MODIFICATION OF MEDIUM-CHROMIUM DEPOSITED METAL

K.K. STEPNOV, V.N. MATVIENKO and **A.I. OLDAKOVSKY**
Priazovsky State Technical University, Mariupol, Ukraine

Investigation results of influence of rare-earth metals on structure and properties of medium-chromium deposits were presented. It is shown that effect of the rare-earth metal additives appears in increase of technological strength, impact toughness and resistance to thermal fatigue failure of metal used for hardfacing of rollers of hot rolling.

Keywords: *arc hardfacing, ceramic flux, rare-earth metals, deposited metal, technological strength, impact toughness, specific fracture work*

Life time of the hardfaced parts, which suffer from dynamic and thermo-cyclic loading in a process of operation, significantly depends on resistance to nucleation and propagation of the technological and service cracks. This in full refers to deposited metal of Kh5MF and Kh12MF type applied for repair of forming rolls and rollers of machines for continuous casting of billets. Structure of such a metal, mechanical properties as well as functional characteristics in many respects depend on content of carbon in it. An increase of the latter in deposited metal of Kh5MF steel type raises hardness and resistance to wear due to metal-to-metal friction (Figure 1). At the same time, a possibility of hot crack formation increases since critical rate of deformation A_{cr} reduces in a process of weld solidification. If high-tempered martensite is formed in the metal structure at carbon content up to 0.25 wt.% and impact toughness makes not less than 0.30 MJ/m^3, than structure of Kh5MF type deposit, in which carbon content is more than 0.25 wt.%, is characterized by presence of acicular martensite, reduced grain-boundary strength and increased embrittlement. Presence of twinned (laminar) martensite [1] is observed together with lath (packet) martensite in structure of Kh5MF deposited metal with 0.33–0.35 wt.% C. Failure of the deposit occurs on micromechanism of intercrystalline chip at dynamic loading. This explains its low (less than 0.15 MJ/m^2) impact toughness. Along with it, resistance to fatigue crack propagation is reduced that, approximately, is evaluated by value of specific fracture work A_f (Figure 2, *a*).

Introduction of the rare-earth metals (REM) in the deposited metal allows increasing technological strength and crack resistance. This effect is obtained due to binding of sulfur in the refractory fine compounds, eliminating of lamination during its distribution, reducing of microchemical inhomogeneity and refining of austenite grain [2, 3]. At that, weld metal contamination by non-metallic inclusions are also reduced. Number of inclusions rises insignificantly in the metal deposited using ceramic flux of ZhSN type, containing cerium fluoride, however, intensive increase of their dispersion (Table) is observed and shape is changed to globular one.

The critical rate of deformation A_{cr} rises with increase of cerium content in the flux (and in deposit) due to refining and modification at hardfacing by Sv-08A as well as PP-Np-30KhGSA wires (Figure 3). As

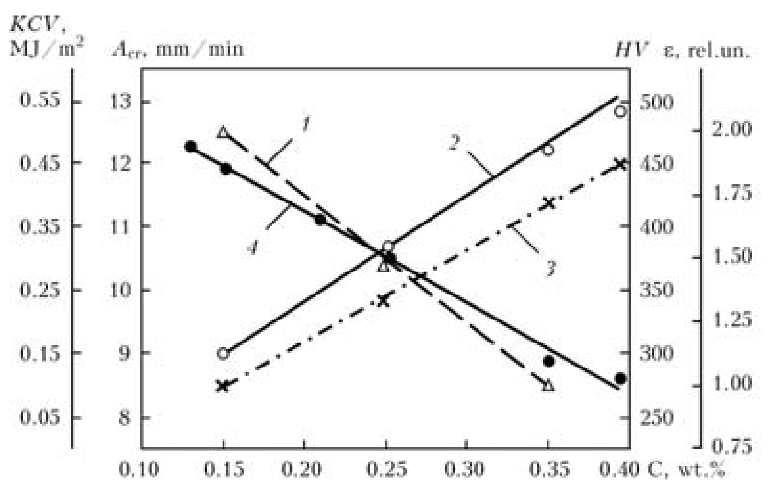

Figure 1. Influence of carbon content on critical deformation rate A_{cr} (*1*), hardness *HV* (*2*), wear resistance ε (*3*) and impact toughness *KCV* (*4*) of deposited metal of Kh5MF type

