

Effect of aluminizing on hardenability of steel (S45C)

D Prayitno*, R Sugiarto

Mechanical Engineering, Faculty of Industrial Technology, Universitas Trisakti, Jakarta, Indonesia.

*Corresponding Author : dodyprayitno@trisakti.ac.id

Abstract. The objective of research is to know the effect of aluminizing on hardenability of steel (S45C). The research methodologies were as follows. The Steels (S45C) were machined into the Jominy test samples. Next the samples were preheating at 700 °C for 30 minutes and then the samples were dipped into the molten of aluminium for 3 minutes as a hot dip aluminizing method. The aluminium molten was 700 °C. Then the samples were cooled into room temperatures. Finally the samples were into the jominy tested. The results show that the aluminizing (include the preheating process) increases the hardenability of steel (S45C).

Keyword : aluminizing hardenability, jominy test, steel

1. Introduction

High-temperature corrosion of carbon steel in N₂/0.1% H₂S mixed gas at 600–800 °C for 50–100 h was studied after hot-dipping in the aluminum molten bath. Hot-dipping resulted in the formation of the Al topcoat and the Al-Fe alloy layer firmly adhered on the substrate. The Al-Fe alloy layer consisted primarily of a wide, tongue-like Al₅Fe₂ layer and narrow Al₃Fe layer. When corroded at 800 °C for 100 h, the Al topcoat partially oxidized to the protective but non-adherent -Al₂O₃ layer, and the interdiffusion converted the Al-Fe alloy layer to an (Al₁₃Fe₄, AlFe₃)-mixed layer [1].

The Hot Dip Aluminizing result intermetallic coating 0.02-0.10 mm for 1-15 minutes on the steel surface. The best time for immersing steel into the molten of aluminium is 3 menit at 1.023K (750 °C) [2]. In 1989 Daimler Benz AG, Stuttgart, introduced hot dip aluminized steel sheet for this application in passenger vehicles. By now, after 10 years' experience, most of this manufacturer's current models are equipped with fuel tanks made from aluminized steel sheet. This material incorporates a combination of a specially designed deep drawing If steel with the excellent corrosion protection properties of Al coatings. The two methods for joining the upper and lower halves of the tank body are resistance roller seam welding with an additional wire or laser beam welding. The first method was applied to the fuel tank bodies illustrated in this paper. In laboratory corrosion test series, aluminized steel sheet performed very well with regard to fuel resistance, including resistance to fuels containing methanol and rape-methyl-ester (bio diesel) [3].

The hot dip aluminizing using the molten of aluminium alloy (Al-53% Cu) at 800 °C while the dipping times are 3 minutes, does not work to prevent die soldering on the steel, H420 J2 [4]. Hot dip aluminizing succed to reduce the corrosin rate of welding area of LPG tube for 3 kg. The rate corrosion reduces from 0.2531 mmy to 0.0734 mmy [5]. The Jominy end quench test measures the effects of microstructure, such as grain size and alloying, on the hardenability of steels. The main alloying elements including Cr, Mn, Mo, Si and Ni; and Boron [6]. The aim of the reseach is to invastige the effect of aluminising on the hardenability of steel (S45C).



2. Research Method

The research flow chart is shown in Figure 1. The steel (S45C) were cut and machined into the jominy test sample. Next the samples were divided into 2 groups i.e non-aluminizing group and aluminizing group where the each group had 5 pieces samples. The non-aluminizing group were not aluminized. The non-aluminizing group were directly to the jominy test. While there were some process for the aluminizing group. The aluminizing group were firstly preheating at 700 °C for 30 minutes. Then the aluminizing group were immersed into the molten of aluminium (700 °C) for 3 minutes as the aluminizing process. Next, the aluminizing group were air cooling and following the Jominy test (heated at 900°C).

