Mechanical Properties of Hot-dip Al and Al-45Zn Galvanized Steel Plates

Kyushu University Student Member ○Yang GAO　　Kyushu University Fellow Member Shigenobu KAINUMA
Kyushu University Regular Member Muye YANG　　Meijo University Fellow Member Hanbin GE

1. Introduction In the actual structural maintenance, hot-dip coating is one of the effective anti-corrosion protection method, used for protecting the steel structure which is vulnerable to corrosion. During the fabrication progress of hot-dip coating, the main process is immerse the steel member into the molten metal solution. The steel is dipped into the molten metal bath and held there until the temperature of the steel equilibrates with that of the bath, then cooled in a quench tank to reduce its temperature and inhibit undesirable reactions of the newly formed coating with the atmosphere. The melting point of Al is about 660℃ whereas the temperature of the molten Al solution will usually exceed it, and the temperature of molten alloy solution is about 570℃. After the hot-dip coating treatment, the influence of the high temperature during the treatment on the mechanical properties of steel members has not been clearly investigated. In this study, the mechanical properties of specimens with two different painting treatments were compared with those of no coating specimens, by conducting the tensile test.

2. Test method In total, 24 pieces of specimens were used for tensile testing, to clarify the fracture characteristics of steel plates with the effect of heat-affected zone. The specimens are made from carbon steel plates (JIS G 3106 SM490A) with two different plate thickness *t*: 9 and 12 mm. The types and serial number of tensile specimens are shown in Table 1. There are three groups of specimen, without coating (named as N type), with hot-dip Al coating (named as Al type) and hot-dip Al-45Zn coating (named as Al-Zn type). The dimensions of specimens are 1A specimen specified in JIS Z2241, are shown in Fig. 1. Moreover, all specimens were tested by MTS machine, subjected to 500 kN under the displacement control and the tensile speed was 0.03 mm/sec. A specimen under the loading is shown in Fig. 2. During the test process, load P and displacement δ were measured and recorded by data logger. Furthermore, the surface crack initiation behaviors of all specimens were recorded continuously by a camera. Finally, according to the measured data, the load-displacement curves were obtained. At the end of the test, the fractured cross section of three types of specimens were photographed as shown in Fig. 3.

Table 1 Types and serial number of specimens

Type	Coating condition	Plate thickness (mm)	Specimen ID
N	Without coating	9	N-1, N-2, N-3, N-4
	Without coating	12	N-5, N-6, N-7, N-8
Al	Hot-dip Al coating	9	Al-1, Al-2, Al-3, Al-4
	Hot-dip Al coating	12	Al-5, Al-6, Al-7, Al-8
Al-Zn	Hot-dip Al-45Zn coating	9	Al-Zn-1, Al-Zn-2, Al-Zn-3, Al-Zn-4
	Hot-dip Al-45Zn coating	12	Al-Zn-5, Al-Zn-6, Al-Zn-7, Al-Zn-8

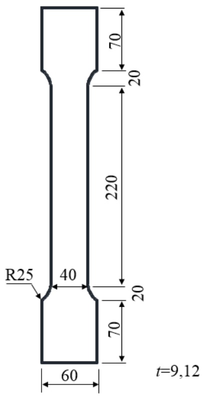

Fig.1 The configuration and dimensions of specimen (unit: mm)

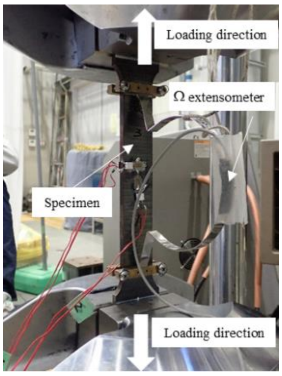

Fig.2 Photograph of a specimen being stretched in test


(a) N-1


(b) Al-1

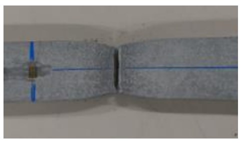
(c) Al-Zn-1

Fig.3 Photograph of fractured specimens after tensile test

3. Test results After the tensile test, the relationships between load and displacement of 9 mm thick specimens are shown in Fig. 4, and those of 12 mm thick specimens are shown in Fig. 5. From Figs. 4 and 5, it can be concluded that all the specimens qualitatively exhibit similar behavior in the shape of P-δ curves, and each type of specimens under the same test condition lead to approximate value of the mechanical parameters. The average measured values of mechanical properties of each type of specimens are shown in Table 2. In addition, the most evident difference among three types of specimens with the same plate thickness is that their mechanical properties were decreased after suffering higher hot-dipping temperature and be largely heat affected. From Fig. 4 and Table 2, the comparison of two kinds of specimens

