Part
3

TECHNOLOGICAL PROCESSES AND MATERIALS

A. A. Bezrukih, R. A. Meister
Siberian Federal University, Russia, Krasnoyarsk

M. A. Lubnin, S. A. Gotovko
Siberian State Aerospace University named after academician M. F. Reshetnev,
Russia, Krasnoyarsk

INVESTIGATION OF SURFACING TECHNOLOGICAL OPPORTUNITIES BY THE INDIRECT THREE-PHASE ARC WITH CONSUMABLE ELECTRODES

This paper is devoted to the high-effective process of surfacing by the indirect three-phase arc with covered electrodes. The share of the parent metal in the surfaced one does not exceed 10 % which is infeasible for one-arc surfacing.

Keywords: surfacing, indirect three-phase arc, consumable electrodes.

Operating conditions of technical systems, including the space machinery, require manufacturing of units and parts with specific properties of working surfaces, such as: heat resistance and thermal stability, wear resistance, corrosion resistance, etc. Thus, economical use of expensive materials is necessary. The problem is solved by using surfacing processes. However, widespread one-arc method of surfacing with consumable electrodes has grave disadvantages such as low productivity and necessity of coating with four or five layers for required structure of surfaced metal.

Application of alternating current in surfacing processes allows using simple and cheap power supplies that have higher efficiency in comparison with rectifiers. The alternating current arc doesn't have such a disadvantage as magnetic blowout. Therefore, using welding transformers, especially-three-phase ones, is rather perspective in surfacing processes.

Three-phase arc has the following advantages: high efficiency of the process reached due to simultaneous melting of three electrodes at once; considerable decrease of fusion penetration in the absence of current in part being surfaced; intensive stirring of molten metal in the pool providing homogeneous structure of rollers. The distinguishing feature of the method is the following: the product being surfaced is not included in a circuit, the three-phase arc is located between three cores, i. e. three one-phase arcs are simultaneously on fire in one general torch, mutually influencing each other and electrodes. Such interaction considerably increases productivity of surfacing operations, reduces the specific consumption of the electric power and strengthens ionization of arc space. Thus, the fusion penetration of the parent metal considerably decreases in comparison with one-phase surfacing processes. It occurs only due to the thermal influence of three-phase arc and molten electrode metal. As a result of 1,6–3,0 mm diameter electrode manufacturing, it is possible to reduce the weight of electrode holders and current-carrying wires for three-phase arc processes that has solved a problem of the method realization [1].

However, in references there is no practically information about application of surfacing by indirect three-phase arc with three electrodes. As a result, investigations have been carried out on three-phase surfacing with consumable electrodes for the purpose of roller formation with the minimum share of the parent metal in the surfaced one by optimization of process parameters.

For the experiments with three-phase processes, a special plant with TSHS-1000-3 transformer has been assembled. The surfacing scheme is presented in fig. 1. Dropping characteristic was provided with single throttles with ring magnetic conductors. It gives the chance to regulate and equalize current in each phase that provides uniformity of burning-off.

The following demands, besides standard ones, are made of electrode covering for surfacing by three-phase arc: electroconductivity and slag viscosity. Their violation may cause short circuits between cores on the inetrelectrode covering layer, complicating a process schedule. Electrodes with three cores in general coating are not produced in industry. They are assembled in laboratory environment from normal 1.6–3 mm diameter electrodes of MP-3, O3C-12 marks, etc. Bundle manufacturing includes coating of the cores tied up by threads with silicate glue, after its drying they are fastened through equal intervals with a thin wire and are dried at 200 °C [2]. Conglutination prevents a divergence of electrodes at bundle burning. The identical distance *I* between cores (fig. 1) provides them with equal electric parameters of modes; that promotes their uniform melting. Assembled bundle was fixed in a simple electrode holder with three mutually isolated copper plates.

The initiation of the indirect arc is carried out by contact of the product with three electrodes while connecting a neutral main to the product. After initiation of the arc and the part warming up, the neutral main is disconnected from the part. It is impossible to turn off the arcs without power cutting; it is a disadvantage of the process. Unlike one-arc welding it is impossible to change arc voltage during surfacing process in this case. Voltage on the arcs depends on the distance between electrodes and the thickness of their covering.

