

Heat-resisting alloys for hard surfacing and sealing pad welding

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Abstract

The paper deals with heat-resisting alloys used to harden surfaces of elements operating in increased temperatures. It also deals with alloys used to seal cooperating surfaces of elements operating in the conditions of increased temperatures and aggressive utilities. Application methods and properties of thus obtained layers have been presented and adhesion of layers with matrix material has been assessed.

Keywords: wear-resistant alloys, superficial layer, heat-resisting alloys, pad welding

1. Introduction

A rational selection of construction materials while designing elements of devices and machines and correctly conducted renovation management constitute a source of considerable savings, fewer failures and extended period of these products' operation.

Practical implementation of new technical solutions is, however, possible only if one has suitable construction materials. This is the reason for incessant search for new material groups with appropriate properties for a given use and numerous tests of practical usefulness of a given material group. Naturally, the economic factor is equally important in the decision-making process on using a given material and technology. Therefore, while manufacturing a given product, its parts are made of a less expensive material and selected surfaces are coated with more expensive materials with specific functional properties.

The paper presents selected materials used to harden surfaces of elements operating in high temperatures and exposed to abrasion and mechanical loads.

Methods and devices used to produce padded layers do not differ from the ones commonly used for welding; therefore, it is quite common to think that welding and pad welding are very

similar processes that can be treated identically from the technological point of view. Such an attitude is, in practice, a frequent reason for failures while padding. One forgets about the fact that welding generally joins materials with similar metallurgical and physico-mechanical properties, whereas during preventive pad welding, it is necessary to join materials with very different properties [1].

With the current development of welding techniques and materials engineering of additional welding materials, it is not a problem to obtain padding welds with required properties. However, it is still crucial to obtain appropriate connection of the basic (padded) material with the material from which the padded layer is constructed.

2. Testing material and methods

A characteristic feature of the pad welding process - unlike other methods of spreading metallic coatings - is weld penetration of the base material on which a padding weld is overlaid. Weld penetration of the base is necessary to obtain sufficient fusion penetration and mixture of the weld metal with the padded material. On the border of the padding weld and base, there is a

fusion penetration area whose chemical composition varies from the chemical composition of the filler metal to the chemical composition of the base material. The properties of the fusion penetration area that constitutes a transitory layer between a padding weld and base material considerably influence pad welding final result [2].

Plasma pad welding consists in fusing additional material in the powder form in plasma arc. Fused powder joins the slightly melted base material creating a padding weld. This method enables to change properties of the surface layer of the padded material.

Another method consists in spraying base surface with stellite powder. The paper analyses layers obtained by stellite powder spraying using a mixture of oxygen, acetylene and argon as a carrier gas. After spraying, the layer was fused with the base in the temperature of 1100°C. When cooled down, annealing process was conducted in the temperature of 700°C during 6 hours with another cooling of a speed of approx 50°/h.

Microscopic observations of the structure of padding welds enable to determine only the structure nature or to describe basic structural components and evaluate the size and orientation of grains. In the cases of considerable differences between chemical compositions of the base material and material used for pad welding, these data are insufficient and therefore, it is necessary to analyse, at least locally, the quantitative content of alloying elements that can create particular structural components or intermetallic compounds. This problem often appears in the case of preventive pad welding of crucial elements of machines and devices, particularly when they operate in difficult conditions, e.g. in high temperatures or are exposed to thermal shocks, changeable dynamic loads etc.

3. Description of results obtained

The conducted research included tests of the area of padding weld connection with matrix material. The joint was obtained by means of pad welding with an electrode, plasma pad welding and spraying with another weld penetration. Constructional alloy steel of 30CrMoV9 type, austenitic steel of X6CrNiMoTi17-12-2 and 0H16N13MFNb type and martensitic steel of X22CrMoV12-1 type were used as matrix material. Chemical compositions of the steel are presented in table 1. Cobalt-chromium heat-resisting alloy, nickel heat-resisting alloy and SF6 stellite were used as overlaid materials. Chemical compositions of these alloys are presented in table 2.

