction coefficient variation of different experiment conditions

4. Conclusions

In this paper, the formed parts which were formed in hot bending process were investigated by using EDS、SEM and nano indenter in order to analysis the coating layer behavior. Actually, there are two layers on the metal material to protect the sheet from oxidation during forming. After heating, the two layers change into one layer and the percentages of chemical changed. The most serious cracks happened on the position of bending line. Different coating layer hardness resulted in different friction coefficient. Low heating temperature matched high hardness and friction coefficient while high heating temperature matched low hardness and friction coefficient. Blank holding force does not affect the experiment results seriously.

Acknowledgement

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Reference

[1] Shaeffler DJ. Introduction to advanced high strength steels,2005,/www.thefabricator.com/MetalsMaterials /MetalsMaterials_Article.cfm?ID=1139S (accessed 10.08.06).

[2] Suehiro M, Kusumi K, Maki J, Ohgami M, Miyakoshi T. Properties of aluminum coated steels for hot forming. Nippon steel technical report no. 88, July 2003.

[3] Akerstron, P., Wikman, B., Oldenburg, M. Modeling and Simulation in Materials Science and Engineer 13 (2005), No. 8, pp 1291-1308.

[4] T. Altan. Hot-stamping boron-alloyed steels for automotive part, Part I: Process methods and used, Stamping Journal, 2006, 40-41.

[5] Hein, P. Advanced Materials Research, 6-8 (2005) pp 763-770.

[6] Geier, M., Merklein, M. and Hoff, C. Advanced Materials Research 6-8 (2005), pp 795-802.

[7] Nak-Hyun Kim, Ki-Young and Chung-Gil Kang. The Effect of Cooling Rate on Mechanical Properties in Hot Press Forming of Al-Si coated 22MnB5 Sheet and it Theoretical Temperature Prediction. 2nd International Conference on Hot Sheet Metal Forming of High-Performance Steel. June 15-17, 2009, pp 17-28