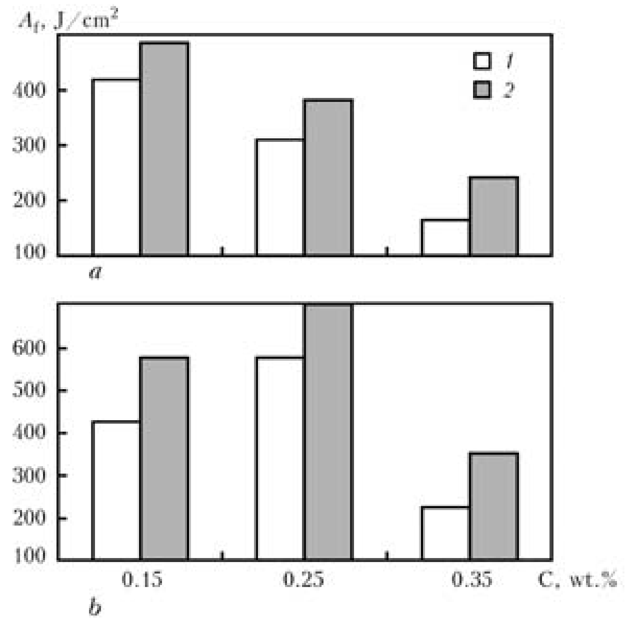

Figure 2. Influence of carbon and cerium content on specific fracture work A_f of deposited metal of Kh5MF (*a*) and Kh12MF (*b*) type without (*1*) and with (*2*) cerium

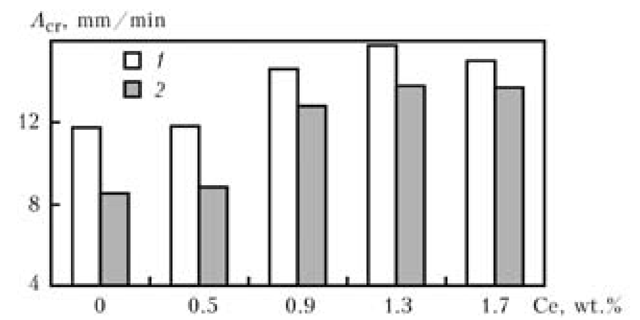

Figure 3. Dependence of critical deformation rate on cerium content in ceramic flux of ZHSN type in hardfacing with Sv-08A (*1*) and PP-Np-30KhGSA (*2*) type

can be seen from the Figure, A_{cr} rises only up to obtaining of optimum cerium fraction in the flux and in the deposited metal, respectively. Impact toughness of 20Kh6GMFS metal increases from 0.40 to 0.54 MJ/m^2 at optimum cerium content (0.008–0.009 wt.%). The level of metal contamination by non-metallic inclusions (see the Table) rises at further (above optimum one) increase of its content. Value of the critical rate of deformation A_{cr} reduces at that.

The specific fracture work of Kh12MF deposited metal is influenced by carbon content in contrast to

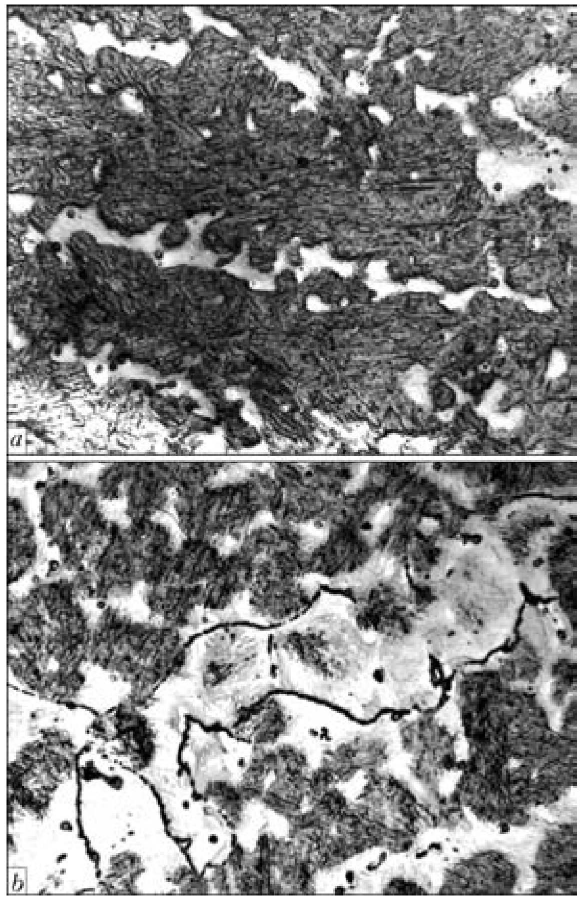

Figure 4. Microstructures (×500) of deposited metal 35Kh8GSMF (*a*) and 34Kh8GSMF with REM (*b*)

Kh5MF steel deposit. This dependence becomes maximum at carbon content of 0.25 wt.% (see Figure 2, *b*). Structure of such a metal contains martensite and ferrite-carbide mixture, that increases the resistance to fatigue failure owing to crack arrest near the interface of martensite with more ductile ferrite. The A_{cr} values rapidly reduce at further increase of carbon content due to low crack resistance of high-carbon martensite. Add of cerium in the composition of deposited Kh12MF steel increases its failure resistance in all range of carbon content.