Next the samples were air cooled and then the hardness of samples were measured. Finally the data were analyzed to make conclusions

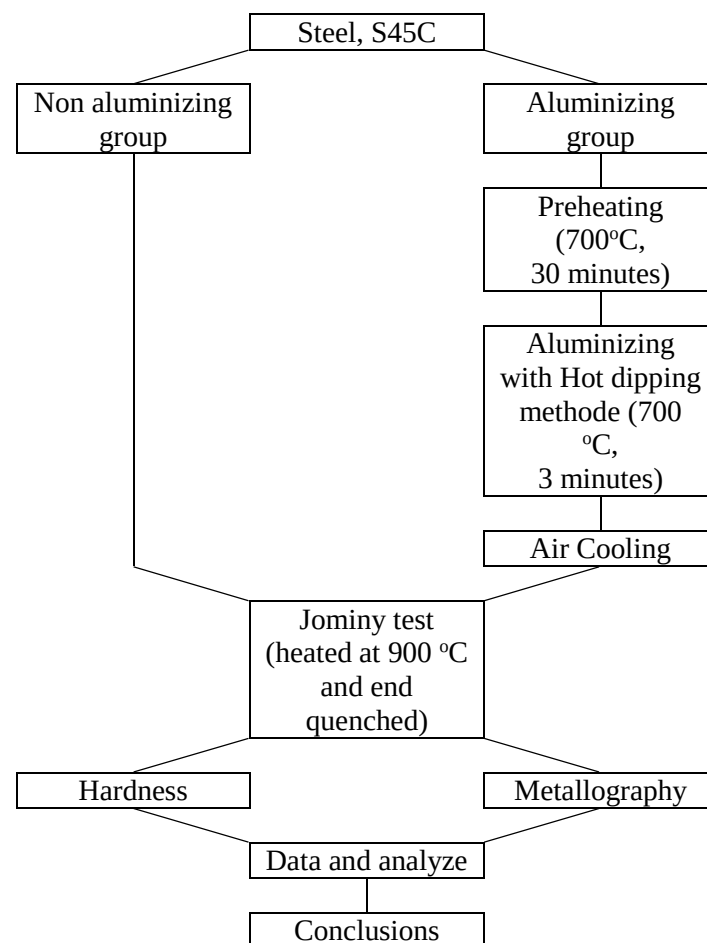


Figure 1. Research flow chart.

3. Results and Discussion

3.1. Sample performance before jominy testing.

The first group is the aluminizing group that the steel S45C was aluminized. The aluminizing group were firstly preheated at 700 °C for 30 minutes and then were hot dip aluminized at 700°C for 3 minutes. Finally the aluminizing group were jominy end quench tested.

The second group is the non aluminizing group or the initial of steel S45C. The non aluminizing group were not preheated and hot dip aluminized. The non aluminizing group of samples were directly jominy end quench tested. Figure 2 shows the samples of aluminizing group and the non aluminizing group before jominy testing. There are aluminium stick on surface of the aluminizing samples group but non on the non-aluminizing samples group. The aluminium stick on the surface after aluminizing process like a die soldering defect. Because it happen in the die casting where a molten aluminum stick on the die.



(a) The aluminizing group



(b) The non aluminizing group

Figure 2. The group samples were before Jominy testing: (a) the aluminizing group (b) the non aluminizing group.

Based on the previous research the die soldering mechanism have 5 stage as follows [7] :

- a) Erosion of phase boundaries of the steel surface;
- b) Pitting of the steel surface;
- c) Formation of iron-aluminium compounds and formation of pyramid-shaped structure of intermetallic phases;
- d) Adherence of aluminium on the pyramids of intermetallic phases ; and
- e) Straightening of erosion pits and intermetallic phases

3.2. Hardness distribution of Jominy test bar

The first group is the aluminizing group and the second is the non aluminizing group. The both of group were jominy tested. Then the hardness of the two groups of samples were measured as a function of the distance from the quenched end to demonstrate the different hardenability of the two groups of sample. The hardness test results are shown as rockwell hardness (Figure 3).

The Figure 3 shows that the average hardness of the aluminizing group are higher than the non aluminizing group from J0 to J50. But the hardness of the both groups are relative similar from J50 to J70. The highest average hardness of the aluminizing group reduced sharply is 55 HRC at the end of

quench or J0. The hardness reduces gradually from 55 HRC to 38.3 HRC at J50. From J50 to J70, the hardness reduce form 38.3 HRC to 35.8 HRC. So the lowest hardness of the aluminizing group is 35.8 HRC at J70.

The higher average hardness of the non aluminizing is 46 HRC at J0. The hardness of Non Aluminizing group reduce gradually from 46 HRC at J0 to 38.1 HRC at J50. The average hardness of non aluminizing groups reduce from 38.1 HRC (at J50) to 35.9 HRC at J70. Figure 3 shows measured hardness of jominy distance from the end quench (J0) to 70 mm (J70) for the aluminizing group and the non aluminizing group. The average hardness of the aluminizing group are higher than the non aluminizing group from J0 to J50. The hardness results show that the aluminizing process in this research improve the hardenability of steel S45C.

