

The Quality of Welded Connections Elements from the Steel 30HGS and Titanium Alloy Ti6Al4V

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Abstract

The aim of that work was the evaluation of the quality of welded connections elements (welds) from the 30HGS steel and titanium alloy Ti6Al4V. The metallographic, factographic tests were used, and measurements of microhardness with the Vickers method. In the head weld of the 30HGS steel there were non-metallic partial division and bubbles observed. The average microhardness in the head connection was 320 HV0.1. There was no significant increase/decrease observed of microhardness in the head influence zone of the weld. There was a good condition of head connections observed, in accordance with the standard EN12517 and EN25817. In the head weld of Ti6Al4V titanium alloy there were single, occasional non-metallic interjections and bubbles observed. There were no cracks both on the weld, and on the border of the heat influence zone. The value of microhardness in head connection was in the range 300-445 HV0.1. Reveal a very good condition of the head connections in accordance with the standard EN12517 and EN25817. The factographic tests prove the correctness of welded connections done and then heat treatment in case of steel and titanium alloy.

Keywords: Heat Treatment, Metallography, Factography, Microhardness, Welding, Head Weld, Titanium Alloy Ti6Al4V, Steel 30HGS

1. Introduction

Materials used for the goods in that industry must comply with the number of requirements depending on the application [1]. We would like the goods were cheap, light and have different shapes and properties in different places. In order to achieve such results, it is necessary to connect the elements of different shapes with one another, often made from different materials. One of the methods of durable elements connections is welding. At present there are lots of welding methods. Due to the low costs of welding and high quality of welded connection GMAW and GTAW are widely used in small and average companies [2-4]. One of the most expensive, and tests techniques used is laser welding [5, 6].

Welding with the use of that method allows for keeping high connection aesthetics, thanks to that the finishing treatment was eliminated. In laser welding there is also the additional material eliminated, used during the welding process, high precision of welding allows the narrow heat influence decreasing the material deformation. In connection with the above, the evaluation of the quality of welded connections is very important, thanks to which we are more sure that all welding mistakes that can unfavorably influence the construction, will be earlier detected. There are many methods, on the basis of which we can evaluate the quality of connection, the most common method is ultrasonic one or the visual evaluation, consisting in taking the microstructure photos and the quality evaluation on their basis.

2. Material and test methodology

The testing material was the 30HGS steel and titanium alloy Ti6Al4V, used on the pressure containers in armaments technique. The aim of that work was the analysis of welded head connections one-sided made from the materials mentioned above. The welding was done with GTAW method, in the protection of argon. The welds were applied twice (one on the other) in the titanium alloy and three times in the steel. The heat treatment was done according to the recommendations included in the standards. The part of that container from the steel 30HGS, from which the samples were cut, were presented in the Fig. 1 whereas Fig. 2 presents the view of metallographic specimens done from the cut material.



Fig. 1. The container fragment from the steel 30HGS after sample cutting

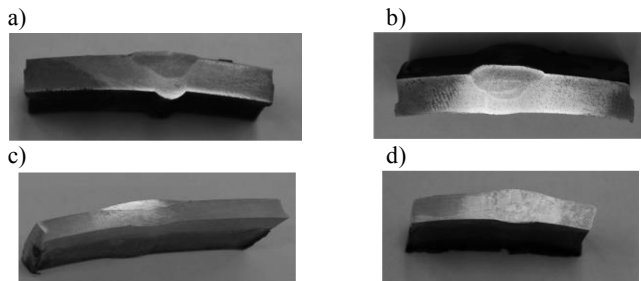


Fig. 2. The metallographic specimens for testing SEM; a-b) from steel 30HGS, c-d) from titanium alloy Ti6Al4V

The microhardness measurements were done with the Vickers method making the imprints every 0,2 mm on paths marked L1, L2, L3, L4, L5 (Fig. 3).

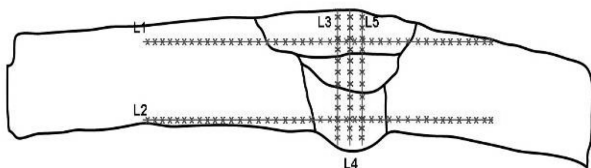


Fig. 3. Diagram of microhardness measurements with the Vickers method with the marked measurement paths marked: L1, L2, L3, L4, L5

Metallographic and fractographic research was made with the optical microscope Neophot 2 and scanning microscope Tesla in different places of the welding zone and base material.