3.1. Layers padded with nickel-chromium alloy

A heat-resisting nickel-chromium alloy was spread by means of arc pad welding method on the base made of austenitic steel of X6CrNiMoTi17-12-2 type and martensitic steel of X22CrMoV12-1 type. The area of austenitic steel connection with the alloy was shown in fig.1, whereas the area of alloy connection with martensitic steel was shown in fig. 2.

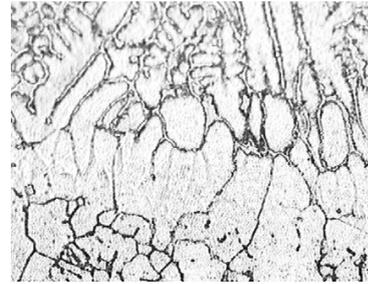


Fig. 1. Area of X6CrNiMoTi17-12-2 steel connection with nickel alloy 500x, etched with Mi1Fe, Mi16Fe

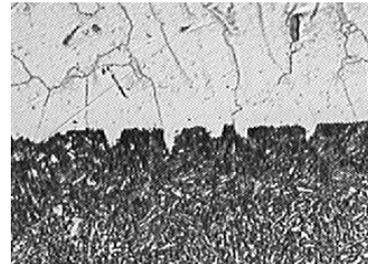


Fig. 2. Area of X22CrMoV12-1 steel connection with nickel alloy 500x, etched with Mi1Fe, Mi16Fe

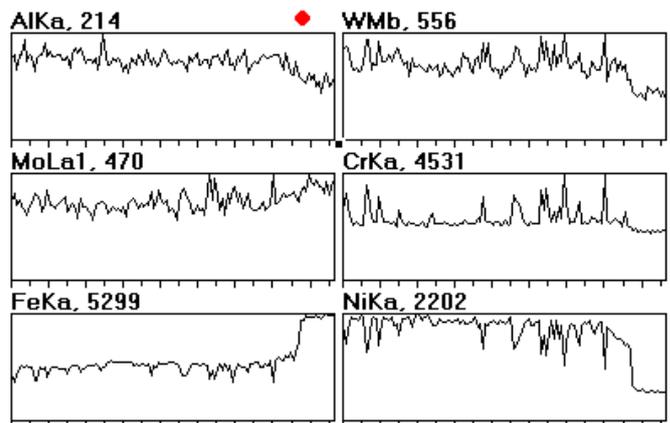
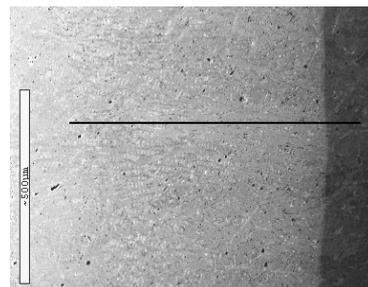


Fig. 3. Surface distribution of elements in area of X22CrMoV12-1 steel connection with nickel alloy

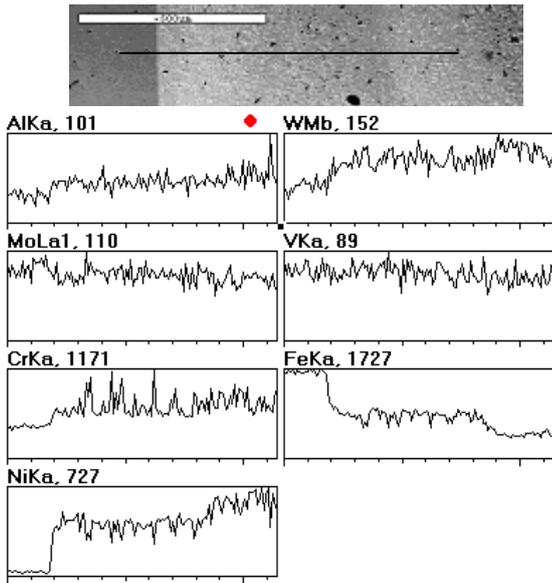


Fig. 4. Surface distribution of elements in area of X6CrNiMoTi17-12-2 steel connection with nickel alloy

