SELECTED PROPERTIES OF THE COMPOSITE STEEL+ALUMINIUM+ALUMINIUM ALLOY MANUFACTURED ACCORDING TO THE EXPLOSIVE WELDING PROCESS

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Results from different investigations related to the properties and structure of the composite steel+aluminium+aluminium alloy manufactured according to the explosive welding process are presented.

On the basis of ultrasonic, mechanical, metallographic and corrosion resistance investigations, the properties and characteristics of the connectors St41+A1+PA11 manufactured for shipbuilding application are described.

INTRODUCTION

Nowadays, technical development requires cheaper and higher quality performances. As a results, the multilayer materials with high strengh indices are gaining a wider use in the industry and egineering.

During the last years, the explosive welding process has been applied as an industrial manufacturing process of multilayer materials. This process is particulary suitable in joining steel with aluminium. This materials present different physicochemical propert- ties properties which renders imposible their welding on the basis of traditional welding process.

Examples of industrial application in shipbuilding of explosive welding process are the three layer connectors St41+A1+PA11 which, as intermediate elements, facilitate the welding between steel deck and aluminium alloy superstructure (Fig.1b). The use of the above named connectors has facilitated the elimination of rivetted joints which are not durable in exploatation and more laborious during the performance (Fig.1a).

The specific characteristics of explosive welding process restrict its application. However, this process can enlarge and complement the range of the processes for the manufacturing of non-ferrous metals.

Reflecting the above, it is useful to present the results of different papers related to the investigations of the properties and structure of the joints obtainted on the basis of the composite steel+aluminium+aluminium alloy.

CONNECTORS St41+A1+PA11.

The cladding technologies between steel, aluminium and aluminium alloys on the basis of the explosive welding process are one of the most interesting welding technologies.

The process of cladding between steel and aluminium alloys is only possible by means of an intermediate layer of pure aluminium.

The welding parameters must be selected in such a manner that the joint be able to guarantee higher strength than that of the weaker of the joined metals. Moreover, the obtained joint must to present a

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wavy structure between the steel and aluminium as well as between the aluminium and its alloy.

Table 1 shows the types and sizes of the three layer plates of steel+aluminium+aluminium alloy manufactured actually on the basis of explosive welding process and according to the polish shipbuilding neccesities. Connectors St41+A1+PA11 of required application sizes are cut out from the above named plates (6).

PROPERTIES OF THE CONNECTORS St41+A1+PA11.

In order to determinate the properties of the connectors St41+A1+PA11 manufactured on the basis of explosive welding process, the joints between the different layers of the three layer plates were subjected to ultrasonic, mechanical, metallographic and corrosion resistance testing.

The results of the ultrasonic testing have permitted to establish the continuity of the bond on the whole surface of the plate except the segments adjacent to the edges. These segments, of about 20+40 mm width, characterized by the disturbances in the continuity of the bond which result from the specific properties of the explosive welding process.

The authors of the paper (6) have carried out mechanical testing of the joints after explosive welding and after welding specimens. Tear off tests weere carried out on the steel41+aluminium A1 joints as well as on aluminium A1+aluminium alloy PA11 joints. Comparative statical elongation and fatigue tests on rivetted and welding joints were carried out.

Shown in table 2 and table 3 are results obtained about the mechanical properties. Bending tests results of the connectors publis- hed in the paper (6) are shown in Table 4. Connectors were bended according to a pattern on rolling cilinders of a radius R=1200 mm. The length and form of the connectors were given according to 1/4 of the perimeter of the contour of the corner of the superstructure. Standarized and investigated non-polished connectors with a width of 24 mm have not presented after bending any fracture or stratification. Also the bending tests which were carried out on the arbor of the connectors did not show any stratification or fracture.

Metallographic tests (macroscopic) carried out by the author have confirmed the obtaining of a reguired wavy surface of the joints of St41+A11 as well as the joints A1+PA11.

