MOLTEN METAL PHASE DURATION EFFECT ON THE STRUCTURE AND HARDNESS OF HIGH-CARBON FUSED COATING

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Abstract: *The duration of the molten metal phase in the process of crystallization is an important factor determining the structure of the fused high-carbon coating. The analysis has shown that the duration of the liquid metal phase in a welding bath is a function of the arc travel speed. As the arc travel speed increases, the heat input into the part in question becomes insufficient for a significant temperature rise within the phase transformation area. This results in a reduced molten metal crystallization time and fast generation of the deposited pad, thus creating an alloyed white iron-structured gradient coating. Based on the results achieved and on the curves of relationship of microhardness vs. depth of the deposited layer, we can see that the deposited layer has the maximum hardness at the distance of 1 mm to 1.5 mm from the surface.*

Keywords: *high-carbon, durability, crystallization, coating, structures*

The main part

The fused metal cooling rate is an important factor determining the structure of the fused high-carbon coating and, primarily, the carbide sizing. The paper "[4]" shows that changing of the carbide sizing at the expense of variable crystallization rate produces a major effect on the cast iron durability.

It is common knowledge that changing of the fusing rate affects the duration of the molten metal phase and changes the duration of the molten metal crystallization.

$$T_{amp}=L/F_{uss} , \quad (1)$$

Where:
L - stands for a welding bath length;
F_{uss} - stands for a fusing rate.

We have studied the effect of the molten metal phase duration (t_{amp}= 0.8; 1; 1.2; 2; 3; 5 s.) on the structure and hardness of high-carbon fused coating. The fusing mode parameters were set at the level of U=28 B, V=104 m/hourr, d_e=1.4 mm. We altered only the fusing rate from 11 to 26 m/hourr whereby changing the molten metal phase duration, as calculated according to Formula 1 shown above.

For our fused coating study, we made 6 sets of samples, 10 mm thick, 50 mm wide and 90 mm long, of 45-grade steel. Each set consisted of 3 samples.

Coating on each set of samples was deposited while decreasing the welding arc travel speed for each set of samples thus increasing the molten metal phase duration. The high-carbon layer was created by way of combined use of Нп 30ХГСА welding wire and UUT-2 carbon fabric of 250 g/m^2 density. The coating was applied with the use an UD-209M protective-gas-environment-fusing plant.

Evaluation of the sample temperature field in the process and after the process of fusing high-carbon coating on the sample surface was made by way of temperature measurements and mathematical simulation in the preset points.

The most dramatic structural changes occur in the temperature field areas located within and nearby the fusion zone.

Practical assessment of the instant temperature in the segment of the part contacting the fusion zone is a task which is hardly feasible and even quite unfeasible, sometimes. So, it makes sense to use computer-aided simulation of the thermal processes relating to the high-carbon coating fusion process, while applying the finite-element method with the use of customized software. Figure 1 shows the plate with the temperature field, which is ascertained by means of calculations with the use of computer-aided simulation, for the sample, fused at the rate of 17 m/hourr (the molten metal phase duration $t_l = 2s$).