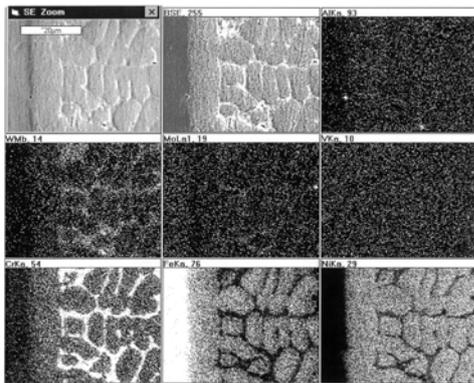


Fig. 5. Surface distribution of elements in area of X22CrMoV12-1 steel connection with nickel alloy

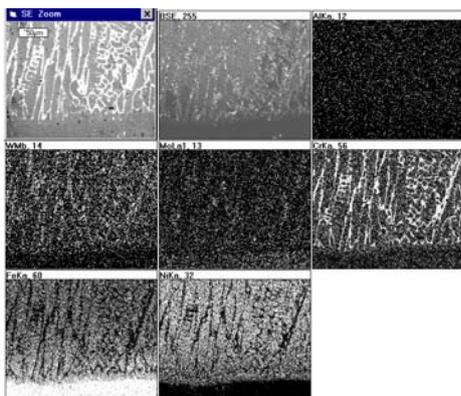


Fig. 6. Surface distribution of elements in area of X6CrNiMoTi17-12-2 steel connection with nickel alloy

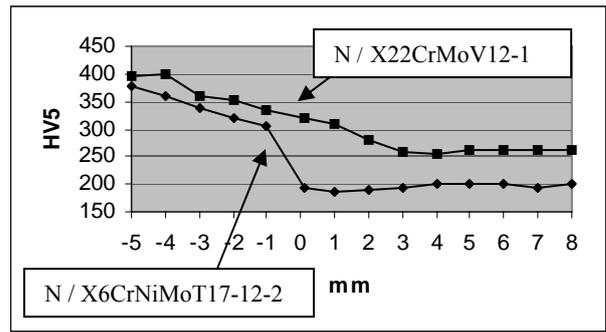


Fig.7. Hardness penetration pattern in area of heat-resisting nickel alloy connection with base material.

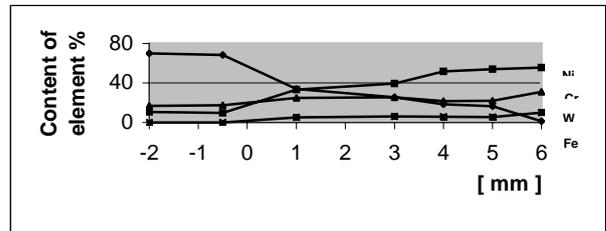


Fig. 8. Change in elements' concentration in padding weld made on X6CrNiMoTi17-12-2 steel

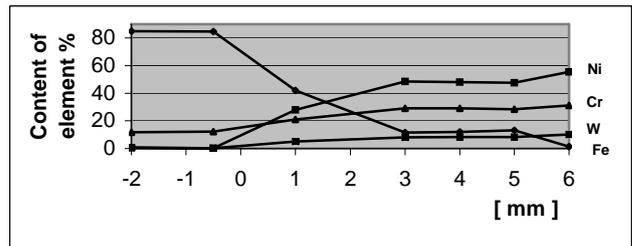


Fig. 9. Change in elements' concentration in padding weld made on X22CrMoV12-1 steel

In order to detect qualitative changes in material chemical composition in the area of padding weld fusion, linear and surface distribution of elements was tested. The tests' results are presented graphically in figures 3-6 [3].

In the area of fusion penetration, concentration of alloying elements changed. Such elements as chromium and tungsten change their concentration in a gentle way, whereas iron and nickel change their concentration abruptly.

Moreover, hardness penetration pattern was measured in the padding weld area. Hardness was measured by means of Vickers method with 49 N load. The measurements were taken along the line running perpendicularly to the fusion line. Their results were presented in the form of a chart in fig.7. On the X-axis, 0 point means the fusion line. The curve section on the left side of this point presents hardness in the padding weld made of nickel alloy, whereas on the right, values of hardness in the steel constituting padding weld base are given. As you see, a change in hardness in the connection area causes no risk of discontinuity.