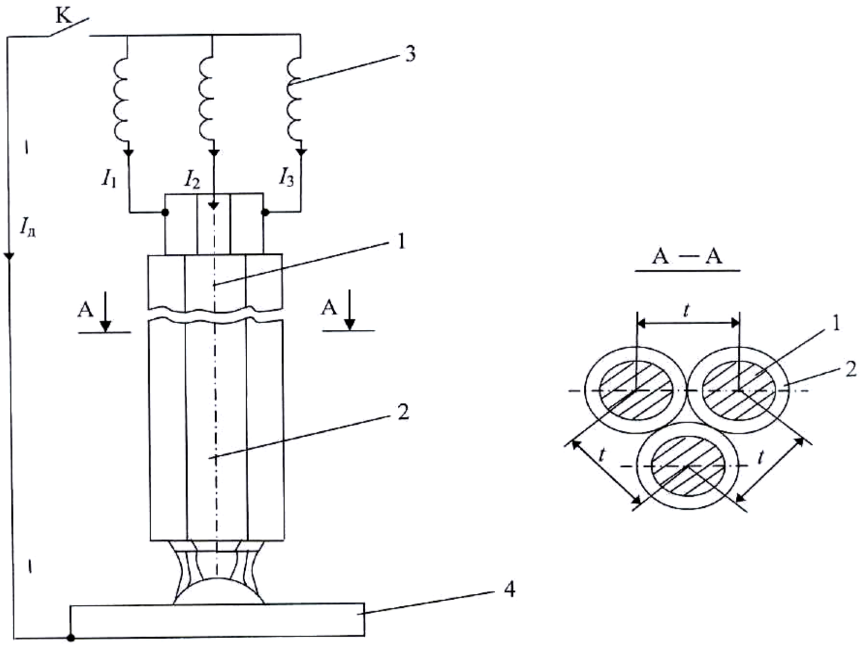


Fig. 1. Scheme of surfacing by indirect three-phase arc:
1 – electrode core; *2* – coating on electrode; *3* – secondary windings of three-phase transformer; *4* – part; I_1, I_2, I_3 – currents in electrodes; $I_д$ – current in neutral main; *K* – contact of neutral main switching off; *l* – distance between electrodes

The most important indices of independent three-phase arc burning stability include simultaneous initiation of three arcs, uniformity of three electrodes melting, burning and spitting losses, stability on fusion penetration depth and roller formation, distance from an independent three-phase arc to the part, absence of three electrodes meltback during breaks in arc burning [3].

Surfacing factor $Q_н$ (g/(A·h)) in experiments was defined as follows:

$$Q_н = G_н \cdot 3600/(3 \cdot I \cdot t),$$

where $Q_н$ – surfaced metal mass, g; t – time of arc burning, s; I – linear current in electrodes, A ($I_1 = I_2 = I_3$).

Percent of burning and spitting losses – ψ was defined according to the formula:

$$\psi = G_{бр}/ G_н \cdot 100 \ \%,$$

where $G_{бр}$ – spark mass, g.

Surfacing was made on scraped bright to metallic luster plates of low-carbon steel of 3–5 mm thickness at following parameters: $I_3 = 55–60$ A; $U_д = 30–32$ B; $U_{xx} = 80$. Metal deposit factor was 6.23–6.37 g/(a·hour), burning and spitting losses – 15–10 %. Thus, efficiency of this process is higher, than at single-phase surfacing as energy is consumed only for electrode bundle melting.

The difference between traditional one-arc process and surfacing by indirect three-phase arc is in considerably greater productivity. It is provided with simultaneous burning of three electrodes at once. Moreover, according to the experiments, on identical current modes three electrodes at surfacing by indirect three-phase arc are melt 20 % faster, than one electrode at usual one-arc surfacing. High efficiency is provided also due to the parent metal fusion penetration reduction. At surfacing with one electrode, the value of parent metal share in surfaced one usually is 30–40 %. As a result, most of the surfacing metal penetrates the parent one, and pure surfaced metal may be provided only in 4th or 5th layer. During surfacing using the method being investigated, samples with share of parent metal in surfaced one less than 10 % have been obtained.

After surfacing samples with rollers were cut across, polished with subsequent etching in the 30 % solution of nitric acid for meltback limit revealing. The share of parent metal in surfaced one was defined by means of digital pictures under the following formula:

$$\lambda = F_{пр}/F_п,$$

where $F_{пр}$ – fusion area of the parent metal; $F_п$ – total cross-section area of the roller (fig. 2).