The characteristic waviness of the joints obtained on the basis of explosive welding process were more evident in relation to A1+PA11 joints. In the case of St41+A1 joints also waviness occurs though wavelength and waveheight are considerably shorter. These results confirm the thesis according to which the obtainment of wavy joints between steel and aluminium is difficult and possible only under the conditions of a very narrow range of welding parameters. Microscopic testing of the joints has shown that they characterize by its high ductibility and a common intimate contact of the joined plates which confirms the good quality of the joint. Fig.2 shows that in the layers adjacent to the joint we can observe crushing and deformation of the superficial layers which is characteristic for the explosive welding process. In the region of constitute the intermediate layers. This layer contains compounds of the type Fe_nAL_m and characterizes by a high hardness which is even higher than that of the steel (2, 3). The explosive welding parameters as well as the frequently existing soaking during the manufacturing process, influence decisively on the formation of of intermetallic phases in the region of the explosive weld. The results of the investigation about the influence of the intermetalic compounds on the strength of the joint steel+aluminium in dependence of the soaking time and temperature, have been shown in

Fig.3. These investigations were carried out according to two different cases of soaking :

a) In the furnace during 600 seconds at a given temperature.
b) Under the real conditions that occur during the welding process of steel+aluminium+aluminium alloy.

From the Fig.3. results that with an increase of the soaking temperature decreases the strength of the joint steel+aluminium+aluminium alloy even during the short time of welding (4). These investigations confirm that the selection of the welding parameters and joints geometry during the performance of the joints using composite steel+aluminium+aluminium alloy, must be carefully carried out (Fig.1b.).

In order to determinate the corrosion resistance, different connectors which were cut out from plates manufactured according to different parameters of the explosive welding process, were subjected to investigation (1). The tests were carried out according to the requirements of the ASTMB-117-57T. This testing standard supposes a continious sprinkling of a 5% solution of sodium chloride. According to the tests results, all joints satisfied the above named standard. However, corrosion resistance of the investigated joints was quite different and its values fluctated between 0.05 mm and 1.25 mm during 1000 hours of sprinkling. The deepest penetration was observed in the PA11 alloy near the joining line with the aluminium A1 (1.25 mm). In the paper (5) the author has investigated the electrochemical corrosion resistance of the composite steel+aluminium+aluminium alloy. The tests were carried out on two layer metals St41+PA11, St41+A1, and St41+bimetalic (A1+PA11) in a 3% distillate water solution on NaCl. From the results of the tests, the corrosionn velocity (mm/year) reached the following corresponded values : 0.0102; 0.0272; 0.3046. The metals that suffered corrosion were the following: aluminium alloy PA11, aluminium A1, and bimetalic (aluminium+aluminium alloy PA11). Investigations results confirmed also a very high corrosion resistance of the composite under sea water action. Shown in Fig.4 is the function E=f(J) which represents the results of the investigations about the behaviour of the two layer metal St41+bimetalic (A1+PA11) under the action of the electrochemical corrosion.

CONCLUSION.

The results of the investigations presented in this paper have indicated that the composite steel+aluminium+aluminium alloy manufactured on the basis of explosive welding process characterizes by its good technological properties. The Classification Societes "Polski Rejestr Statkow" and "Det Norske Veritas" have recognized officially the high quality of the connectors.

The possibility of application of the composite steel+aluminium+aluminium alloy are very wide. The application, actually limited to the shipbuilding industry, can be extended to another branches such as railway industry, automotive industry and architecture. Every-where there are corrosion problems near the region of the joing between steel and aluminium. it is possible to improve the construction on the basis of the application of the above named composite. In this way, it is possible to replace the rivetted joints by weld joints.

According to the results of the investigations and concluding remarks presented in this paper, the explosive welding technology is a useful additional process in the manufacturing of non-ferrous metals, and its application would improve production quality and would increase the volume of production.

TABLE 1. Type and sizes of the plates manufactured according to the explosive welding process.

Material	γ (g/cm^3)	HV	R_m (MPa)	Thickness (mm)	Length (mm)	Width (mm)
Steel St41	7.95	143	443	20	400	200
Aluminium A1	2.7	19.6	87	6	420	200
Alloy PA11	2.66	70	224	10	420	200

TABLE 2. Mechanical properties (R_o, R_s, R_m) of the connectors St41+A1+PA11.

