Modification of the structure and properties of hardfaced layers with TIG high frequency method

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Abstract. In this work the investigation is focused on changing the structure and hardness of the surface with high content of carbon and chromium. The use of welding methods to modify the properties of the surface layer allows for optimal use of the properties of materials or changing their properties by differentiate their structure. The surface and structure of hardfaced layers can be improved by additional treatment with another welding arc. The use of the new TIG methods with frequency up to 20000 Hz gives new possibility of the surfacing. The subject of the research were padding welds with the structure of chromium cast iron, which were subjected to the process of remelting the surface layer using the TIG high frequency method. The use of hardfacing and remelting with the TIG method allowed for a noticeable differentiation of the structure, hardness and wear resistance in relation to the initial state.

Keywords: hardfacing, remelting, structure, hardness, wear

1. Introduction

Materials with the structure of chromium cast iron are often used in technology as materials to increase the wear resistance of machines and devices [1,2] The structure of these materials is rich in chromium carbides and other elements, that are mainly responsible for high wear resistance. To protect against wear, other types of add-on materials can also be used, depending on the intended operating environment and wear mechanism. In the case of surfaced layers, their properties depend not only on the chemical composition, but also on the same parameters of the surfacing process. The improvement of the surface layer properties is achieved by the use of appropriate techniques of surfacing, spraying or remelting the surface with a controlled amount of heat supplied to the padding weld [3-5]. An important factor that may affect the properties of the welds is also the shape of the bead from which the abrasion-resistant boards are made. The use of straight beads and weaving beads may affect the conditions of crystallization padding welds and their natural heat treatment, which they are subjected to during the welding of the next bead. The properties of the surface deposited with
spraying methods can be changed by remelting surface using the TIG [6,7], induction remelting [8] laser [9], electron beam [10] or other methods [11]. There is a lack of information of the remelting hardfaced structures with TIG method. The aim of the research was to check the possibility of remelting padding welds using the traditional TIG method and the TIG method with high frequency. The study examined how the remelting process affects the structure of padding welds, their hardness and wear resistance.

2. Materials and research methods

As the basis for making the padding welds, samples made of S235 steel with dimensions of 8x70x200 mm were used. The padding welds were made with the use of a self-shielding core wire of the trade name HARDFACE BNC-O with a diameter of 1,2 mm. The chemical composition of the wire is presented in table 1. The padding welds were made on the OZAS SYNERMIG 400 device using the PRO DC-20 welding trolley. 2 techniques of arranging the beads were used, i.e. three straight beads (samples marked 1) and a weaving bead (samples marked 2) to obtain padding welds with comparable geometric values. The samples prepared in this way were remelted at half of their length using the TIG method using the ESS TIGARC 2705 source and welding trolley. In the remelting process the traditional TIG method (samples marked A) and TIG with the high-frequency currents method were used. The parameters of the hardfacing and remelting process are given in table 2.

| Sample | Voltage (V) | Current (A) | Wire length (mm) | Welding speed (mms⁻¹) | Remelting current (A) | Remelting speed (mms⁻¹) | Current frequency (Hz) |
|--------|-------------|-------------|------------------|------------------------|----------------------|------------------------|------------------------|
| 1      | 163         | 25,4        | 30               | 3,33                   | -                    | -                      | -                      |
| 2      | -           | -           | -                | -                      | -                    | -                      | -                      |
| 1A     | -           | -           | -                | -                      | 110                  | 1,33                   | -                      |
| 2A     | 163         | 25,4        | 30               | 3,33                   | -                    | -                      | 20 000                 |
| 1A-Hz  | -           | -           | -                | -                      | -                    | -                      | -                      |
| 2A-Hz  | -           | -           | -                | -                      | -                    | -                      | -                      |

Table 1. Chemical composition of the cored wire for surfacing.

| Chemical composition (% weight) |
|-------------------------------|
| C    | Mn | Si | Cr | Nb | B  |
| HARDFACE | 2,5 | 2  | 0,6 | 11,5 | 5  | 2,2 |

Table 2. Parameters of the hardfacing and remelting process.

After hardfacing, the samples were visually inspected in accordance with PN-EN ISO 5817, and specimens were prepared, which were assessed on the Olympus GX51 optical microscopre and hardness tests. To determine immunity wear tester G65 and procedure A according to ASTM G65 standard were used.
3. Research and discussion

The visual examination of the padding welds after hardfacing revealed the existence of numerous nonconformities in the form of cracks transverse to the welding direction and spatters (figure 1). There are characteristic welding imperfections for wear-resistant padding welds, which although not eliminating the use of welds, may affect their wear resistance. Fragments of padding welds that have been remelted do not show any cracks on their surfaces. The remelting process contributed to the disappearance of cracks, which may have a positive effect on the durability of padding welds.

Figure 1. The sample views of the padding welds with the melted part.

a) the sample made with a straight beads and melted with the TIG method.

b) the sample made with a weaved stitch and remelted using the TIG method with high-frequency current.