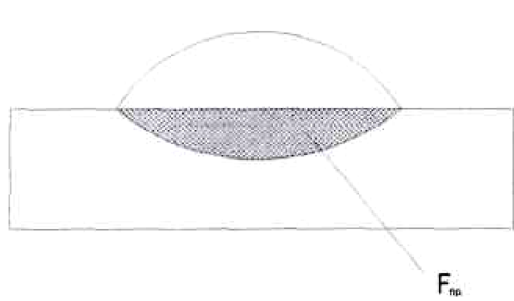


Fig. 2. Cross-section area of the roller

It is established that fusion penetration of the parent metal is minimal; the share of the parent metal in surfaced one has reached 10 %. It is obvious, that the method of three-phase surfacing by indirect arc allows solving a problem of parent metal fusion penetration. Producing of pure surfaced metal without impurities of parent metal is possible from the first or the second layers that is inaccessible with standard one-arc methods of surfacing. It is revealed, that current increasing considerably improves weld forming, initiation of arc, and stability of its burning. However, fusion penetration increases from 2–7 to 8–10 %.

Surfacing on simple steel with electrodes of austenitic class has shown also good results. 2.5 mm diameter electrodes ОК 61,30 of ESAB were used for surfacing. Minimal fusion penetration of parent metal has been obtained at the following modes: $I_{эл}$ = 50 A, $U_{л}$ = 32–34 B, U_{xx} = 75 B. The share of the parent metal in the surfaced one does not exceed 5 % (fig. 3).

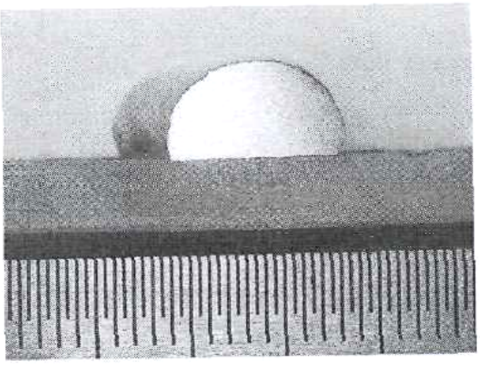


Fig. 3. Outward appearance of the sample surfaced with electrodes of austenitic class in cross-section

Micro section metallographic specimens are made from surfacing samples with electrodes MP-3 for microstructure character revealing (fig. 4). Reagent of the following composition was used for micro section metallographic specimen etching by means of rubbing in: HCl – 60 cm^3, $CuSO_4$ – 12 g, H_2O – 60 cm^3. Examination was carried out using МЕТАМ ЛВ-31 microscope with × 50 and × 100 magnification.

The micro section analysis has revealed the structure lamination of the surfaced roller (fig. 5), relating probably to the specific character of the electrode bundle. The dendrite structure typical for melting processes is well visualized. The boundary between the parent metal and the surfaced one is distinguished.

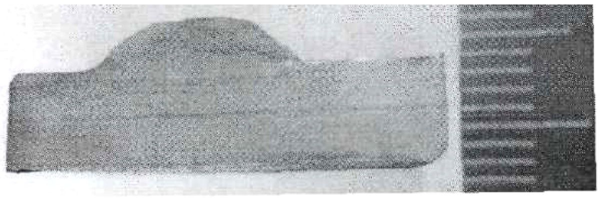


Fig. 4. Cross-section of the roller surfaced with 2 mm diameter MP-3 electrodes

The transitional area (fig. 6), from which a growth of columnar crystallite blocks begins, consists of the parent metal and the surfaced one. Heat-affected zone has a coarse-grained structure, as a result of overheating of the parent metal during surfacing. It is evidence of high efficiency of thermal source. Overcoming coarse-grained structure of the parent metal near meltback boundary is possible by forced cooling of a part back side with running water, by means of surfacing speed increasing, and the subsequent thermal processing (normalization).

Conclusions

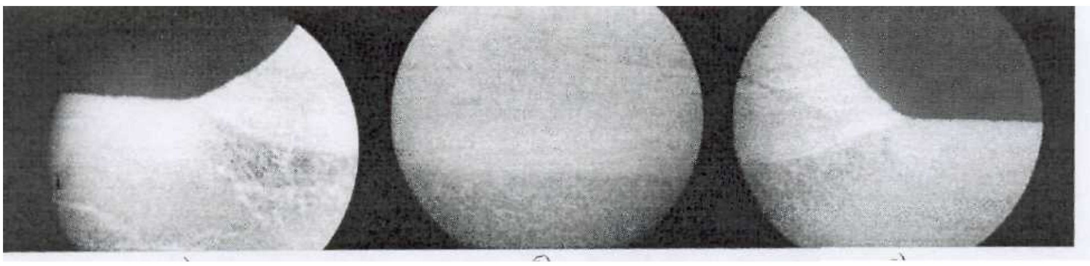
– the minimum current of steady-state combustion of indirect three-phase arc for 2 mm diameter electrodes is 55 A. At reduced values the initiation of the arc becomes difficult;

– the optimal interval of currents is 60–70 A. Exceeding these values causes excessive depth of the parent metal fusion penetration;

– one has obtained samples of surfacing by indirect three-phase arc in which the share of the parent metal in surfaced one is less than 10 %.