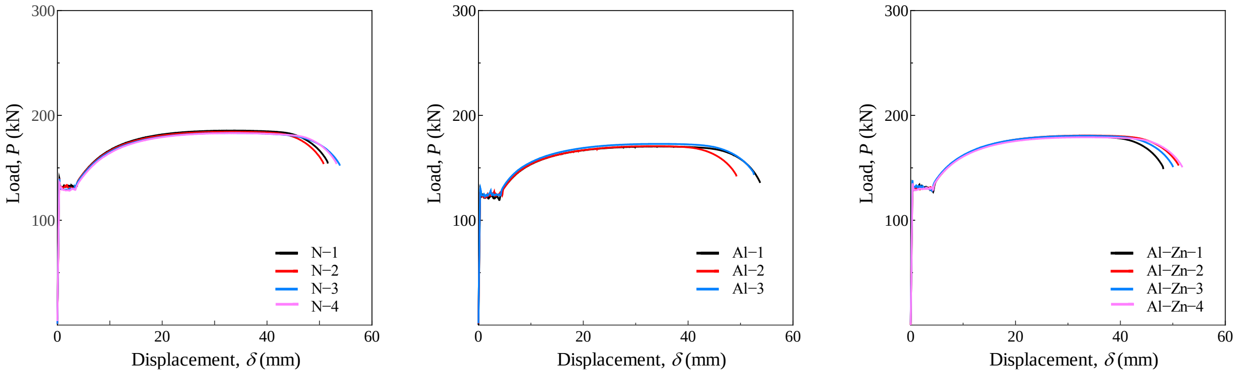

Fig. 4. *P*-δ curves of specimens (Plate thickness: 9 mm)

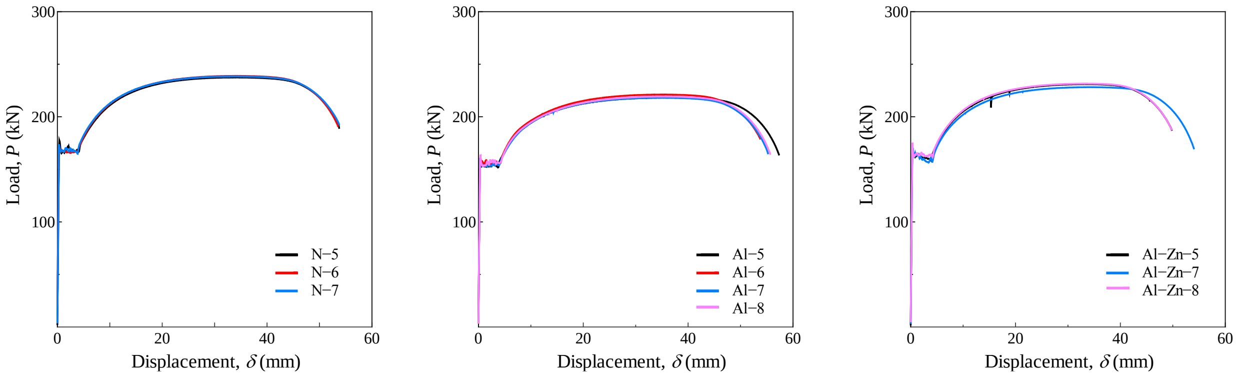

Fig.5 *P*-δ curves of specimens (Plate thickness: 12 mm)

Table 2 Mechanical properties of tested specimens in each group

Specimen type	Young's modulus E (GPa)	Maximum load P_{max} (kN)	Tensile strength σ_b (MPa)	Yield stress σ_y (MPa)	Elongation φ (%)
N (*t*=9mm)	203	184	537	382	26
Al (*t*=9mm)	185	171	446	322	23
Al-Zn (*t*=9mm)	180	180	508	369	24
N (*t*=12mm)	208	238	510	360	27
Al (*t*=12mm)	207	219	485	326	28
Al-Zn (*t*=12mm)	207	231	489	344	26

(Plate thickness: 9 mm) without hot-dip coating and hot-dip Al coating indicates that, all the average measured values of mechanical properties were decreased slightly. In this test the mechanical properties of materials would also be changed in different degree according to different plate thickness. When specimens affected by higher temperature in hot-dipping process, the reduction of tensile strength and elongation would be larger, which is more evident in the specimen with thin plate. Besides, comparing the mechanical properties of specimens without coating and hot-dip Al-45Zn, it shows the same trend. Comparing the mechanical properties of specimens with hot-dip Al coating and hot-dip Al-45Zn coating, the mechanical properties of those with hot-dip Al coating decrease more obviously than those with hot-dip Al-45Zn coating.

Comparing the 12 mm thick specimens in the same way, the same results can be obtained from Fig. 5 and Table 2. The mechanical properties of specimens (Plate thickness: 12 mm) are reduced after hot-dip coating. Comparing the specimen without coating, the mechanical properties of hot-dip Al specimens decrease obviously, but those of hot-dip Al-45Zn specimens were reduced slightly. The temperature of hot-dip Al coating process is about 100℃ higher than the Al-45Zn coating, therefore the reduction in mechanical properties of Al coating is more obvious.

4. Summary 1) Due to the influence of heat-affected zone caused by the hot-dip coating treatment, the mechanical properties of common steel plate would be decreased slightly in certain extent. 2) Comparing with the hot-dip Al-45Zn coating, the effect of hot-dip Al on the mechanical properties of common steel plate is more prominent. As the specimens affected by higher temperature, the decreasing in the tensile strength and elongation would be larger, which is more evident in the specimen with thin plate thickness.

References 1) L. Kang, H. B. Ge, T. Kato: Experimental and Ductile Fracture Model Study of Single-Groove Welded Joints Under Monotonic Loading, Engineering Structures,Vol.85, pp.36-51, 2015. 2) A.M. Kanvinde, B.V. Fell, I.R. Gomez, M. Roberts: Predicting Fracture in Structural Fillet Welds Using Traditional and Micromechanical Fracture Models, Engineering Structures, Vol.30, pp.3325-3335, 2008.