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Research Article

THE MICROSTRUCTURAL PROPERTIES OF EXPLOSION WELDED Ni/Ti JOINT

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ABSTRACT
Explosion welding is one of the ways of bonding materials. This method is used to bond metals which either cannot be joined or they are difficult to bond by other methods. The study investigates the metallographic characteristics of Ni/Ti joints in the form of a plate. Microstructures of the joints are examined and hardness measurements are carried out on the bonded materials and their interfaces. A detailed analysis of the distributions of wave length and width is presented. An average microhardness of the interface is found to be higher than that of the base materials.

Keywords: explosion welding, joint, Ni/Ti microstructure.

INTRODUCTION

Explosion welding is one of the most efficient methods for bonding materials. The resulting joint is usually permanent but with different physicochemical properties. The explosion welding process consists of welding materials with the use of energy generated by the explosion of explosives. Although the method is characterized by high efficiency, it is not popular due to the danger posed by the use of explosives and due to the requirement of having an area to carry out the explosions. For this purpose, special halls and firing grounds are used [1, 2, 3].

In Poland, research centers, such as the Military University of Technology, the Czestochowa University of Technology, or the Gdansk University of Technology are engaged in conducting research on explosion welding process [1, 2, 3, 4, 5]. Although there are many types of explosions, it is chemical explosion, based on an exothermic reaction, that is most often applied. This is due to such factors as energy transport mechanism and detonation velocity. The two are the basic criteria that determine whether a particular reaction is an explosion or not [1, 2].

The research on the explosion welding process with the use of explosives has led to the identification of several parameters these substances should be characterized by, namely: detonation stability and velocity, ability to maintain their properties for a long time, safety in transportation, storage and use. Numerous experiments have found that mixtures are more suitable for welding than pure explosives. Therefore, the mixtures of TNT and ammonium nitrate are frequently used [1, 2, 6, 7].

Explosion welding is used to produce metal objects, clad coatings, and composites reinforced with fibres and particles [8, 9, 10]. Moreover, this method can be applied to bond materials that either cannot be joined by conventional bonding methods or they are difficult to bond in general, examples of such materials being Ni and Ti plates. For this reason, there is little information available on the microstructural properties of explosion welded Ni-Ti joints.

The aim of this paper is to characterize the microstructural properties of Ni–Ti plates bonded via the explosion welding process.

MATERIALS AND METHODS

In the study, nickel and titanium joints produced by the explosion welding process with optimal process parameters were pretested. The bonded plates (Figure 1) had a thickness of 1 mm. The macro and microscopic interface of the examined element was investigated. The microphotography was taken using an Olympus SZ 61 light microscope (Figure 2–4) and a Phenom World ProX scanning electron microscope (Figure 5).

Microhardness measurements were made with a Future-Tech FM7 microtester, using the Vickers method, hardness scale HV0.05 and a load duration of 6s. Ten indentations were measured at random locations for Ni and Ti base metals as well as for the interface of Ni/Ti. The results are summarized in Figure 6. Moreover, the length and height of waves generated as a result of the explosion welding process in the bonding zones are examined based on the micrographs obtained. Both the height and length of these waves were estimated. The measurements are summarized in Table 1.

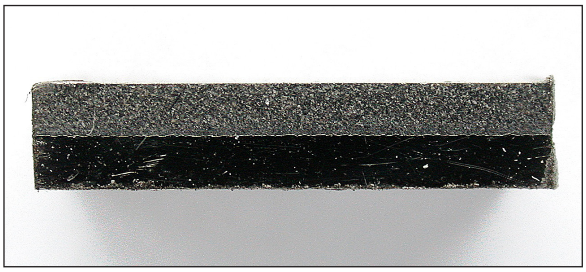

Fig. 1. Cross-section of the explosion welded joint (top layer – Ti, bottom layer – Ni)

RESULTS AND DISCUSSION

The explosion welded Ni/Ti joints are characterized by a wavy shape over their entire length. According to many studies, e.g. [11, 12], this wavy shape is characteristic of the explosion welding process. At the joint edge of the plates the waves have lower height, while their height in the remaining area of the joint is higher and more uniform. The length and height of the waves vary. The wave height at the measuring section ranges from 59.85 to 27.32 μm, while the wave length at the measuring section ranges from 250.68 to 97.22 μm (Table 1). The influence of heat is visible in the heat-affected zone; the shock waves are visible there, too. The wave distribution is shown in Figures 3 and 4.

Figure 5 shows the zone where the two materials are bonded. Figure 5b illustrates the non-uniformity of the joints, which may lead to the delamination of these joints later. In some of the joints small cavities can be observed. In the vicinity of the bonding zone fine grain is visible.