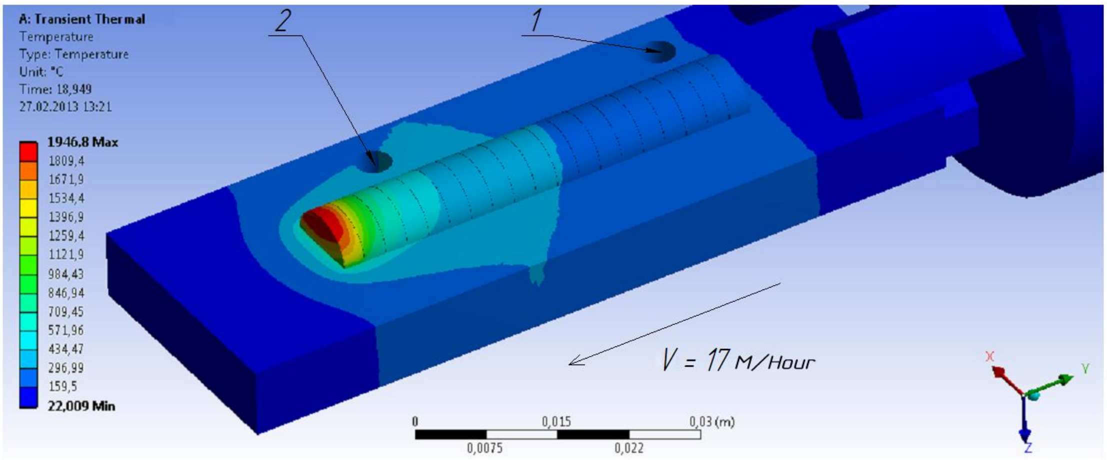


Figure 1: *Plate Temperature Field during Fusion*

The adequacy of the simulation results was proved by way of comparison of the part temperature field simulation results with measured temperature in the preset points of the part which are adjacent to the fusion zone (coating application zone). Measurements were taken both in the course of fusing and throughout the whole sample cooling period.

Juxtaposition of the simulation and measurement results '**Figure 2**' shows that the deviation does not exceed 15%. A minor time deviation can be explained by the fact that in the process of measurement we use chromel-alumel thermocouples with a lag-effect of 5 to 6 sec., as well as copper bushing used to secure the thermocouples. It is a matter of fact that the bushings have the thermophysical properties which differ from those of steel, so we observe a total time shift within 10 to 20 sec.

Therefore, the model suggested proves to be adequate, for it allows to determine temperature in any point of the sample body both in the course fusing of its coating and during its cooling period. Moreover, the results of the simulation can be used to investigate into the fused coating structure formation processes.

Figure 2 shows the correlation diagrams of temperature distribution in the sample preset points at different points of time of the molten metal phase duration. Curves 1 and 4 of the diagrams represent the temperature assessment results in points 1 and 2 '**Figure 1**', respectively, while curves 2 and 3 show the simulation results in the same points.

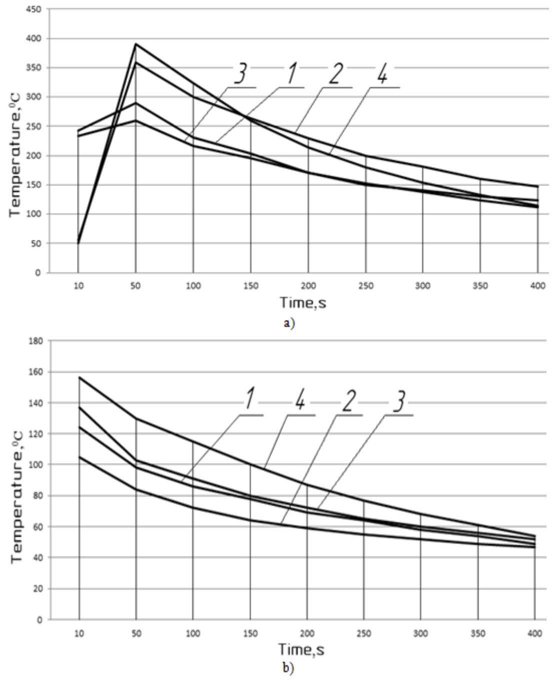


Figure 2: *Temperature Variations in Sample Preset Points in the Course of Fusing and Cooling:*
a) tamp= 5 s; b) tamp= 1 s.

The samples were cut out into templates and sliced with the use of an electric (spark) erosion machine. To study the structure of the same, we used a optical microscope with subsequent photographing. See the place where the fused metal structures were studied in '**Figure 3**'.

