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Methods of improvement in hardness of composite surface layer on cast steel

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Abstract

The paper presents a method of usable properties of surface layers improvement of cast carbon steel 200–450, by put directly in founding process a composite surface layer on the basis of Fe-Cr-C alloy and next its remelting with use of welding technology TIG – Tungsten Inert Gas. Technology of composite surface layer guarantee mainly increase in hardness and abrasive wear resistance of cast steel castings on machine elements. This technology can be competition for generally applied welding technology (surfacing by welding and thermal spraying). However the results of studies show, that is possible to connection of both methods founding and welding of surface hardening of cast steel castings. In range of experimental plan was made test castings with composite surface layer, which next were remelted with energy 0,8 and 1,6 kJ/cm. Usability for industrial applications of test castings was estimated by criterion of hardness and abrasive wear resistance of type metal-mineral.

Keywords: Cast steel, Composite surface layer, Hardness, TIG

1. Introduction

In the last years in machine-building industry is required a large number of castings with special properties, for example high abrasive wear resistance and heat-resisting. These elements are produced from expensive and difficult to available materials. However in many cases high properties are necessary for surface layers of castings. Therefore unprofitable is founding of complete element with expensive alloy additions i.e. Ni, Cr, Mo or Ti [1÷3].

In methods of composites production on special attention deserves founding method. This technology by put directly in founding process a composite surface layer is the most economic methods of enrichment of casting surface [1, 2].

Modern technologies of surface engineering are connected with manufacturing of composite surface layer on casting surface sectors, where are very difficult conditions of working. These surfaces perform technical and useful requirements and moreover increase life of casting. In case of strengthening of complete surface, favourable is founding of complete casting from highly alloyed material. Then parameters of founding technology of composite surface layer are nearly identical with manufacturing of usual casting [1÷3].

The other metod of increase of hardness and abrasive wear resistance is application of surfacing by welding and thermal spraying technology. Welding technology may be used to surface hardening by remelting with energy of electric arc, plasma stream or laser beam. Often, for this aim is used welding technology for example TIG – Tungsten Inert Gas also known as GTA – Gas Tungsten Arc. In this technology to remelting is used heat of arc, which glow between non-consumable tungsten electrode and remelted material. The weld area is protected from atmospheric contamination by a shielding gas - usually an inert gas such as argon or seldom helium [4÷8].

2. Range of studies

The main aim of studies was improvement of usable properties i.e. hardness and abrasive wear resistance of type metal-mineral of surface layer of cast carbon steel 200-450 (Tab.1) castings, by put directly in founding process a composite surface layer on the basis of Fe-Cr-C alloy (Tab.2) and next its remelting with use of welding technology TIG. The results of these studies was compared with other methods of surface hardening.

Table 1.
Chemical composition of cast carbon steel 200-450

Mass contents in %				
C	Mn	Si	P	S
0,60	1,25	0,60	0,03	0,03

Table 2.
Chemical composition of Fe-Cr-C alloy

Mass contents in %				
C	Cr	Si	P	S
8,65	66,50	0,75	0,02	0,01

Remelting of castings surface was realized with use of welder device CastoTIG 2002 AC/DC with current intensity 40A and 80A. On the basis of registered value of arc voltage and remelting velocity was determined remelting energy:

$$E = \frac{I \cdot U}{V}[J/cm] \qquad (1)$$

where:
I – current intensity: 40 or 80A,
U – arc voltage: 20V,
V – remelting velocity: 1cm/s.

Rate of flow of shielding gas – argon was 5l/min. Non-consumable electrode (W + 2%ThO_2) ϕ 3,2mm was used.

Usability for industrial applications of test castings was estimated by criterion of hardness, which was measured on ultrasound MIC2 hardness tester with load 49N and abrasive wear resistance of type metal-mineral, which was measured on the basis of ASTM G 65 - 00 standard [9].

Moreover metallographic examinations was made with use of light microscopy Nikon EPIPHOT-TME with magnification from 50x to 600x. Surfaces of samples which were prepared for microstructure analysis were etched with use of [10]:

1. Mi1Fe (Nital) on composition: 3cm^3 nitric acid and 100cm^3 ethyl alcohol;
2. Mi19Fe on composition: 3g ferrous chloride, 10cm^3 hydrochloric acid and 90cm^3 ethyl alcohol.