It is a tendency to improve the properties of surface (wear-resistant) layer for increasing a life time of the hardfaced part.

However, working capacity of the part in many respects depends on composition of a sublayer, its

Amount of non-metallic inclusions per 1 mm^2 in Ce-contained 20Kh6GMFS deposited metal

Ce, wt.%	NMI volume fraction, %	Size of NMI, μm					
		1.0–1.5	1.5–2.0	2.0–2.5	2.5–3.0	3.0–5.0	<5.0
0	0.217	682	113	110	3	7	49
0.005	0.288	816	138	49	5	7	2
0.008	0.279	887	209	77	18	12	3
0.011	0.274	830	125	46	9	7	0
0.015	0.339	1116	302	105	24	16	2

plasticity [4], reliability of fusion with the base metal as well as formation of hot and cold cracks in it. The hot cracks appearing in the process of sublayer hardfacing can provoke formation of failure of chip type during rollers' operation.

The wires containing REM are used for hardfacing of the sublayer of electrode materials with increased resistance to hot crack formation, however, their choice is limited by using of Sv-15GSTYuTsA and Sv-20GSTYuA ones.

Composite low-alloyed metal of 0.18–0.26 C, up to 1.5 Cr, 0.75–1.05 Mn, 0.55–0.75 Si, ≤0.025 S, ≤0.025 P and 0.020–0.058 wt.% of REM was investigated for evaluation of the possibility of its application as a sublayer obtained by hardfacing with flux-cored wire and flux. High technological strength and crack resistance of metal with 0.18–0.20 % C and 0.040–0.045 wt.% of REM allows recommending PP-Np-26Kh1G1S flux-cored wire for hardfacing of the sublayer during forming rolls repair.

Along with it, application of PP-26Kh1G1S flux-cored wire with 0.25–0.26 wt.% C and 0.047–0.052 % of REM for hardfacing with ceramic flux ZhSN-5 allows obtaining of wear-resistant layer with the structure more favorable in comparison with obtained with PP-Np-30KhGSA wire.

In both cases, the metal has martensite-ferrite structure with well-defined dendrite pattern (Figure 4). At the same time, crystals of the tempered martensite become more dispersed (Figure 4, *b*) due to REM addition, besides, the fraction of martinsite component increases, that determines high hardness *HV* 450 and sufficient plasticity of deposited metal.

Such a metal differs by higher technological strength and resistance to thermal fatigue fracture: deposit of 35Kh8GSMF type has relative strength index 1.0 at average 230–380 number of thermal cycles up to crack appearance, and deposited 34Kh8GSMF metal with REM has, respectively, index 1.3–1.4 at 370–490 cycles at average.

Thus, addition of REM in the composition of Kh5MF and Kh12MF deposits applied for repair of forming rolls and rollers of machines for continuous billet casting increases its technological strength, impact toughness, resistance to thermal fatigue fracture and specific fracture work.

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EFFECT OF MANGANESE ON STRUCTURE AND WEAR RESISTANCE OF DEPOSITED METAL OF THE LOW-CARBON STEEL TYPE

V.L. MALINOV
Priazovsky State Technical University, Mariupol, Ukraine

Investigation results are presented on structure and wear resistance of metal deposited by using flux-cored strips and having chemical composition of the low-carbon steel type with differing manganese content. The possibility of improving wear resistance of the deposited metal due to subsequent heat and thermochemical treatments is studied. It is shown that achievement of the optimal amount of meta-stable austenite in structure leads to improvement of wear resistance of the deposited metal.

Keywords: *arc cladding, flux-cored strips, deposited metal, structure, martensite, austenite, bainite, strengthening, tempering, case-hardening*

Peculiarities of commercial application of consumables providing formation of meta-stable austenite in the deposited metal and characterised by dynamic deformation martensitic transformation (DDMT) are described in study [1]. Also, it is noted in that study that inadequate attention is given now to development of such consumables. Known austenitic cladding consumables of the 110G13L steel type, containing an increased amount of manganese and carbon, as well as chrome-manganese consumables of the PP-Np-25Kh10G10T type are insufficiently practicable, as metal deposited with them is hard to process by machining [2]. In a number of cases expensive alloying elements are used in such consumables. Therefore, the problem of development of sparsely alloyed cladding consumables is still topical. This problem can be addressed by providing the multi-phase structure in the deposited metal, where austenite is present along with other components (martensite, carbides, carbonitrides, etc.), rather than the austenitic one. For this it is important to have the meta-stable structure that is self-transformable under loading and characterised