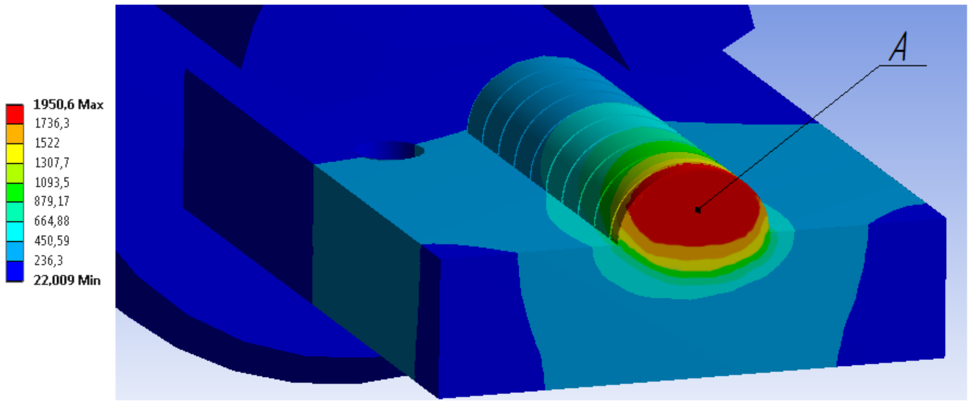


Figure 3: *Temperature Distribution and Structure Study Location.*

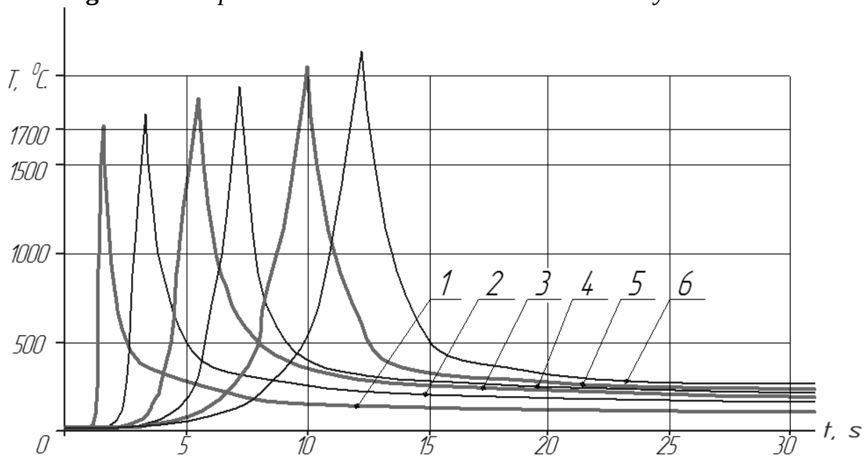


Figure 4: *Temperature Distribution Comparison in Sample Structure Study Location (A):*
1- t_l = 0.8 s; 2- t_l = 1 s; 3- t_l = 1.2 s; 4- t_l = 2 s; 5- t_l = 3 s; 6 – t_l = 5 s;

Analysis of '**Figure 4**' graph shows that the duration of the molten metal phase is a function of fusing rate. As a result, the cooling and crystallization rate varies, thus generating multi-structured coating.

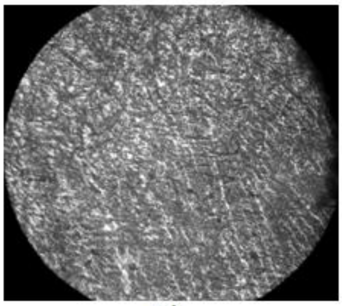
Decreasing the arc travel speed increases the temperature within the zone around the molten metal area and in the molten metal area itself '**Figure 2** and **Figure 4**' thus reducing the melting time of the carbon material which is added to the melt.

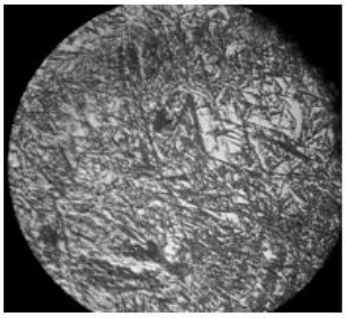
When the molten metal phase exists for 5 s, homogeneous fine martensite (Hµ 960) is formed '**Figure 5a**' "[2]".

When the molten metal phase duration is reduced to 3 s., coarse acicular martensite is formed '**Figure 5 b**'.

The martensite base material offers the best resistance to shock-free abrasion wear.

As the molten metal phase duration decreases to 1.2 … 0.8 s., the heat input into the part in question becomes insufficient for a significant temperature rise within the phase transformation area '**Figure 4**'. This results in a reduced molten metal crystallization time and fast generation of the deposited pad, thus creating an alloyed white iron-structured coating (ledeburite, cementite, carbides) '**Figure 5 c, d, e, f**'.


a)


b)