Whereas X-ray examinations was made using RTG XPertPro Panalytical diffractometr with Co anode λ_{Co}=1,789 $\mathring{A}$. X-ray tube was supplied with the current I = 10mA under voltage of U = 25kV. Diffraction examinations were performed within the range of angles 2θ from 35° to 115°. The measurement step was 0,05° in lenght while the pulse counting time was 5s. On the basis of International Center for Diffraction Date ICDD was made identification of phases.

Full experimental plan is shown in table 3.

Table 3.
Range of studies

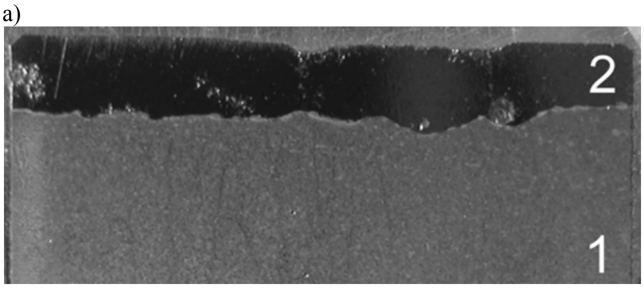
Sample number	Characteristic of applied hardening treatment
1	As-cast condition.
2	Composite surface layer on the basis of Fe-Cr-C alloy.
3	Volumetric hardening of cast steel: T = 850°C, t = 34min., water-cooling.
4	Volumetric hardening of cast steel with composite surface layer: T = 850°C, t = 34min., water-cooling.
5	Surface hardening with use of oxy-acetylene flame: T ≈ 800÷860°C, t ≈ 5min., water-cooling.
6	Cast steel remelting with use of electric arc TIG: I = 40A, U = 20V, V = 1cm/s, **E = 0,8kJ/cm**, air-cooling.
7	Cast steel remelting with use of electric arc TIG: I = 80A, U = 20V, V = 1cm/s, **E = 1,6kJ/cm**, air-cooling.
8	Cast steel with composite surface layer remelting with use of electric arc TIG: I = 40A, U = 20V, V = 1cm/s, **E = 0,8kJ/cm**, air-cooling.
9	Cast steel with composite surface layer remelting with use of electric arc TIG: I = 80A, U = 20V, V = 1cm/s, **E = 1,6kJ/cm**, air-cooling.
10	Surfacing by welding TIG of cast steel with use of filler in form of alloy cast steel G90CrSi13-1: I = 100A, U = 20V, V = 0,1cm/s.
11	Surfacing by welding TIG of cast steel with composite surface layer with use of filler in form of alloy cast iron EN-GJN-XCr15: I = 100A, U = 20V, V = 0,1cm/s.

3. Results and analysis

On figure 1 is presented view of cross-section of cast steel 200-450 castings with composite surface layer and with alloy cast steel G90CrSi13-1 and alloy cast iron EN-GJN-XCr15 padding welds. On the basis of metallographic examinations it was affirmed, that high quality of joint between layers and cast steel was obtained.

On figures 2, 3 and 5÷12 are presented results of metallographic microscopic examinations. Investigated cast carbon steel 200-450 has pearlite and ferrite in configuration of Widmanstätten in structure. Whereas composite surface layer on the basis of Fe-Cr-C alloy, which was put directly in founding process has structure with alloy ferrite and eutectic ferrite + M_7C_3 carbides (Fig. 2 and 3). In structure of joint area occur boundary between composite layer and cast steel. Behind transition line in cast steel area occur ferritic layer, which was created as result of diffusion in solid state. This diffusion concern move of carbon from cast steel to composite layer, which contain carbide-forming element – Cr. This phenomenon assure about very permanent joint between composite layer and cast steel base.

a)



b)

c)

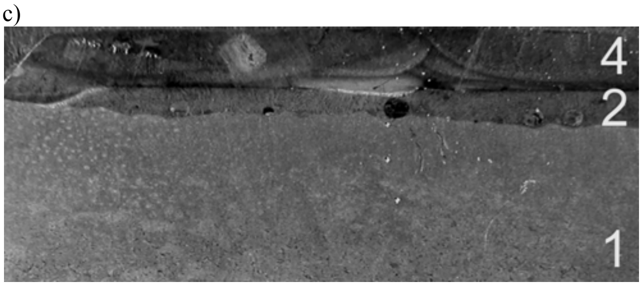


Fig. 1. View of cross-section of cast steel 200-450 castings (1) with composite surface layer (2) – fig. a, with alloy cast steel G90CrSi13-1 padding weld (3) – fig. b, alloy cast iron EN-GJN-XCr15 padding weld (4) on composite layer – fig. c