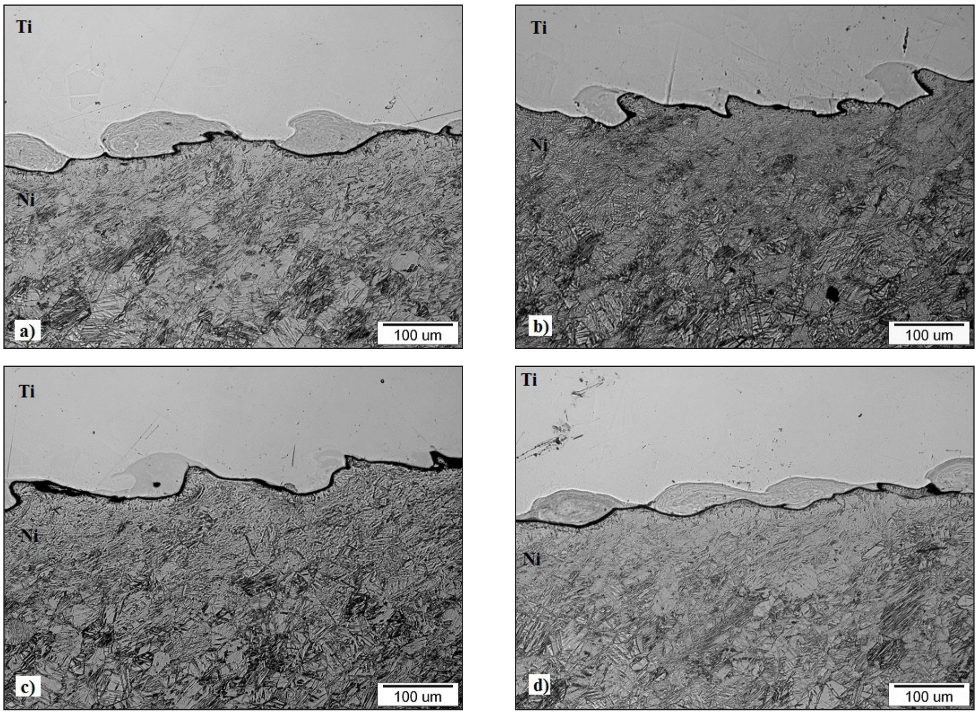

Fig. 2. Microstructure of the explosion welded Ni / Ti joints, 200×

Table 1. Wave length and height results for the explosion welded Ni / Ti joints

Wave height [μm]						
Ni/Ti	48.64	56.32	59.85	27.32	32.50	average 44.92
Wave length [μm]						
Ni/Ti	97.22	200.96	250.68	218.14	118.27	average 117.05

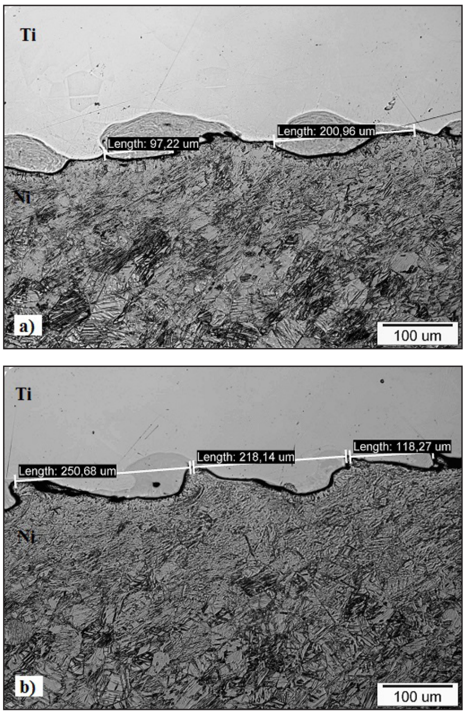

Fig. 3. Wave length in the cross section of the explosion welded Ni / Ti joints, 200×,
a) edge of the sample, b) center of the sample

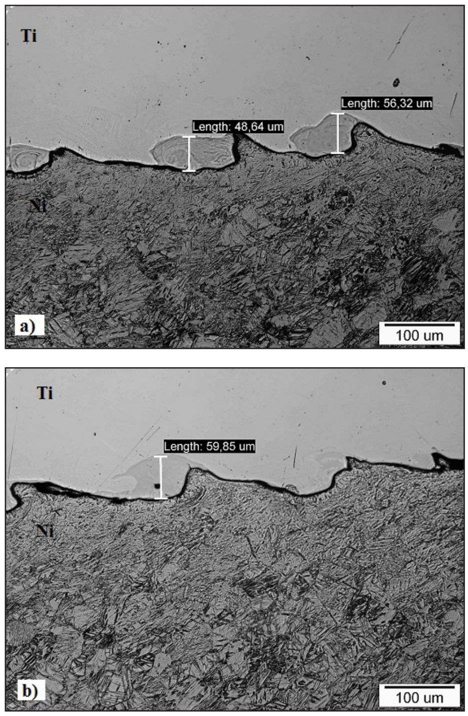

Fig. 4. Wave height in the cross section of the explosion welded Ni / Ti joints, 200×,
a) edge of the sample, b) center of the sample