3. Results

The microhardness measurements done along the measuring line L1 showed higher hardness of the titanium alloy in compares to the steel (Fig. 4.1-2). There was no significant decrease/increase of microhardness in the area of HIZ of the weld.

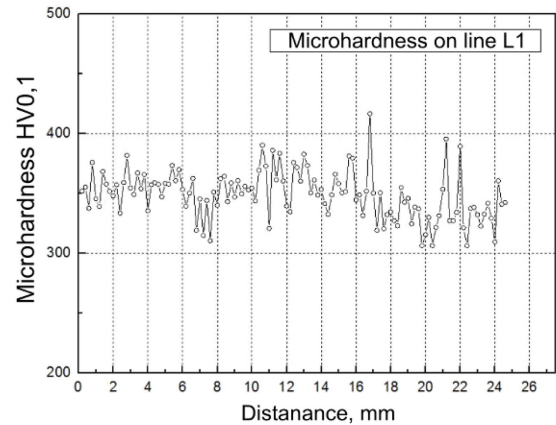


Fig. 4.1. Microhardness HV0.1 calculated along the measuring line L1 for the steel 30HGS

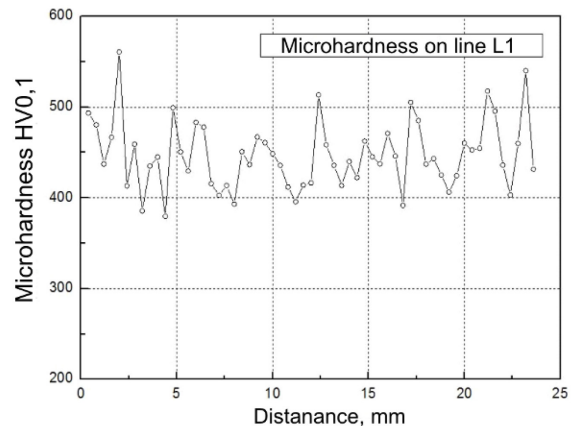


Fig. 4.2. Microhardness HV0.1 calculated along the measuring line L1 for the titanium alloy Ti6Al4V

It appears from the average microhardness curve calculated from measuring lines L3-L5 (Fig 4.3) that the average value of microhardness on the head connection of the 30HGS steel was about 320 HV0.1. There was no significant decrease/increase of microhardness in HIZ marked one by one of the weld stitches. In the titanium alloy Ti6Al4V (where the double stitches were put) the average value of microhardness in the first weld stitch was about 300 HV0.1 and in the second about 445 HV0.1. The increase of microhardness within the area of HIZ of the first weld stitch was observed. (Fig. 4.4).

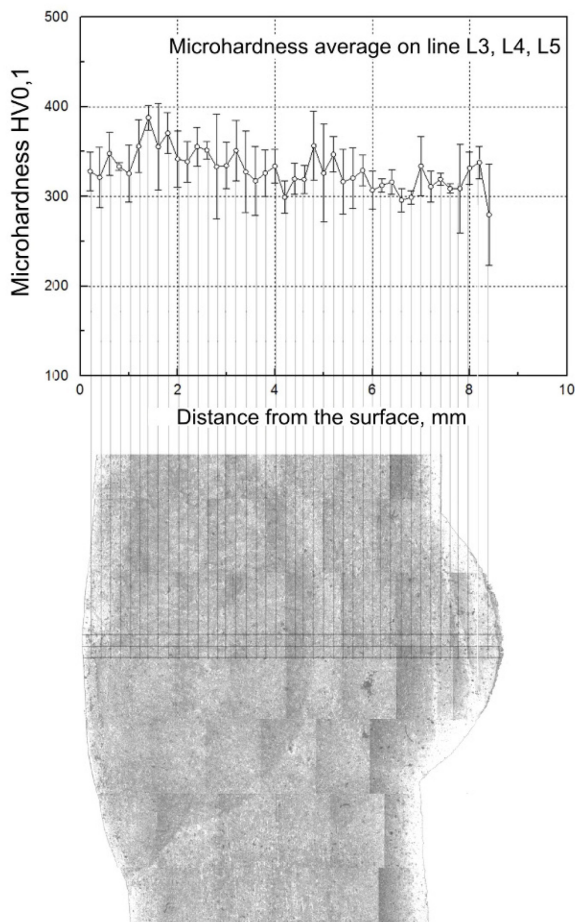


Fig. 4.3. Average microhardness HV0.1 calculated from the measurement lines L3, L4 and L5 for steel 30HGS