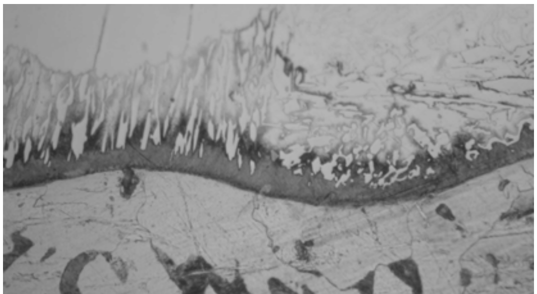


Fig. 2. Structure of joint area between cast carbon steel and composite layer – pearlite and ferrite in cast steel and alloy ferrite and eutectic ferrite + M_7C_3 carbides in composite layer – etching Mi1Fe, magnification 600x

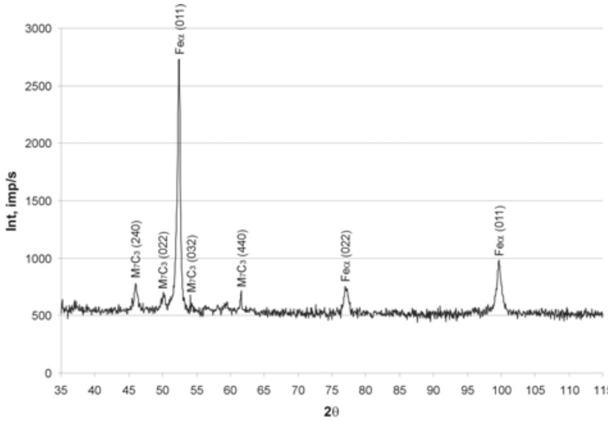


Fig. 3. X-ray diffraction of composite surface layer on the basis of Fe-Cr-C alloy

Fig. 4. Structure of joint area between cast carbon steel and composite layer after volumetric hardening – martensite in cast steel and with carbides in composite layer – etching Mi19Fe, magnification 600x

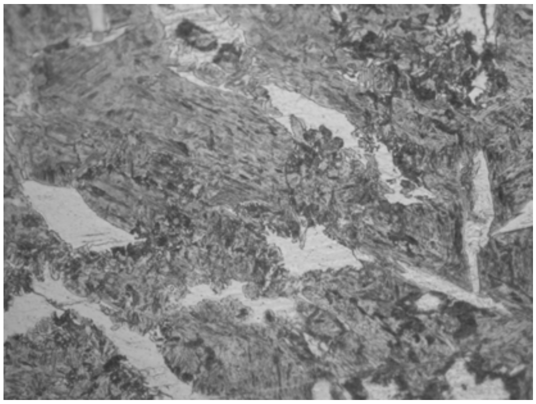


Fig. 5. Structure of cast carbon steel 200-450 after flame surface hardening – martensite and ferrite – etching Mi1Fe, magnification 600x

Martensite in structure in whole volume result from volumetric hardening of cast carbon steel 200-450. Likewise volumetric hardening of cast steel with composite surface layer result in structure, which contains carbides on borders of matrix dendrites – martensite (Fig. 4). Also martensite is present in structure of cast steel after flame surface hardening (Fig. 5). However presence of ferrite is a proof about too low austenitizing temperature.

a) b)

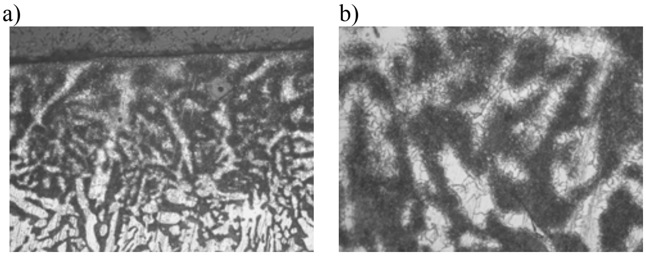


Fig. 6. Structure of cast carbon steel 200-450 surface after electric arc TIG remelting with energy E=0,8kJ/cm – pearlite, bainite and ferrite – etching Mi1Fe, magnification 200x (a) and 600x (b)

a) b)