Figure 3 shows the hardenability result from the previous researchers [8], and [9]. The steel samples were heated by [8] at 870 °C for 30 minutes before Jominy testing. While the steel samples were annealed by [9] to get full pearlit. Comparing the hardenability of aluminized steel to to the previous reseach as Figure 2, shows that the hardenability of the aluminizing group is higher than the [7] and [8] results.

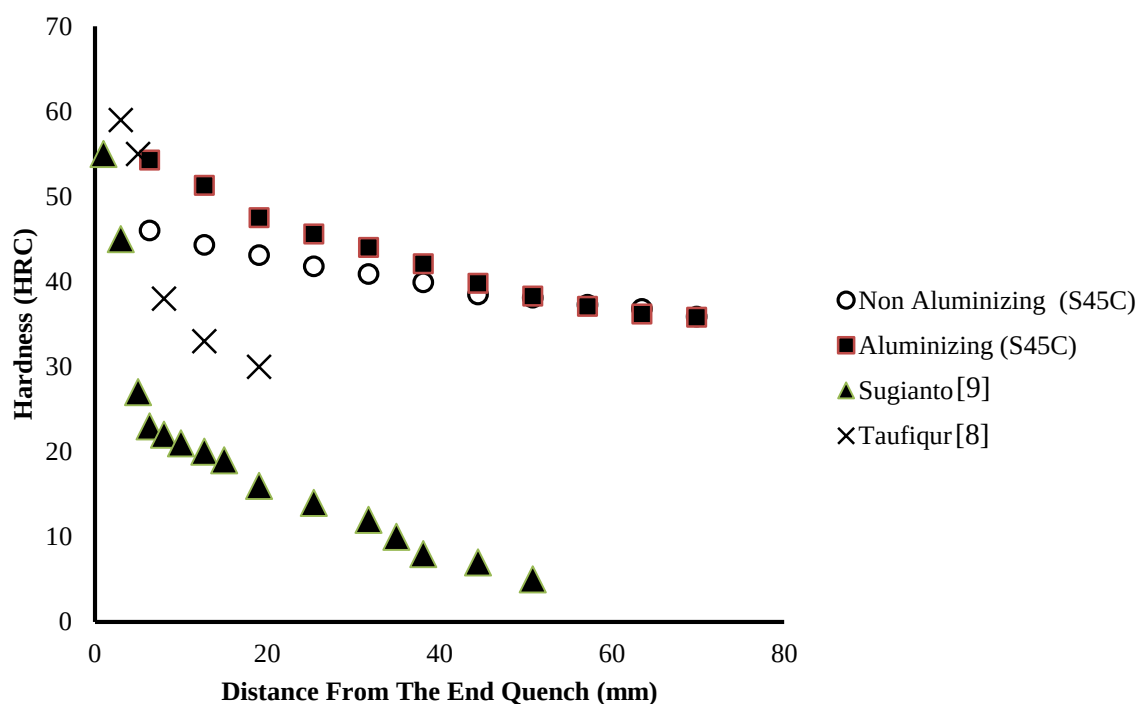
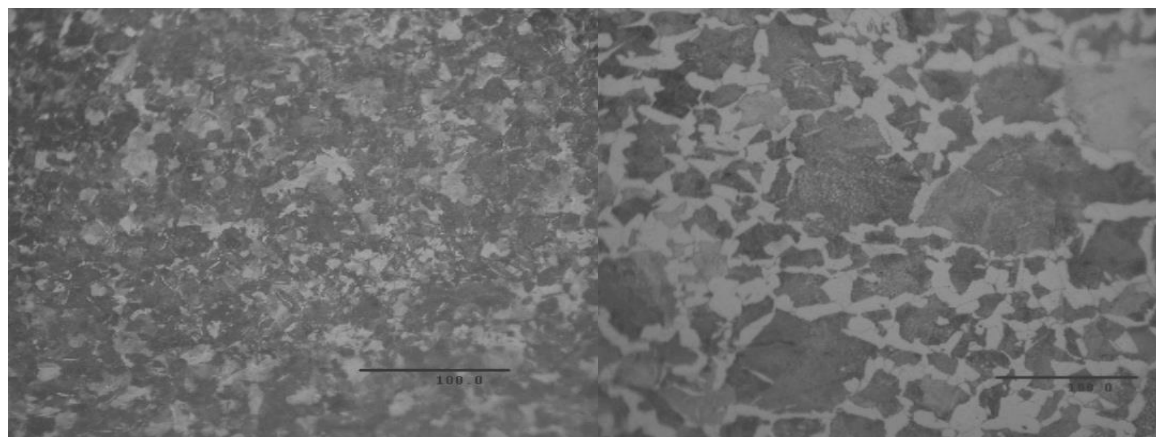


