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Flux-cored wires for restoration of parts operating under cyclic loading conditions

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ABSTRACT: This article provides a study of restoring parts operating under cyclic loading conditions

KEY WORDS: arc surfacing, submerged arc surfacing, flux-cored wires, development, deposited metal, structure, fatigue strength, testing

I. INTRODUCTION

One of the methods for restoring parts operating under cyclic loading conditions is surfacing with pearlitic and austenitic steels. However, a serious obstacle to the widespread use of such surfacing is the low fatigue resistance of parts deposited with these alloys. The welded shafts have a fatigue limit that is 25....40% lower than the base metal [1, 2].

II. LITERATURE SURVEY

The Institute of Electric Welding has developed several grades of flux-cored wires (table), the suitability of which for surfacing critical parts has been verified by fatigue testing of cylindrical samples with a diameter of 70 mm made of steel 35 with a deposited layer 2.0...3.0 mm thick. The tests were carried out on machines that perform pure bending in an alternating cycle while rotating the sample. Test base -1·107 cycles, frequency - 1500 cycles per minute. Tests were carried out in air.

III. METODOLOGY

Surfacing of samples with flux-cored wire ПП-Нп-08Х16Б with a diameter of 2.2 mm was carried out in the following mode: $I_{св} = 200 ... 220$ A, $U_{д} = 24 ... 26$ V, $v_{н} = 0.4$ см/с, $v_{п\ пр} = 100$ м/ч, surfacing pitch 8....10 mm. The thickness of the deposited layer was 3 mm.

Fatigue tests showed that the endurance limit of samples deposited with ПП-Нп-08Х16Б, wire is at the level of 175 MPa (Picture. 1), which is only 12.5% lower than the endurance limit of the base metal.

Fatigue resistance can be further enhanced by strengthening treatment (roller rolling, ultrasonic impact treatment, explosion hardening).

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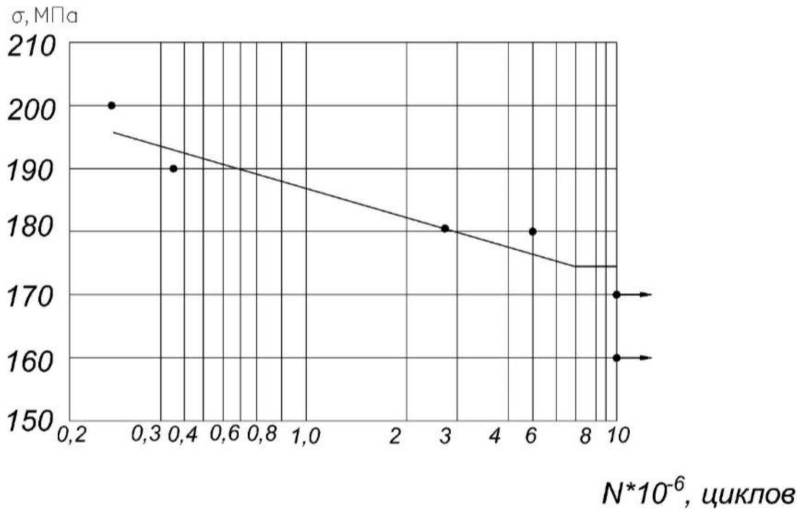

Picture. 1. Fatigue curves of samples with a diameter of 70 mm, deposited with flux-cored wire ПП-Нп-08Х16Б

Flux cored wire grade	Chemical composition of deposited metal (% by mass)				
	C	Mn	Si	Cr	
ПП-Нп-08Х16Б	0,05...0,10	0,45...0,60	0,60...0,90	17,0...19,0	
ПП-Нп-09Х13Н4М2Г2С	0,08...0,10	1,50...2,0	1,0...1,20	12,0...13,5	
ПП-Нп-07Х12Н3М2Г2С	<0,10	1,5...2,5	0,7...1,1	12,0...14,0	
Flux cored wire grade	Chemical composition of deposited metal (% by mass)				
	Ni	Mo	Nb	S	P
ПП-Нп-08Х16Б	-	-	0,45...0,65	≤0,012	≤0,04
ПП-Нп-09х13Н4М2Г2С	3,0...4,5	1,5...2,5	-	≤0,013	≤0,04
ПП-Нп-07Х12Н3М2Г2С	2,5...3,5	1,5...2,5	-	≤0,012	≤0,04