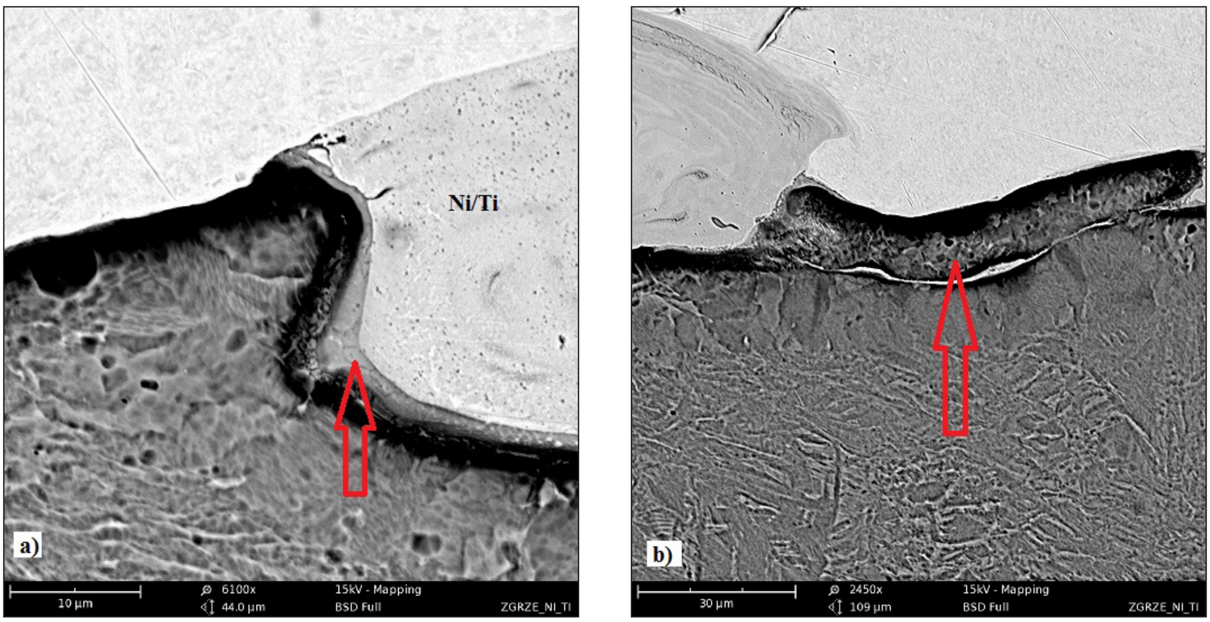

Fig. 5. SEM micrographs of the explosion welded Ni / Ti joints,
a) bonding zone, b) non-uniformity of the joints

It is obvious [12] that the microhardness results showed an increase in hardness in the direction of the joint. Interestingly, there is the increase in hardness of the joint. The highest values of microhardness (up from 700HV0.5) are observed in the bonding zone (Figure 6). The increase in hardness may be caused by the detonation velocity, cold plastic deformation caused by the explosion, or by sudden (thermal) shock hardening [12]. The average microhardness is almost four times higher for the interface (403HV0.5) than for Ni (156HV0.5) or Ti (166HV0.5) base metals. It points to the possibility of formating different hard phases, such as various intermetallic compounds, especially at the bonding zone. These phases were also identified for other explosion welded materials, such as Ti and stainless steel joints [13].

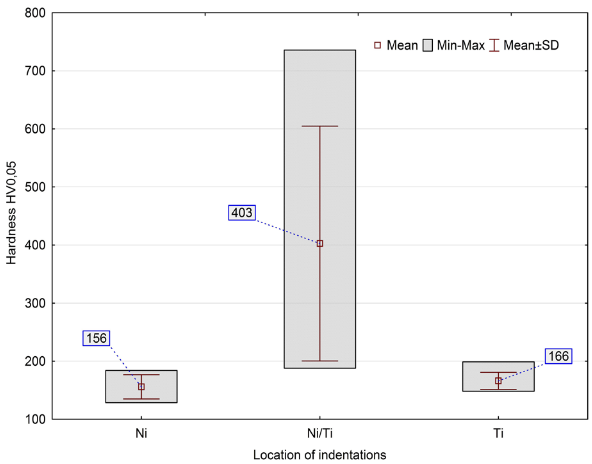

Fig. 6. Microhardness results of the Ni/Ti interface and base materials

CONCLUSION

To conclude, it can be observed that the explosion welded Ni / Ti joints exhibit a non-uniform wavy shape. The waves are formed over the entire length of each joint; however, their length and height vary considerably. The differences in wave lengths may be due to the material used and the arrangement of the explosive plates. Some of the explosion welded Ni/Ti joints reveal the presence of cavities, which can lead to delamination. The study also showed that the hardness of the examined joints increases. The substantial difference in the value of joint hardness may cause delamination of these joints in their future use.

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