The microstructure of the heat influence zone (HIZ) of the head weld 30HGS steel are the products of bainite transformation, on the grain borders of the former austenite there is a light net of carbides phase visible, inside the former austenite, locally there are fine carbides visible of the diameter below $0,5 \mu\text{m}$. The average diameter of grains of the former austenite was about $10-15 \mu\text{m}$ (Fig. 5b). In the remelting zone (RZ) of head weld of the steel, there is a structure made due to the primary crystallization and further heat treatment. Locally there is a net of carbides visible on the borders of the crystals of the primary phase, the matrix is bainite with fine sintered carbides (Fig. 5c). There are non-metallic partial division and gas bubbles visible in the remelted zone in the Fig. 5d,e of the size about $5 \mu\text{m}$. The microstructure of the bottom area of the weld (in the remelting zone) - Fig. 5 f,g is consisted with light net of the carbides phase on the grain borders, inside of the former austenite there are tiny carbides visible below $0,5 \mu\text{m}$.

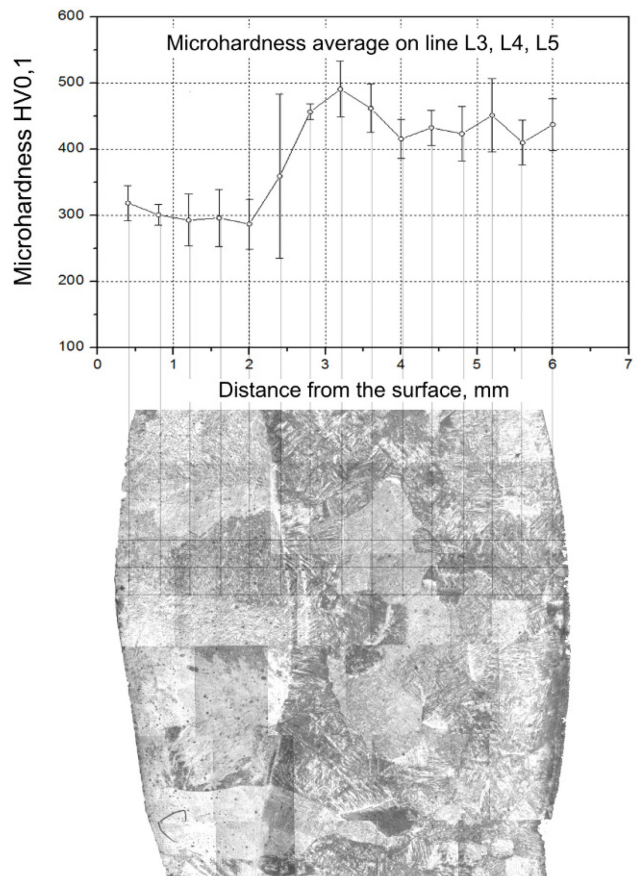


Fig. 4.4. Average microhardness HV0.1 calculated from the measurement lines L3, L4 and L5 for titanium alloy Ti6Al4V

The microstructure of the titanium alloy Ti6Al4V in HIZ the welds were consisting of phase α and β of the grain size about $5 \mu\text{m}$ (Fig. 6b). There is a visible weld structure on the border of RZ and HIZ in the Fig. 6c,d. On the right there is a heat influence zone with phase α and β and on the left there is a remelting zone, where the coarse plate of α phase and β phase are visible (Fig. 6.e,f). In the remelting zone of the weld there are also single occasional non-metallic partial division and gas bubbles observed.

The fractographic research shown the presence, in the basic material of the 30HGS steel mixed fracture: transcrystalline ductile and transcrystalline brittle, whereas (Fig. 7a,c,e). There was a transcrystalline ductile within the remelting zone of the steel weld (Fig. 7.b,d,f). In case of the Ti6Al4V titanium alloy, both in the basic material and within the remelting zone of the weld there was a transcrystalline ductile fracture (Fig. 8a-f). There is a fact worth mentioning, that in both cases: steel and titanium alloy, the pits was visible on the fracture have lower diameter within the weld (in compares to the basic material).

