The Effect of the Thickness of Fe_2Al_5 Phase Layer at Fe/Al Interface on the Mechanics Behavior of Hot Dip Aluminizing Coating

XIA Yuan[1], YU Sheng-xue[2,1], CHEN Ling[2], CUI Rui-yi[1], YAO Mei[3]

(1. Institute of Mechanics, Chinese Academy of Science, Beijing 100080; 2. Department of Environment Science & Chemical Engineering, Yanshan University, Qinhuangdao 066004; 3. College of Material Science and Engineering, Yanshan University, Qinhuangdao 066004, P. R. China)

[**Abstract**] Hot Dip Aluminized Coatings with different thickness were prepared on Q235 steel in aluminum solutions with different temperature for certain time. Through tensile tests and in-situ SEM observations, the effect of the coating's microstructure on the tensile strength of the samples was studied. It was disclosed at certain aluminum solution temperature, transaction layers mainly composed of Fe_2Al_5 phase got thicker with time prolonging, and this changed initial crack's extending direction from parallel with to vertical with stretching direction. The change in crack direction decreased tensile strength of samples, thus made the coating easy to break. It was concluded that the existence of thick Fe_2Al_5 phase layer was the basic reason for the lowering of tensile strength of the coating.

[**Key words**] Fe_2Al_5 phase; mechanics behavior; crack; hot dip aluminizing coating

0 Introduction

During researches about steel's hot dip aluminizing, many were focused on effects of microstructure on heat resistance and corrosion resistance, seldom were focused on effects of the coating on mechanics performances of samples[1~4].

In fact, brittle Fe_2Al_5 phase was easy to appear during hot dip aluminizing process[5], it will affect performances of samples greatly. Seldom was reported about this.

Hot dip aluminizing coating was composed of two layers[6]: surface layer and transaction layer, the former contained mainly α-Al and a little $FeAl_3$, its thickness was determined mainly by raising speed and dip time; the latter contained mainly Fe_2Al_5, its thickness was determined mainly by aluminum solution temperature and dip time.

According to the basic conclusions that the thickness of hot dip aluminizing coating increased with dip time and the relation between the coating's thickness and dip time was in conformity with Arrhenius relation, the relation between hot dip aluminizing parameters and mechanics strength was studied by means of in-situ tensile tests on samples. The control mechanism of microstructure on macro performances was discussed, and scientific basis were provided for optimizing coating.

1 Experimental

Q235 steel was used to prepare samples. The shape and size of samples were shown in Fig. 1. The sample had a Φ3.2 mm hole on its top. After degreasing and rust removing, samples were immersed in aluminizing-aid solution at 70 ℃ for 1 min, then baked, hot dip aluminizing at certain temperature for certain time. The raising speed was carefully controlled at 800 mm/min.

In-situ observation of samples in tensile tests was conducted on S-80 type SEM, accelerating voltage was 20 kV and specified load was 200 kg.

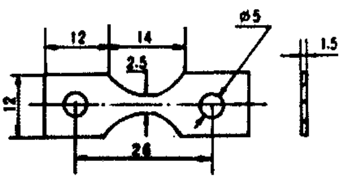

Fig. 1 Tensile specimen for SEM in-situ observation

2 Results and Aanalysis

Through tensile tests on samples prepared at different raising speed it was found that the thickness of surface layer affected tensile strength less. Besides, before aluminizing, Q235 steel has been annealed at 920 ℃, thus the temperature changes of aluminum solutions in the range of 690 ~ 750 ℃ will affect tensile strength of the sample little. So the effect of transaction layer's microstructure on tensile strength was studied in detail.

The relation between tensile strength and aluminizing temperature and relation between tensile strength and aluminizing time were shown in Fig. 2. It can be seen that with temperature increasing and time prolonging, tensile strength tended to de-

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crease. When hot dip time is shorter than 3 min, tensile strength decreased little, when the time is prolonged to 5 min, tensile strength decreased obviously. Based on dynamic studies on the thickness of hot dip aluminizing coating, transaction layer, which was composed mainly of hard and brittle Fe_2Al_5 phase, got thicker with temperature increasing and time prolonging [7]. So, it was deduced that microstructure and thickness of the transaction layer was an important factor affecting tensile strength of aluminized sample.