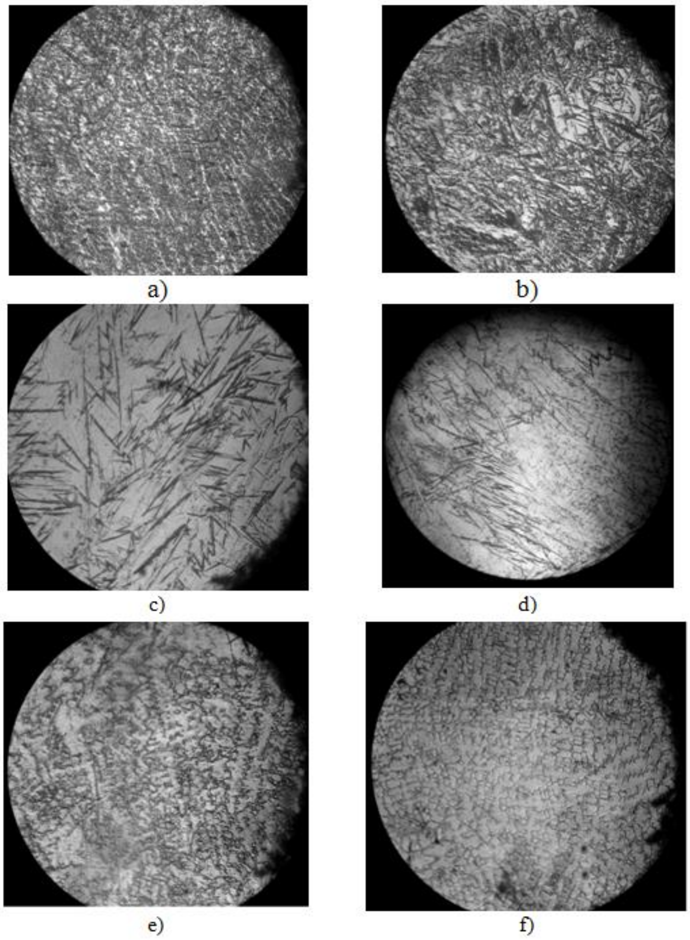


Figure 5: *High-Carbon Fused Coating Microstructure (x150):*
a) sample 1(t_l =5 s); b) sample 2 (t_l =3 s); c) sample 3 (t_l =2 s); d) sample 4 (t_l =1.2 s);
e) sample 5 (t_l =1 s); f) sample 6 (t_l =0.8 s).

To determine the qualitative indices, the hardness parameters have been defined. See the Rockwell hardness testing results graphed below '**Figure 6**'.

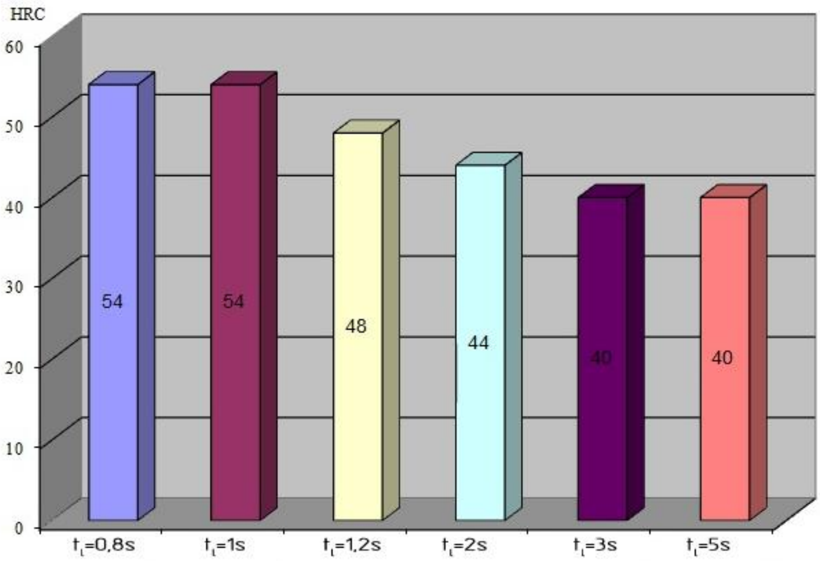


Figure 6: *Hardness of Fused Samples*

Summary

The results of the study demonstrate that in the course of fusing with a reduced molten metal phase time the deposited high-carbon coating becomes hard.

The changes in the structure of each sample, and, therefore, in their hardness turned out to be quite sizeable.

Finite element simulation of coating fusion processes makes it possible to assess, with due accuracy (accuracy error less than 15 %), the temperature in the part arbitrary points and to foresee any phase transformations in the substrate material and in the coating material.

References

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