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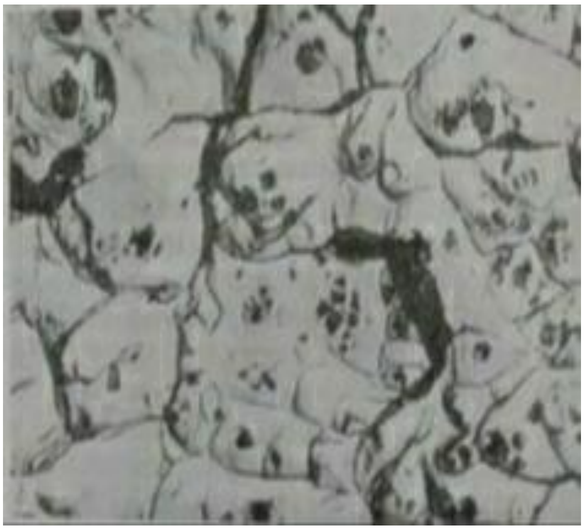
Picture. 2. Fatigue fractogram destruction of metal deposited cored wire PP-Np-08H16B (X320, reduced 2/3)



Picture. 3. Crack (decrease 1/2) in the ferrite layer at the boundary Fusion of base metal steel 08X16Б (a, X320) and source of fatigue cracks (b, X96)

Picture. 4. Microstructure (reduced 2/3) steel 09X13H4M2Г2C (a, X320) and fractogram of its destruction (b, X3000)

A sufficiently high level of fatigue resistance can be achieved by choosing the optimal ratio of chromium, nickel, manganese and silicon, as well as by introducing niobium and rare earth metals into the deposited metal. The deposited metal is distinguished in this case by its high resistance to the formation of hot cracks and high resistance to the propagation of fatigue cracks, as evidenced by the track marks extending from the grain boundaries (Picture. 2). Fatigue

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failure is trans granular in nature. First, the deposited metal is destroyed along the crystallite boundaries, and then along the grain body.

The ferrite layer turned out to be the most weakened, which was the source of initiation of fatigue cracks (Picture. 3, a, b).

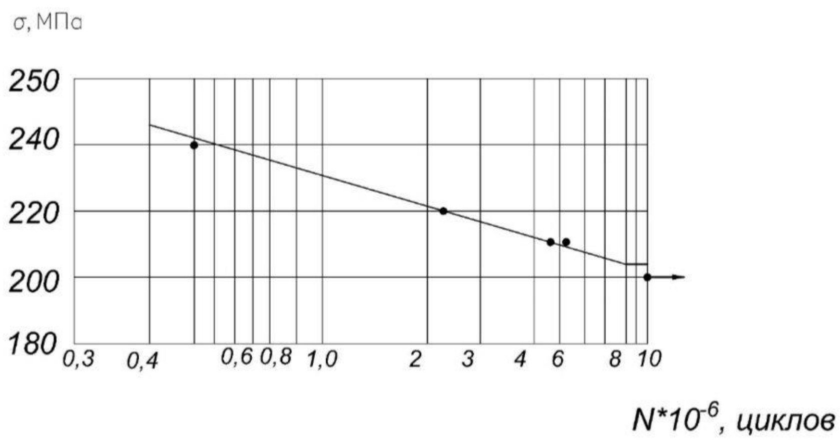
The occurrence of this defect is prevented by ensuring such cooling rates of the near-seam zone at which diffusion processes are suppressed [3].

The positive test results obtained allow us to recommend ПП-Нп-08Х16Б flux-cored wire for the restoration of parts operating under cyclic loading conditions. It can also be used for surfacing a sublayer, on top of which metal with increased corrosion resistance is deposited.

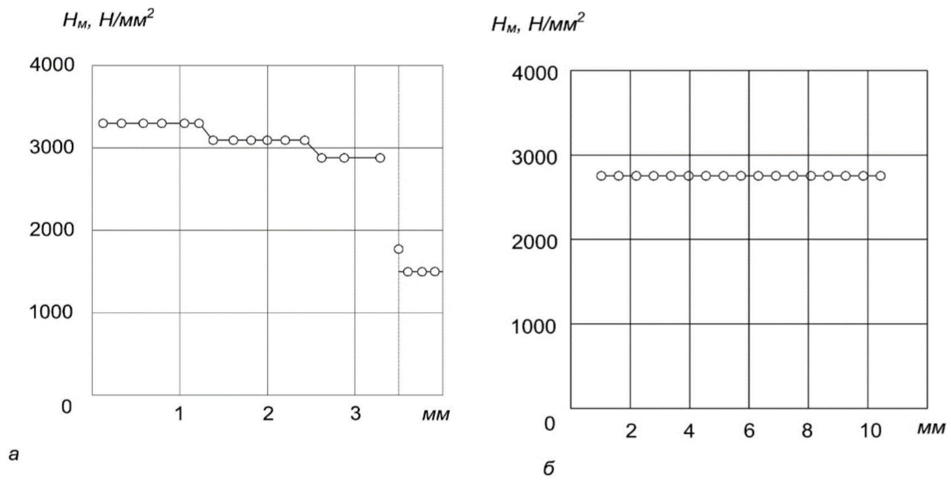
The cyclic durability of samples deposited with flux-cored wire using АН-26П flux was studied in the following mode: $I_{св}$ =170... 180A, $U_{д}$ =24...26 V, $\upsilon_{н}$ =0.4 см/с, $\upsilon_{п.пр}$ = 66.5 м/ч, surfacing pitch 8...10 мм. The thickness of the deposited layer is 3 мм.