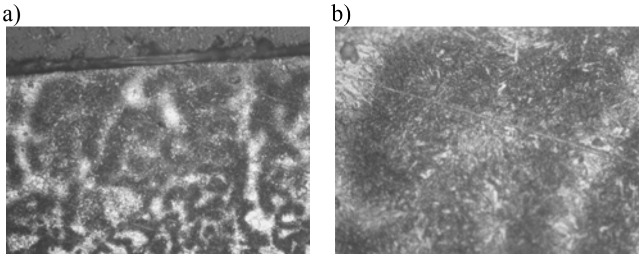


Fig. 7. Structure of cast carbon steel 200-450 surface after electric arc TIG remelting with energy E=1,6kJ/cm – pearlite, bainite and ferrite – etching Mi1Fe, magnification 200x (a) and 600x (b)

Remelting of cast carbon steel 200-450 surface with use of electric arc TIG with energy E = 0,8kJ/cm and E = 1,6kJ/cm result in presence of bainite, pearlite and ferrite in structure (Fig. 6 and 7). Application of remelting energy E = 1,6kJ/cm guarantee obtainment of wider hardened zone and increases in quantity of bainite in comparison with remelting energy E = 0,8kJ/cm.

Whereas remelting of composite surface layer on the basis of Fe-Cr-C alloy with use of electric arc TIG result in refinement of structure (Fig. 8 and 9). Degree of refinement fundamentally depend from applied remelting energy.

Alloy cast steel G90CrSi13-1 padding weld, which was made with use of TIG technology has martensite and interdendritic ferrite in structure (Fig. 10). Moreover in range of studies was made bimetallic „weld-casting" i.e. cast carbon steel 200-450 with ferritic-pearlitic structure – composite surface layer on the basis of Fe-Cr-C with alloy ferrite and eutectic ferrite + M_7C_3 carbides structure – alloy cast iron EN-GJN-XCr15 padding weld, which was made with use of TIG surfacing by welding technology with carbides in pearlite structure (Fig. 11 and 12).

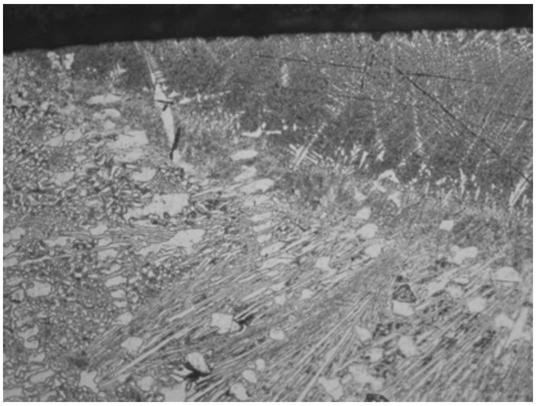


Fig. 8. Structure of boundary in composite surface layer after electric arc TIG remelting with energy E=1,6kJ/cm – etching Mi19Fe, magnification 200x

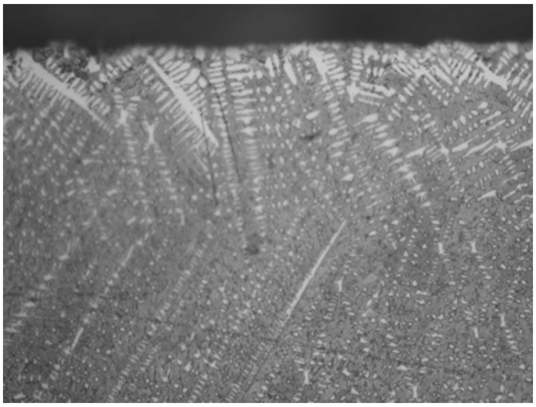


Fig. 9. Fine-grained dendritic structure of remelted area of composite surface layer – remelting energy E=1,6kJ/cm – etching Mi19Fr, magnification 600x