The microscopic examinations also revealed significant differences in the structure of the tested padding welds. The very application of various surfacing techniques (straight and weaving stitching) resulted in different conditions for the crystallization of the padding welds, which translated into the structure of the surface layer produced. In the case of straight stitches, a dendritic structure arrangement can be observed (figure 2) with clearly marked precipitations of primary carbides. The structure of the padding weld made with weaving bead (figure 3) is similar, but the dendritic structure is more randomly oriented and more fragmented. The carbides are located in interdendritic spaces. The use of traditional TIG remelting of padding welds caused the greatest changes in the structure of padding welds made in the straight bead technique (figure 4). The dendritic structure has been transformed into a fine-grained structure with a small amount of primary carbides. The structure is dominated by small-dispersion secondary carbides. Remelting the padding weld made with weaving stitch did not bring about radical changes in the structure (figure 5). The only changes are visible at a distance of about 100 μm from the padding weld surface, where the dendrite arms are enlarged. Significant greater changes in the structure resulted from the use of TIG remelting with currents with a frequency of 20,000 Hz. In this case, the structure of the padding weld made with straight stitches
(1A-Hz) shows a layered structure. Near the surface of the padding weld, a fine-dispersion structure with secondary carbides can be observed (figure 6), and at a distance of about 300 μm from the surface, a layer of large primary carbides with a width of up to 100 μm is visible. In case of the sample 2A-Hz (figure 7) the remelting process leads to dendritic structure with more main axis parallel to the surface onto distance up to 500 μm. In some areas, the dendritic structure has disappeared and a fine dispersion structure with a large amount of secondary carbides has appeared.

Figure 2. The structure of the sample 1.

Figure 3. The structure of the sample 2.
Figure 4. The structure of the sample 1A.

Figure 5. The structure of the sample 2A.
Figure 6. The structure of the sample 1A-Hz.

Figure 7. The structure of the sample 2A-Hz.

The next stage of the research was to test the hardness of the ground samples, prepared for the wear resistance tests. Figure 8 presents the average hardness values, close to the surface, for 5 measurements for each sample. The high hardness for the 1A-Hz sample results from the presence of large carbide clusters near the surface.
The last test performed was the wear resistance test according to procedure A according to the ASTM G65 standard. The test was carried out with the abrasive efficiency of about 300 g / min. The results are presented in table 3, which shows that the remelting of the top layer caused a reduction in wear resistance compared to the initial state. Only in the case of sample 2A, no decrease in wear resistance was noted after padding with a weaving beads and remelting with traditional TIG.

| Sample | Mass before test (g) | Mass after the test (g) | Mass loss (g) | Volume loss (mm³) |
|--------|----------------------|-------------------------|---------------|-------------------|
| 1      | 158,155              | 158,128                 | 0.027         | 3.515             |
| 2      | 142,153              | 142,129                 | 0.024         | 3.125             |
| 1A     | 135,187              | 135,157                 | 0.030         | 3.906             |
| 2A     | 139,541              | 139,517                 | 0.024         | 3.125             |
| 1A-Hz  | 158,062              | 158,032                 | 0.030         | 3.906             |
| 2A-Hz  | 140,890              | 140,859                 | 0.031         | 4.036             |
The obtained test results indicate the influence of the applied surface remelting on the functional properties of the padding weld. Big differences are already visible when using different hardfacing techniques, i.e. using straight and weaving beads. The differences between these techniques are seen in the hardness of the surface layer and the wear resistance. In this case, the greater hardness of padding welds made with a weaving beads also changes into greater wear resistance of the padding weld (by nearly 12%). The remelting process changed the hardness on the surface of padding welds, while a significant increase in hardness was noted for padding welds made with a straight bead pattern (figure 8). In the case of remelting with traditional TIG, it is an increase of about 70 HV units. For TIG remelting with high frequency currents, this increase is by about 150 HV units. A similar effect of increasing the hardness can be obtained by remelting with TIG hard particles on the surface layer [12]. This is also confirmed by the observations of the structure of the samples, which show a large fragmentation of the structure and numerous precipitates of carbides. In the case of sample 1A-Hz, the hardness is increased by areas with a high concentration of carbides. However, it should be noted that the increase in hardness does not translate into an increase in wear resistance under the conditions of the experiment. In the soft materials the increase in hardness results in increase of the wear resistance [13], what is not so obvious in other materials [14,15]. In this case, there was a decrease in wear resistance after remelting the surface by about 11%, regardless of the applied method of surfacing. The structure with fine-dispersion precipitates of secondary carbides was not a sufficient obstacle for the particles causing the wear process. A similar relationship can be observed for samples made with a weaving stitch. In the case of a fine-grained structure, even on a limited surface as for the 2A-Hz sample, a decrease in wear resistance is noted despite obtaining a comparable surface hardness as for the initial sample. The decrease in wear resistance is in this case the greatest, reaching almost 30%, while the conventional TIG remelting sample has the same level of wear resistance as the starting material. In this case, the structure of the material after remelting is close to the original structure with only slight changes in the size of the dendrite arms. The use of high-frequency remelting has the greatest impact on structure and wear resistance. The electric arc when using high frequency is concentrated on a smaller area compared to the traditional arc in the TIG method. The greater concentration of the electric arc translates into greater changes in the structure at greater depth, which mainly consist of the fragmentation of the primary structure and the release of a large number of small-dispersive secondary carbides. However, this is not conducive to increasing the wear resistance, where large primary carbides play a major role.

Summary

The conducted research and the analysis of their results allowed for the formulation of the following conclusions:
- The use of remelting wear-resistant layers adversely affects their wear resistance under the conditions of the experiment. The fragmentation of the structure and above all dissolution of primary carbides, while maintaining high hardness, is the main factor that reduces the wear resistance.
- Hardness is not a factor that determines wear resistance under test conditions. In the analyzed case, the decisive factor is the structure of the material, which may undergo large changes depending on the hardfacing technique used and the adopted surface remelting parameters.
- High-frequency remelting causes changes in the structure of the material to a much greater depth that the conventional TIG method. High frequency of welding / hardfacing current causes arc concentration and thus increase the depth of the impact of thermal phenomena in the material. By changing the frequency, it is possible to influence the surface area and the depth of action of the arc.
- The future directions of the research can be focused on the high frequency TIG parameters process optimization for the remelting process and with using sprayed and hardfaced layers with high carbides volume fraction.
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