Changes in the chemical composition of the padding weld (positive section of X-axis) stretches out for a much longer section – in the case of austenitic steel – approx 4 mm (fig. 8), and in the martensitic steel – approx 3 mm (fig. 9). On these sections, the content of nickel and chromium clearly falls, the amount of iron going from the base material to the padding weld decreases gradually, whereas tungsten behaves almost steadily. It is also confirmed by results of surface analysis of distribution of elements that are similar despite different morphology of structural components [4].

3.2. Layer padded with stellite

The stelliteing process was conducted on austenitic steel of 0H16N13MFNb type. Before stelliteing, samples were initially heated to the temperature of 300C, and then, samples' cylindrical surfaces intended to be covered with a stellite layer were cleaned by sand blasting with corundum powder. The sample temperature during sand blasting did not drop below 90C. The air for sand blasting was cleaned of moisture and fat with the use of appropriate filters.

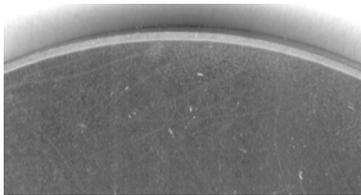


Fig. 10. Fragment of sample cross-section
Magnification of approx 1.6x, etched with Mi1Fe

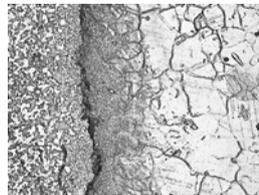


Fig. 11. Connection area structure
500x, etched with Mi1Fe, Mi16Fe

Spraying with stellite was carried out by means of a Rotolloy gun, using a mixture of oxygen, acetylene and argon as a carrier gas. Directly after spraying, the layer was melted with the base. In order to do this, the whole sample is heated up to 700 – 800C. Next, stellite surfaces are heated with a torch up to 1090 – 1150C. After cooling the sample down in the air to the temperature of about 800C, the sample is placed in a furnace of the temperature of 700C for 6 hours. After soaking, the samples are cooled to approx 80C with a speed not greater than 50C/h.

As a result of the conducted stelliteing process, an approx 0.5mm-thick stellite layer was obtained on the steel surface. The entirety of changes resulting from the stelliteing process reaches the depth of about 0.6 mm. The stellite layer view was shown on the fragment of sample cross-section in fig.10. The material structure in the area affected by stelliteing process was shown in fig. 11. There is a complex stellite structure on the surface. Under the structure, you can see a thin area that was created as a result of melting the stellite with the sample material. Under this area, there is a visible area of penetration of stellite elements (through diffusion) into the sample material. The changes in elements' distribution in the area of stellite layer connection with the sample material were shown in fig. 12. It is clearly visible that the area of interpenetration of elements from both materials does not exceed

several dozen micrometers. The changes in hardness take place in a gentle manner, which is shown in fig.13.