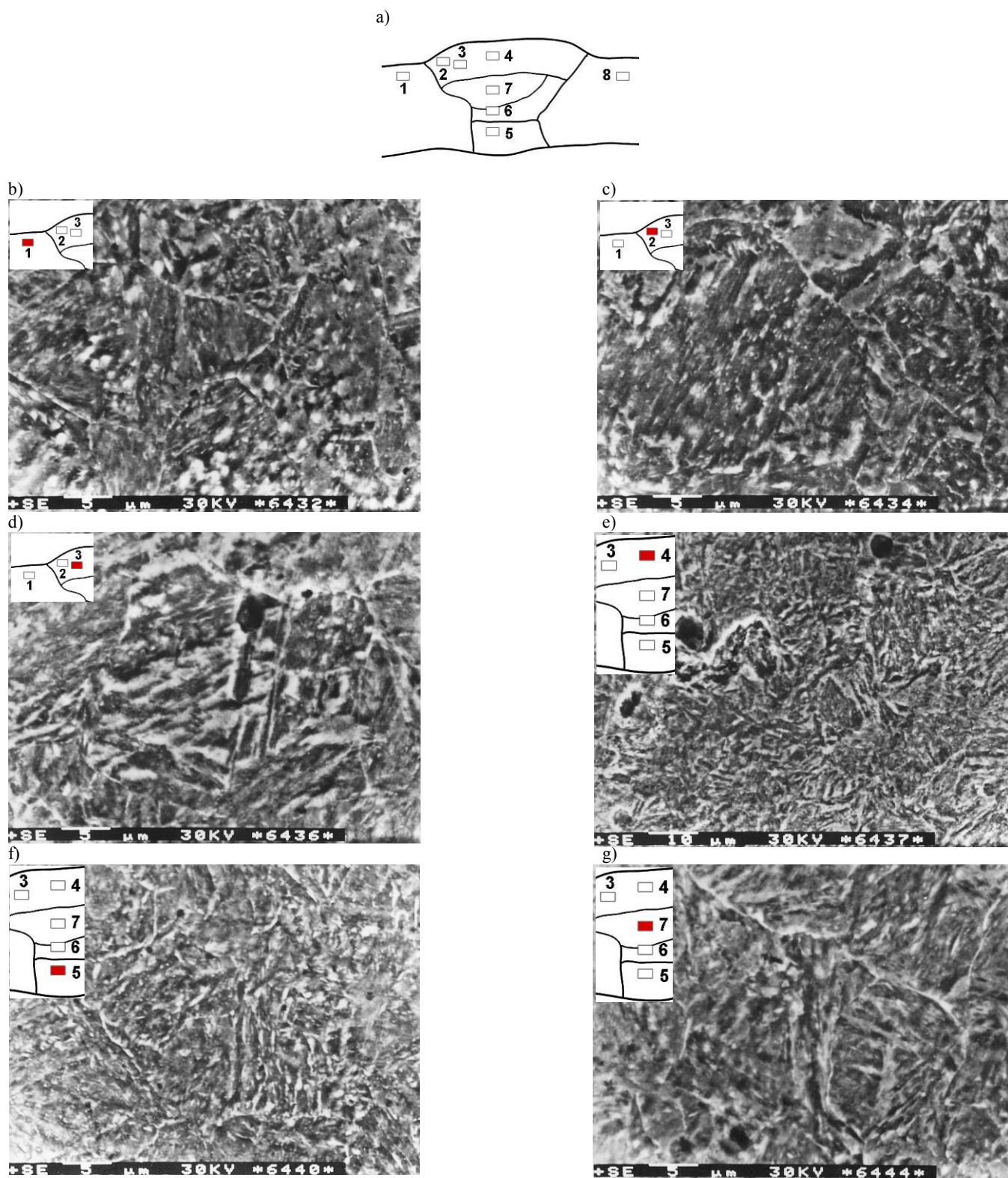


Fig. 5. a) scheme of the weld microstructure observation places of the steel 30HGS, b-g) microstructure of 30HGS steel with marked places on the scheme