Figure 3. Jominy test result of the aluminized s45C comparing the previous results. [7], [8]

3.3. Microstructure

The microstructure at the end quench were observed using an optical microscope. The microstructures are shown in Figure 4. The observation on microstructure start from the end quench to 1.0 mm. (mm) microstructure of the non aluminizing and the aluminizing group was observed start from the end quench (J0) to 1.0 mm (J10).



(a) Non aluminizing sample

(b) Aluminizing sample

Figure 4. Microstructures at J10 for the non aluminizing sample (a) and the aluminizing sample (b).

The grain size of the non aluminizing samples and aluminizing sample increase with increasing the distance from J0 to J10. The grain size of the non aluminizing samples are smaller than the aluminizing samples at the all observation location, i.e Figure 4. For the aluminizing group, the preheating process at 700°C for 30 minutes and the aluminizing process at 700°C for 3 minute gives much time to the grain to grow up. When the aluminizing group were heated (900°C for 30 minutes) before quench, the grain grow up more to become a bigger austenit grain. The nucleation of ferrite and pearlite take places at heterogeneous sites such as the austenite grain boundaries. Therefore, increasing the austenite grain size decreases the available nucleation sites, which pauses the rate of the ferrite/pearlite phase transformation. Thus increasing the austenite grain size increases the hardenability of steels.

4. Conclusion

The hardenability of steel S45C can increase by preheating at 700 °C for 30 minutes and following by the hot dip aluminizing 700 °C for 3 minutes.

References

- [1] Muhammad Ali Abro and Dong Bok Lee, Effect of Al Hot-Dipping on High-Temperature Corrosion of Carbon Steel in N₂/0.1% H₂S Gas, Metals, MDPI. 2016.
- [2] R, Rajendran, S, Venkataswamy, U, Jaikrishna, N, Gowrishankar, A, Rajadurai B.S.A., Effect Of Process Parameters In Hot Dip Aluminizing Of Medium Carbon Steel. Crescent Engineering College, Chennai 600048, India, 2IP Rings Ltd, D 11/ 12, Industrial Estate, Maraimalainagar 603 209, India, 3 Anna University, Chennai 600 044, India, Student Papers from FISITA. 2006.
- [3] Warnecke W, Froeber J, and Bode R. 1999. Hot Dip Aluminized Steel Sheet - An Excellent Material for Fuel Tank Application. *SAE Technical Paper* 1999-01-0022. doi:10.4271/1999-01-0022.
- [4] Fathony Arief Rhamdhany, Dody Prayitno. 2016. Studi Metode Almunizing Untuk Mencegah Die Soldering Pada Baja H420 J2, *Prosiding Seminar Nasional Cendekiawan 2016*, p. 8.1-6. <http://www.trijurnal.lemlit.trisakti.ac.id/index.php/semnas/article/view/880>. 2016.
- [5] David Ray. 2015. Semnas Cendekiawan, Pengaruh Aluminizing (Al-Cu) Terhadap Laju Korosi Sambungan Las Busur Rendam Tabung Gas Elpiji 3 Kg, *Prosiding Seminar Nasional Cendekiawan*. p. 331-341. <http://www.trijurnal.lemlit.trisakti.ac.id/index.php/semnas/article/view/154>.
- [6] R.W.K Honeycombe and H.K.D.H. Bhadeshia. Edward Arnold. Steels: Microstructure And Properties. 1995.

- [7] A. Sugianto 1, M. Narazaki 2, M. Kogawara 2, and A. Shirayori 2. 2008. Prediction Of Hardness Distribution Of Water-Quenched S45c Steel Parts By Computer Simulation, *Proceedings of the 8th Asia-Pacific Conference on Materials Processing*. June 15-20. Guilin -Guangzhou, China.
- [8] Taufiqur Rokhman. 2015. Perancangan Alat Uji Kemampukerasan Jominy Test, *Jurnal Ilmiah Teknik Mesin*, 3(1) Februari 2015. <http://ejournal.unismabekasi.ac.id>.