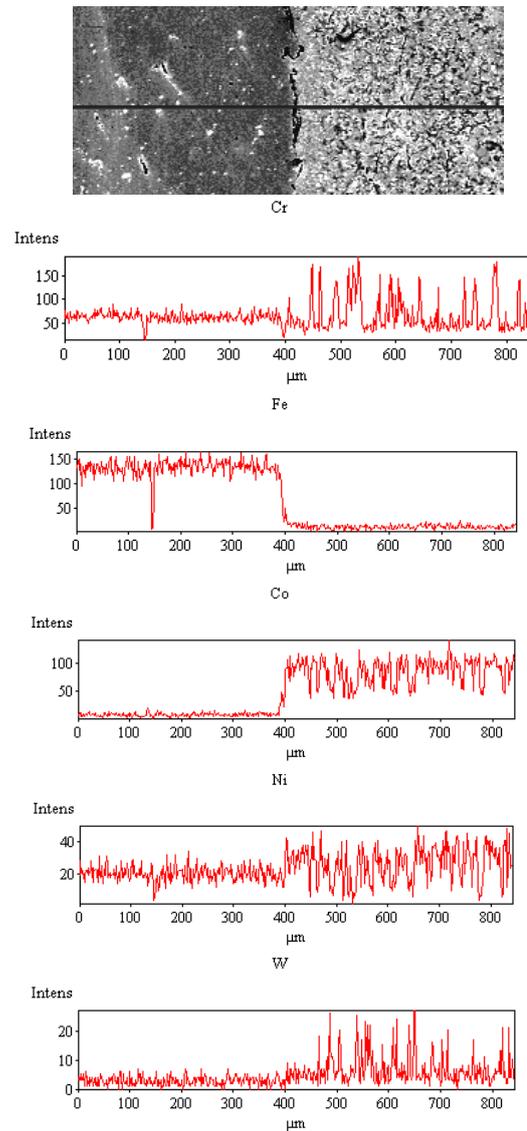


Fig. 12. Linear distribution of elements in connection area

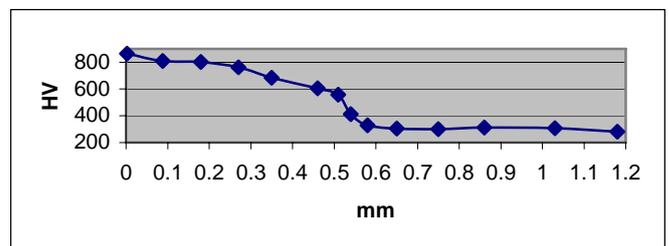


Fig. 13. Change in hardness from sample surface

3.3. Plasma padded layer

The hardness of the overlaid sealing layer's material was 455 HV30. The layer was applied on the helical surface of worm line ridge. The worm turns in a cylindrical sleeve. The system aimed to transport the substance inside the sleeve with maintained leak tightness between the worm ridge and sleeve wall. The layer applied was 3mm-thick. The worm was made of constructional steel of 30CrMoV9 type, of hardness 311 HV30.

The sealing layer's chemical composition was analysed on an X-ray microprobe analyser installed on a scanning microscope. Figure 14 shows a spectral image of the analysed material. The sealing layer is a heat-resisting alloy on the basis of cobalt. The alloy chemical composition is presented in table 1.

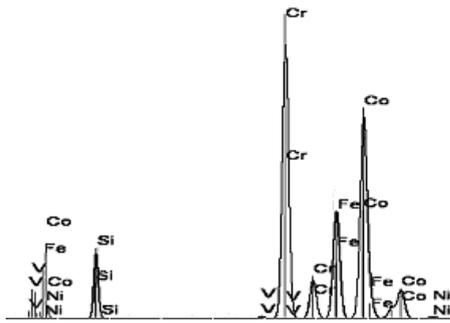


Fig. 14. Spectrum of sealing layer material

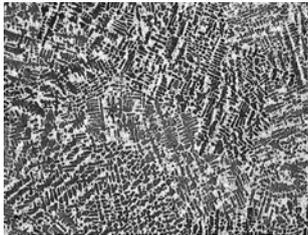


Fig. 15. Microstructure of sealing layer
Magnification 100x, etched with Mi16Fe

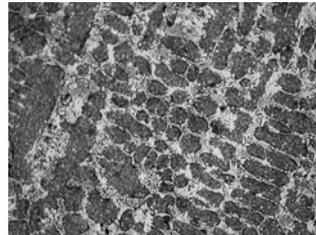


Fig. 16. Microstructure of sealing layer
Magnification 500x, etched with Mi16Fe

The structure of padded layer's material was shown on figure 15 and 16. The change in chemical composition of elements in the connection area was presented on figure 17.