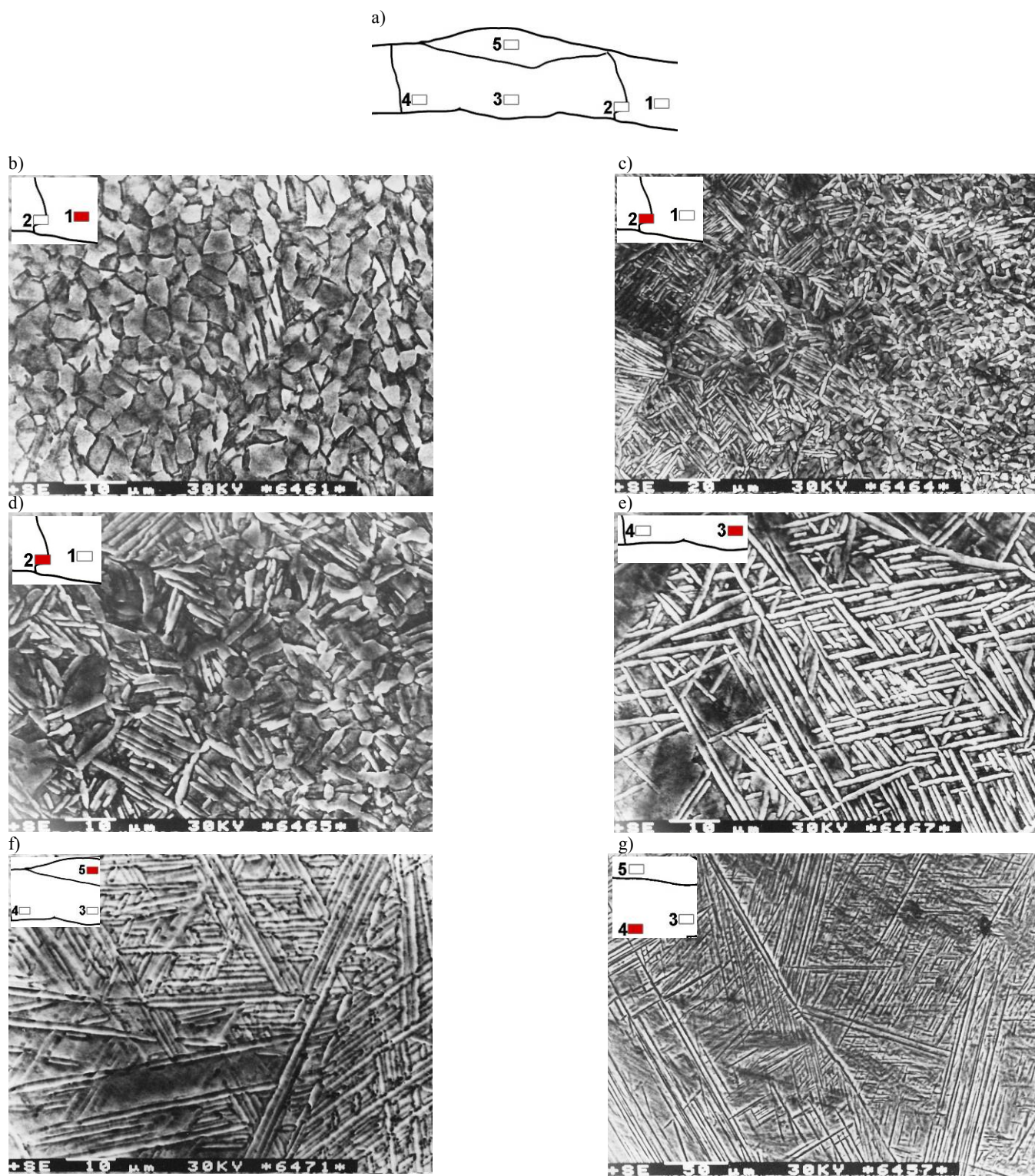


Fig. 6. a) scheme of the microstructure observation of the titanium weld alloy Ti6Al4V, b-g) microstructure of the Ti6Al4V titanium alloy with marked places on the scheme