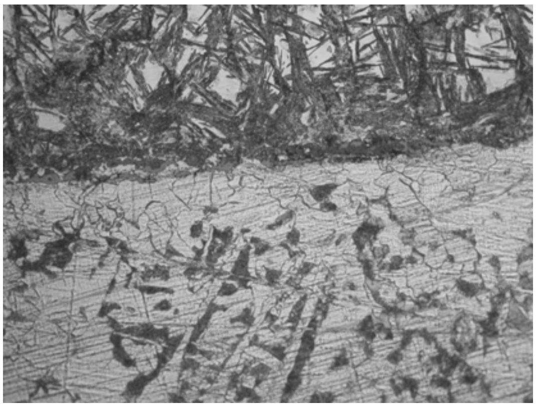


Fig. 10. Structure of fusion area in cast carbon steel 200-450 after surfacing by welding TIG with alloy cast steel G90CrSi13-1 – etching Mi1Fe, magnification 200x

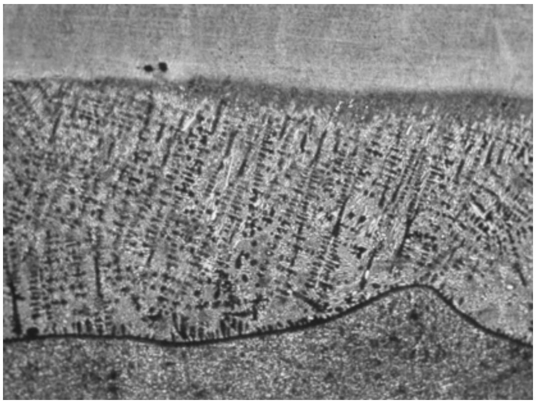


Fig. 11. Bimetallic structure, which contains from above alloy cast iron EN-GJN-XCr15 padding weld, composite surface layer on the basis of Fe-Cr-C alloy and cast carbon steel 200-450 – etching Mi19Fe, magnification 50x

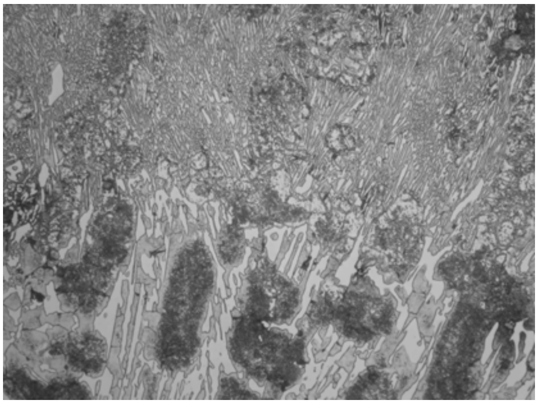


Fig. 12. Structure of fusion area of alloy cast iron EN-GJN-XCr15 padding weld – composite layer – etching Mi19Fe, magnification 200x

On the basis of results of hardness measurements following statement have been formulated, that largest degree of hardening result from electric arc TIG remelting of composite surface layer on the basis of Fe-Cr-C alloy with energy E = 1,6kJ/cm (Fig. 13).

Generally every of applied in studies methods of surface hardening influences on increase of hardness in comparison with as-cast condition of cast carbon steel 200-450. However increase of hardness for surface treatment of composite layer is stronger, than for surface without this composite layer, which was put on cast carbon steel surface directly in founding process.

Moreover, in range of studies was made distribution of hardness on cross-section of cast carbon steel 200-450 with composite surface layer and with alloy cast iron EN-GJN-XCr15 padding weld. This padding weld so as previously was made with use of TIG surfacing by welding technology. On the basis of this research was affirmed, that used filler does not guarantee obtainment of gradual increas of hardness in direction from core to surface (Fig. 14).

Results of hardness measurements was confirmed by results of abrasive wear resistance of type metal-mineral researches (Fig. 15).