The structure of the deposited metal is fine-grained and is represented by metastable austenite, martensite, sorbitol, bainite, ferrite and carbides (Fig. 4, a). The nature of metal destruction is viscous (Picture. 4, b).

The metal deposited with flux-cored wire ПП-Нп-09Х13Н4М2Г2С, has a composition that provides high resistance to the formation of hot cracks and resistance to the initiation and development of fatigue cracks.



Picture. 5. Fatigue curve of samples with a diameter of 70 mm, deposited with flux-cored wire ПП-Нп-09Х13Н4М2Г2С under АН-26П flux.



Picture. 6. Microhardness distribution of metal deposited with flux-cored wire ПП-Нп-09Х13Н4М2Г2С under АН-26П, flux, perpendicular (a) and along (b) the fusion boundary

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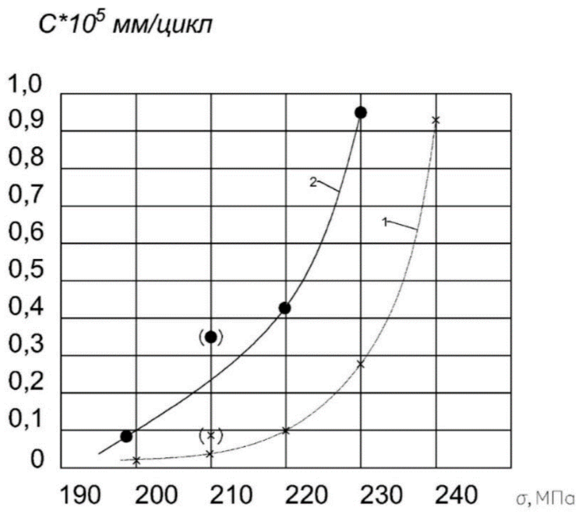
It has been established that the ratio of manganese and silicon in the deposited metal should be no less than 1.5. Silicon content above 1.2% reduces the resistance to hot cracking.

Fatigue tests (Picture. 5) showed that the endurance limits of the deposited and base metal (σ-1 ═ 200МПа). The spread of test results is small (correlation coefficient r ─ 0.98), which confirms the high chemical and mechanical homogeneity of the deposited metal and the absence of hot cracks and other defects in it.

On the microhardness change curve, no peaks or "dip" in hardness were observed on the side of the base metal, which indicates the absence of a ferrite layer in the deposited metal (Picture. 6). Despite the high chromium content in the deposited metal, the diffusion of alloying elements at the fusion boundary is not detected.

Fatigue tests were also carried out on samples deposited with flux-cored wire ПП-Нп-07Х12Н3М2Г2С.

Tests have shown that the deposited metal in this case has a higher fatigue resistance than metal deposited with ПП-Нп-09Х13Н4М2Г2С. wire. Even if there are defects such as slag inclusions at the fusion boundary, the fatigue resistance of the product does not decrease; the endurance limit reaches 220 МПа, which is higher than that of the base metal.



Picture. 7. Change in the rate of development of a fatigue crack in the base metal (1) and metal deposited with ПП-Нп-07Х12Н3М2Г2С wire under АН-26П submerged arc (2); sample with defects such as slag inclusions

CONCLUSION

The rate of propagation of a fatigue crack in the deposited metal is significantly lower than in the base metal (Picture. 7). This confirms the high resistance of the deposited metal to the propagation of fatigue cracks, which originate in the heat-affected zone and propagate both in the deposited and in the base metal.

This allows us to recommend ПП-Нп-07Х12Н3М2Г2С wire for surfacing critical products operating under cyclic loading conditions, including ship propeller shafts, stocks, rudder pins, etc.

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