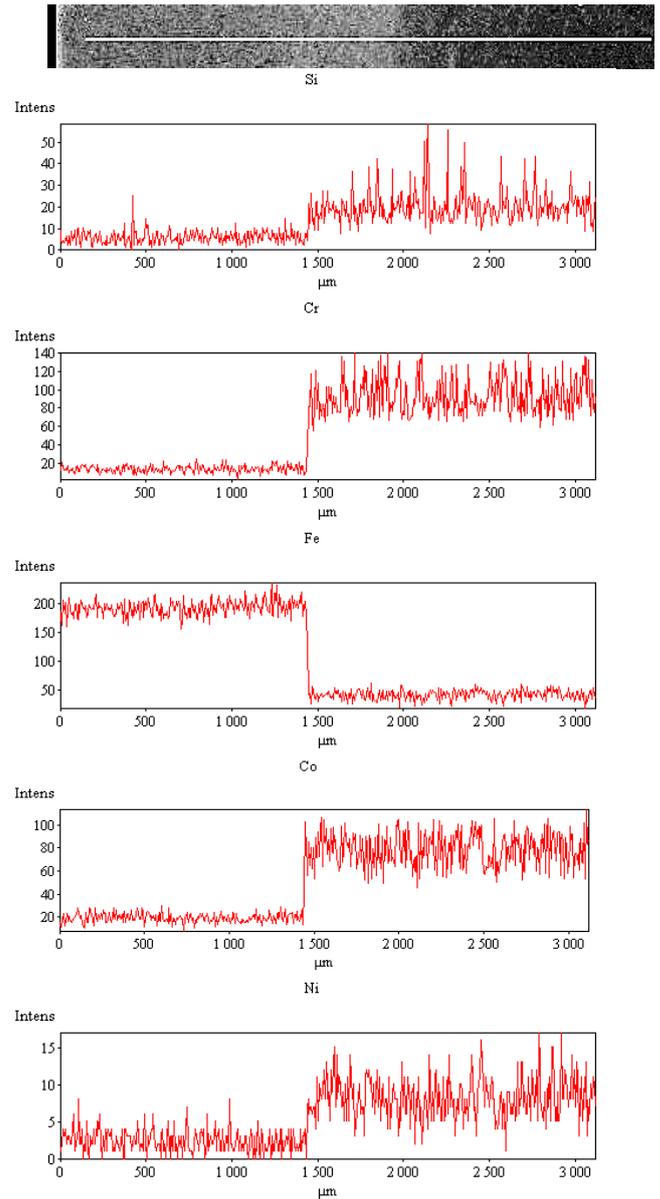


Fig. 17. Linear distribution of elements in connection area

Table 1.
Steel of the base

Material	C	Si	Mn	Cr	Ni	Mo	V	W	Nb	Ti
X22CrMoV12-1	0.24	0.33	0.69	11.7	0.43	0.98	0.34	0.6	0.01	
X6CrNiMoTi17-12-2	0.047	0.45	1.61	16.7	10.6	2.04				0.40
0H16N13MFNb	0.063	1.22	0.64	17.51	11.69	1.44	0.35		0.76	
30CrMoV9	0.276	0.219	0.483	2.37	0.16	0.206	0.137			

Table 2.

Materials used for pad welding

Material	C	Si	Mn	Cr	Ni	Al	Co	B	W	Fe
Co-Cr alloy		5.5		30.8	3.2		42.8			16.9
Ni-Cr alloy	1.1	0.84		31.8	54.8	1.1			10.1	
SF6 stellite	0.7	2.3	1.0	19.0	13.5		51.5	1.6	7.5	

4. Conclusions

The research conducted has shown that during pad welding by means of the MIG method, the analysed nickel alloy creates connection of complete metallic continuity with martensitic and austenitic steel used in power industry. In the fusion area, no indirect layer is created, grain growth is relatively small and takes place on very small width from 0.1 to 0.15 mm. A lack of oxidation and overheating traces in the fusion area also proves a correct selection of pad welding parameters. The changes found in concentration of alloying elements and hardness penetration pattern fuel no fear of lowering mechanical properties of padding weld connection with the base.

The diversity of structures in the padding weld observed under an optical microscope results not only from changes in chemical composition in these areas but also, in great measure, from local conditions of solidification of material and padding weld and alloying elements' interaction. Therefore, the diversity of structures in a padding weld should not be recognised only as a sign of the padding weld low properties. Simultaneously, it needs to be emphasised that the analysed padding welds did not show any discontinuities which proves that a nickel alloy can be taken into account as an additional material to pad elements made of steel for power industry.

Hardening obtained by stellite process reaches the depth of approx 0.6 mm. The course of change in hardness in the connection area guarantees that the hardened layer will not peel or chip off.

The research within properties of the area of fusion of padding welds made of heat-resisting cobalt alloys on austenitic steel with the use of plasma pad welding method has shown that the layers obtained through this method have good properties. The area of the layer connection with the material is coherent and had a distinct transitory area with elements present in both materials. The hardness of the applied layer enables good cooperation with the material of a cylindrical sleeve made of constructional steel of 30CrMoV9 type and appropriate sealing during devices' operation.

Selection of the method of applying a heat-resisting alloy's layer on the base material depends on a few factors. They include properties that the applied layer should have, its required thickness and type of the base material.

References

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