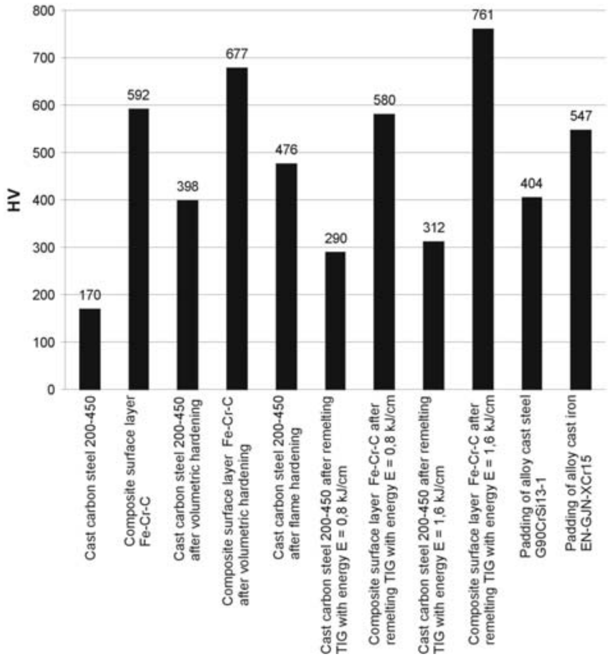


Fig. 13. Graphic interpretation of results of hardness measurements

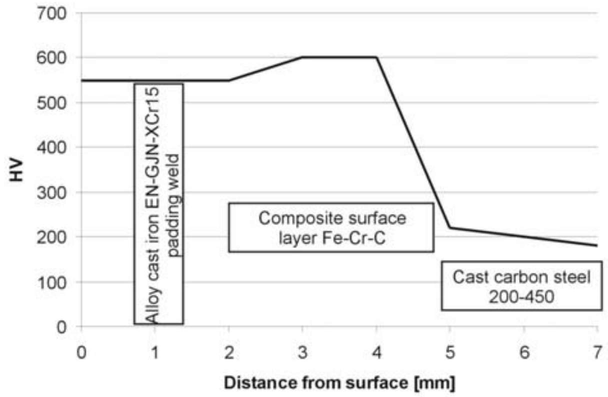


Fig. 14. Distribution of hardness on cross-section of cast carbon steel 200-450 with composite surface layer and with alloy cast iron EN-GJN-XCr15 padding weld

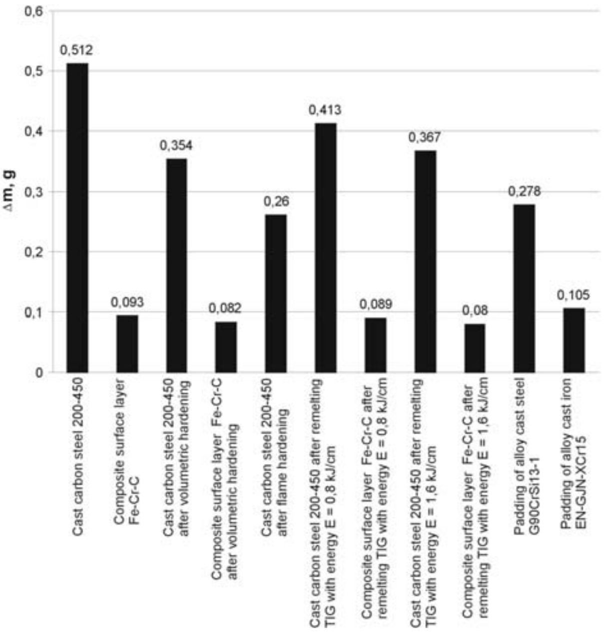


Fig. 15. Graphic interpretation of results of abrasive wear resistance of type metal-mineral, Δm - mass loss

4. Conclusion

Based on conducted studies following conclusions have been formulated:

1. Application of welding technology TIG to remelting of composite surface layer on the basis of Fe-Cr-C alloy, which was put directly in founding process, results in increase of hardness of about 150HV.
2. Welding technology TIG may be applied in aim of improvement of abrasive wear resistance of type metal-mineral on surface of cast carbon steel castings. However use of air-cooling after remelting result in smaller degree of hardening in comparison with volumetric and surface hardening, composite surface layer on the basis of Fe-Cr-C alloy and surfacing by welding TIG with use alloy cast steel as filler.
3. Possibility have been shown of effective surfacing by welding TIG on composite surface layer on the basis of Fe-Cr-C alloy, which was made with founding method. However used filler in form of alloy cast iron EN-GJN-XCr15 rods, does not guarantee obtainment of gradual increas of hardness in direction from core to surface. In relation of this is propose used of other filler, for example on the basis of Co with wolfram carbides WC, which is more expensive, but guarantee larger hardness of padding weld.

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