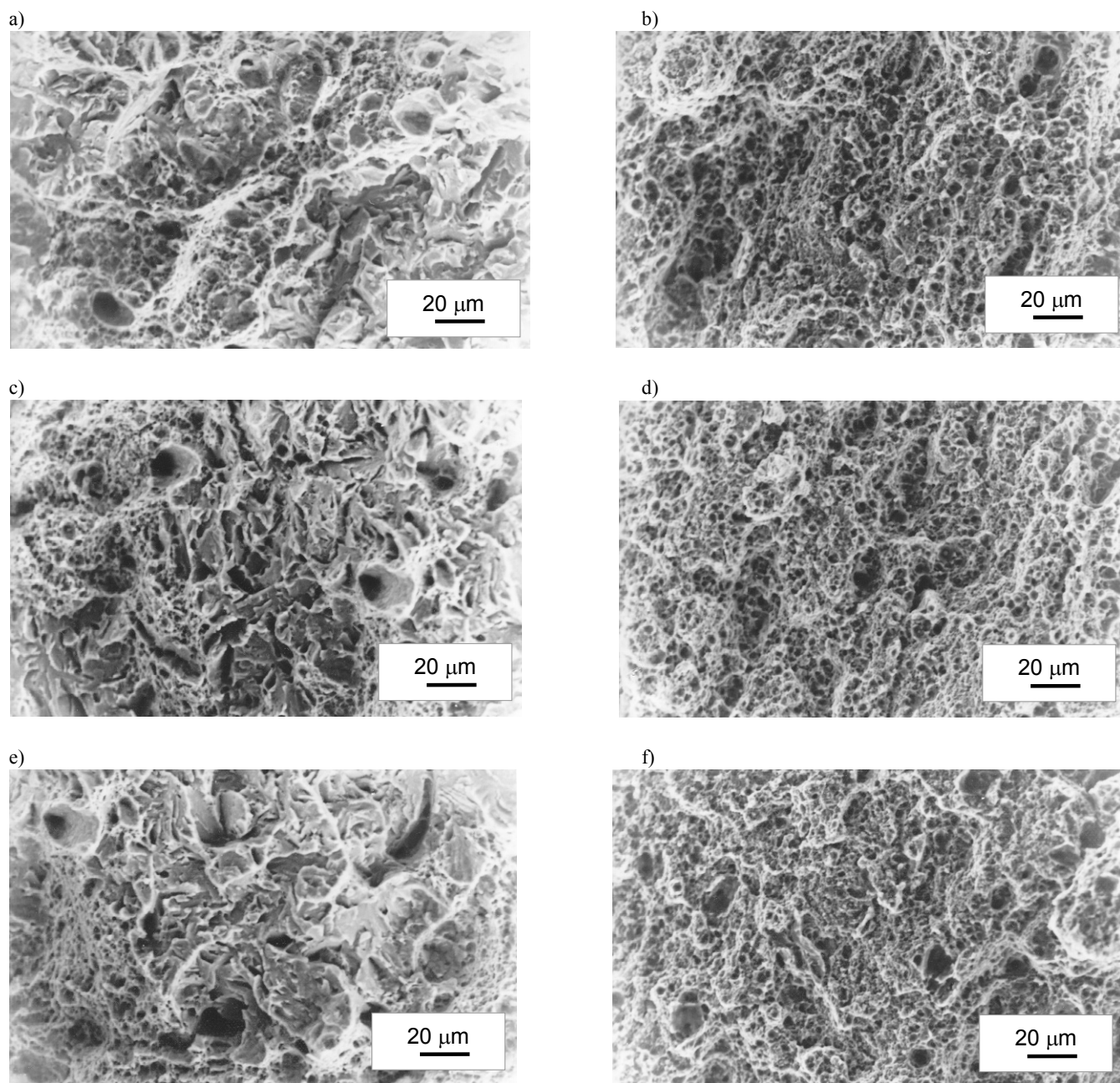


Fig. 7. Fracture of 30HGS steel; a, c, e) of basic material, b, d, f) in the weld, remelted zone