Type of test	Specimen's condition	Average results of the test (MPa)	Remarks
Tear off test on St41+A1	After pressure welding After welding	R_o = 123 R_s = 107	Destruction of the aluminium A1.
Tear off test on A1+PA11	After pressure welding	R_o = 141	Destruction of the aluminium A1.
Shear test on St41+A1 according to ASTMA 264-44T	After pressure welding After welding	R_s = 138 R_s = 103	Destruction of the aluminium A1 and partially of the steel St41
Tension test on the welded joint	After pressure welding		Destruction in the region of thermal influence of the PA11 alloy; partially in A1; significantly in the region of thermal influence of the PA11 alloy.
Tension test on rivetted joint	-		Destruction of the plate of PA11 alloy along the row of rivets.

TABLE 3. Results of the fatigue test carried out on welded and rivetted joints (Fig.1).

Type of joint	Cross section load (MPa)		Amount of cycles until destruction	Place of destruction
	$R_{oz_{min}}$	$R_{oz_{max}}$		
Welded	34	68	1.218.000	Bond and region of thermal influence of the PA11 alloy.
Rivetted	34	68	222.300	Plate of PA11 along the first row of rivets.

TABLE 4. Results of bending tests carried out on the connectors St41+Al+Pa11.

Specimen's surface	Bending angle (deg) on the arbor with a diameter (mm)		
	d=150	d=300	d=600
Row	60	90	150
Polished	145	160	-

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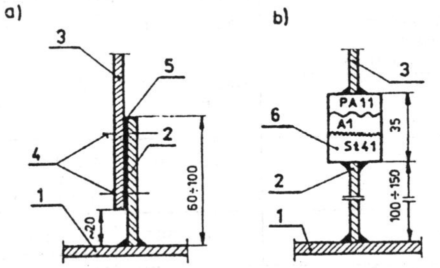

Figure 1 Construction of the union between the superstructure and deck.(a - Rivetted joint, b - Welded joint) 1-Deck, 2-Metallic flat bar,3-Aluminium alloy (PA11) shell plates, 4-Rivets, 5-Insulating separator, 6-Connector St41+Al+Pa11.

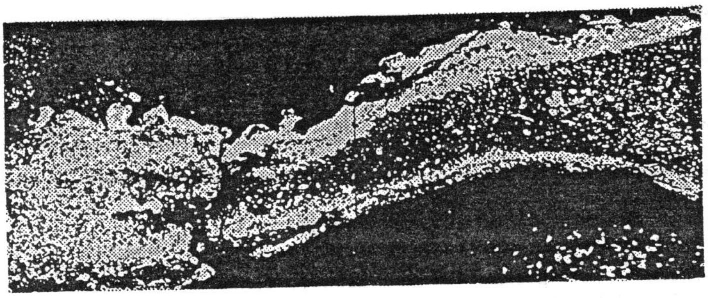

Figure 2 Photography of the transition region of the joint St41+At. Enlargement 800 x.

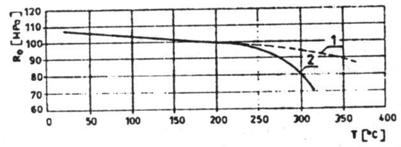

Figure 3 Influecne of the soaking temperature on the tear off strength of the joints St41+Al. Specimens were subjected to the action of the thermal welding cycle (1), specimens were subjected to soaking inside a furnace (2).

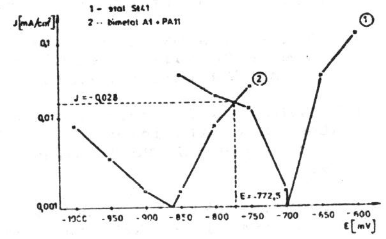

Figure 4 Diagram of the function E=f(J) for two component metal (St41)+bimetalic (A1+PA11).