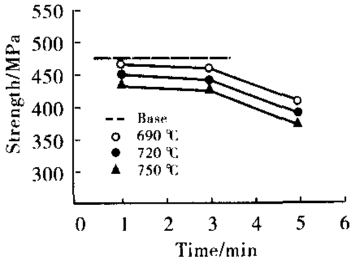
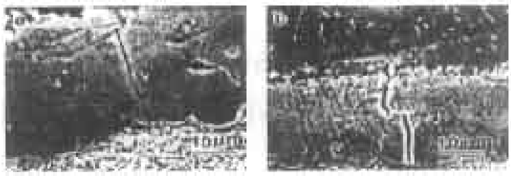


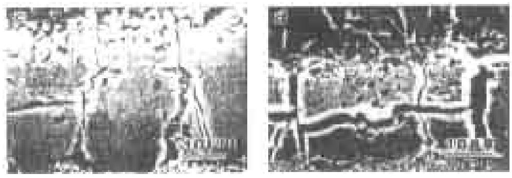
Fig. 2 Strength of aluminized specimen vs hot dip time and temperature

Lack of reference about mechanical strength of Fe_2Al_5 phase, in-situ SEM observation was used to study the effect of hot dip aluminizing coating on tensile strength of samples. In-situ SEM figure for coatings prepared at 720 ℃ for 1 min and 6 min were shown in Fig. 3 and Fig. 4. It can be seen from Fig. 3 that Fe_2Al_5 phase layer is thin (about 30 μm) at this time. During tensile test, because Fe_2Al_5 phase is brittle, its tensile strength is low, some horizontal cracks vertical with tensile direction appeared first (Fig. 3a), with load increasing, vertical cracks appeared (Fig. 3b) and joined together horizontal cracks, with load increasing further, vertical cracks extended to form inner layer-cracks (Fig. 3c and 3d). At this time, some Fe_2Al_5 phase layer about 15 μm thick still existed near substrate (Fig. 3e), with load increasing, substrate broke along the cracks in remaining Fe_2Al_5 phase (Fig. 3f).

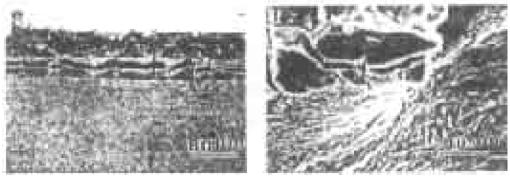
SEM figure of sample aluminized at 720 ℃ for 6 min was shown in Fig. 4a, it can be seen that transaction layer become thicker obviously. In tensile test, horizontal cracks running through the layer appeared vertical with tensile direction, with load increasing, surface layer broke (Fig. 4b), this differed from that for coating aluminized for 1 min. With load increasing further, cracks extended inner along cracks in transaction layer (Fig. 4c) to join with inner mixture, and led to the early break of the sample (Fig. 4d). It can be concluded that with time prolonging, transaction layer got thicker, this changed initial break mode of aluminized samples and led to the decrease of the substrate's tensile strength. That means thick Fe_2Al_5 phase layer is harmful to sample's mechanics performances.



(a) initial crack in transition layer (b) crack

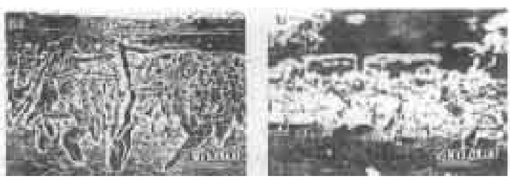


(c) crack (d) crack

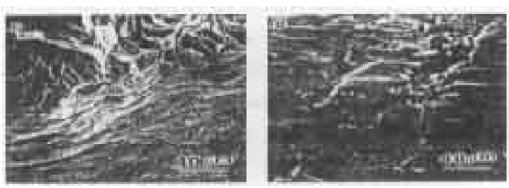


(e) crack (f) fracture of HDA steel

Fig. 3 In-situ SEM figure of sample aluminized at 720 ℃ for 1 min in tensile test



(a) initial crack in transition layer (b) fracture of surface layer



(c) crack propagation of transition layer to base (d) fracture of HDA steel

Fig. 4 In-situ SEM figure of crack propagation in surfacee layer of steel aluminized at 720 ℃ for 6 min

3 Conclusions

Fe_2Al_5 phase layer will get thicker with dip time prolonging or temperature degreasing, this leads to the coating easy to break. Not only corrosion resistance degreased but also tensile strength degreased because of the appearing and extending of cracks in the coating. So, this factor should be considered in the further optimizing of hot dip aluminizing technology.

Acknowledgements

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titanium is stronger than that of copper. For the corrosion resistance of coating layer, it decreases with the content of copper increases, while the corrosion resistance ability is the best when the content of alloying element Ti is 0.3%. The results are in accordance with the SEM observation and the theoretically analysis.

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