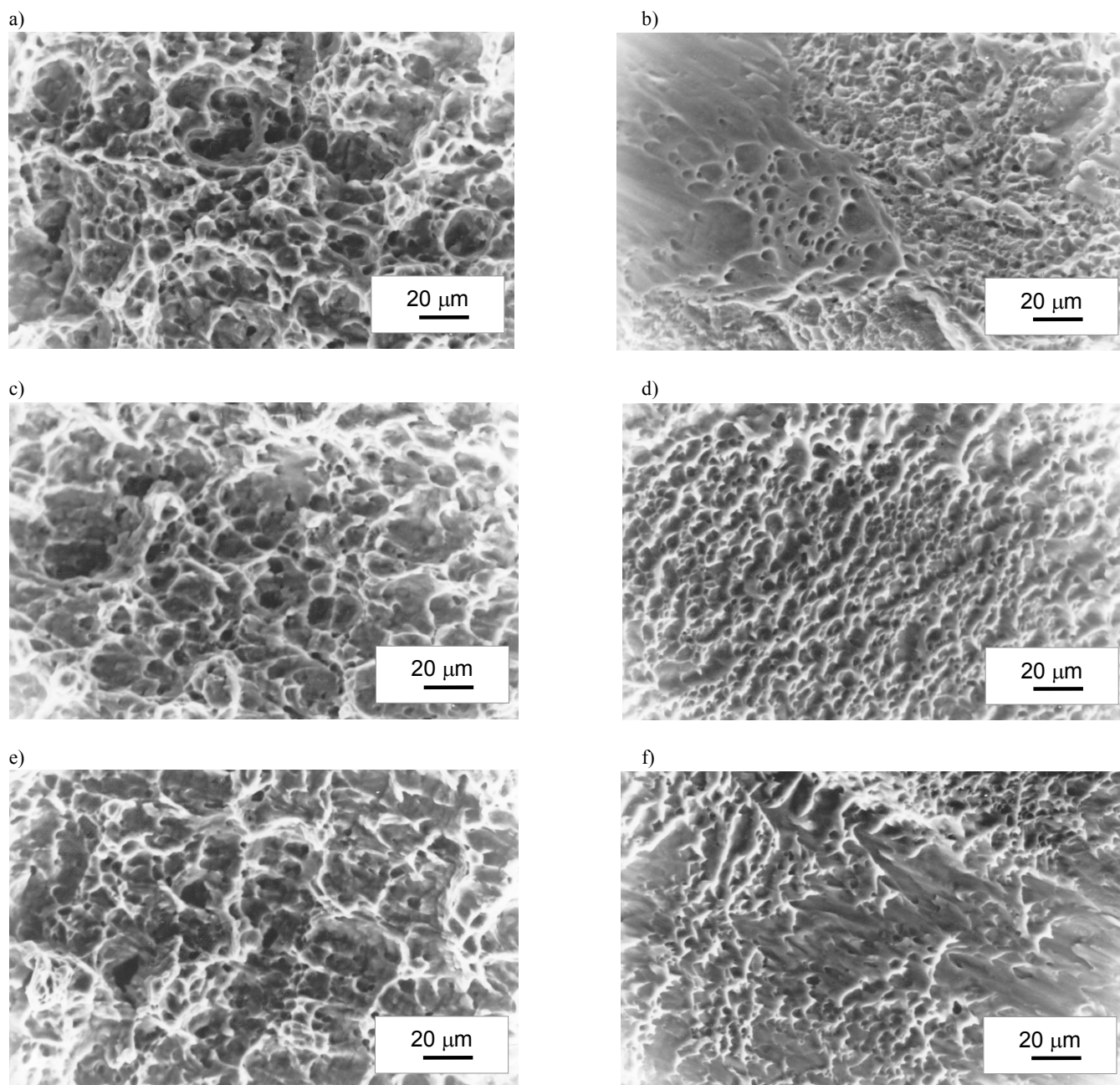


Fig. 8. Fracture of Ti6Al4V titanium alloy; a, c, e) of the basic material, b, d, f) in the weld, remelted zone

4. Conclusions

In the remelting zone of the head weld of the 30HGS steel there were few non-metallic interjections observed and bubbles, the average microhardness value on the head connection was 320 HV0.1, there was not the significant increase/decrease of the microhardness in head influence zone (HIZ) weld noticed, there was a good head weld connection, in accordance with the standard EN 12517 and EN 25817.

In the remelting zone of the head weld of the titanium alloy TiAl4V the single non-metallic interjections and bubbles were observed occasionally, there were no cracks both on the weld and on the border of the HIZ weld, the good condition of the head connections was observed, in accordance with the standard EN 12517 and EN 25817.

The fractographic research prove the correctness of the welded connections and then heat treatment in case of the steel and titanium alloy.

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