High efficiency of surfacing technological process by indirect three-phase arc with covered electrodes is confirmed.

Surfaced roller lamination, related to electrode bundle, and dendrite structure are revealed by metallographic method. The boundary between the parent metal and the surfaced one is distinguished, it relates, probably, to reduced influence of indirect arc on the parent metal.



a *b* *c*

Fig. 5. General view of microstructure in surfaced metal zone (x 50):
a, *c* – roller edges; *b* – the middle

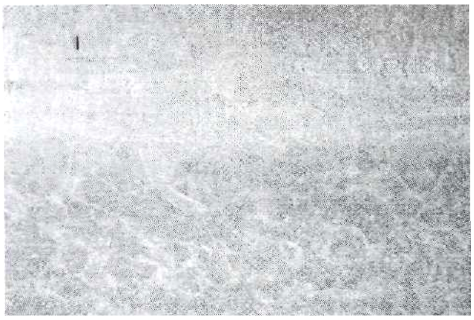


Fig. 6. Transitional area, × 100

References

1. Михайлов Г. П. Сварка трехфазной дугой. М. : Машгиз, 1956.
2. Мейстер Р. А., Падар В. А., Безруких А. А. Наплавка трехфазной дугой плавящимися электродами // Машиностроение: сб. науч. тр. / отв. ред. Е. Г. Синенко. Красноярск : СФУ, 2007. С. 30–34.
3. Мейстер Р. А., Мейстер А. Р., Безруких А. А. Многодуговая наплавка покрытыми электродами // Сварочное производство. 2008. № 8. С. 21–23.

N. V. Morozov, V. P. Karasev
Siberian State Aerospace University named after academician M. F. Reshetnev,
Russia, Krasnoyarsk

STEAM TURBINES WITH A LOW-BOILING WORKING AGENT

The subject of the article is the assembly of a steam-generator plant with a natural working agent. A method of calculation for steam turbines with a low-boiling working agent is offered, which accounts for the correlation between the adiabatic curve indication, pressure and temperature in the overheated vapor area.

Keywords: steam turbine, Freon, adiabatic curve indicator, low-grade heat, coolant.

Nowadays the problems of electric power production are becoming more and more essential. This is the result of the rising cost of energy sources (oil, gas, coal) and consequently their consumer prices are growing.

In the routine work of industrial enterprises (using various heat-carrying agents) a great amount of heat which could be used in some other production cycles is dumped and lost. These heat-carrying agents can vary from slightly warm sewage water with low temperatures to coal coking gases with the temperature up to four hundred degrees (Celsius). Other sources of heat can come from all kinds of plants and systems that dump heat in their working cycle. Some of these sources and their temperatures are listed in the table.

Heat-carrying agents

Heat-carrying agents	Temperature, °C
Sewage water	15–19
Industrial gases flow	250–300
Heating equipment temperature	30–100
Coal coking gas temperature	400–430
TV3-117 engine oil	80–150
VR-14 reductor oil	70–80

Thermal power could be accumulated by means of thermal pumps. But thermal pumps cannot convert heat into other kinds of energy. And it is desirable to get from this heat the power that is easy to be transmitted for long distances, i. e. electric power.

Rather low temperature of most heat sources, their non-gaseous state, such as that of oil in helicopter systems, for example, as well as rather low pressure in gaseous sources do not allow direct application of their thermal energy. The energy is to be extracted by means of low-boiling working agents, such as in thermal pumps. After the heat is extracted from the source, its thermal energy is converted into mechanical energy by a rotodynamic machine-steam turbine.

Taking into consideration the ecological and economic requirements, the working circuit of the plant should be a closed system, i. e. the working agent is to be used many times over. As coolants are usually chemically active and dangerous compounds, this system permits to avoid environmental pollution by the direct ejection of the used coolant from the system. The possible harmful influence on human health is ten times less.

To put this closed system into practice it is necessary to install a component for circulation of the working agent inside the system. The component can be a pump (for the circulation of a liquid working agent) or a compressor (for the circulation of the agent in the form of overheated vapour). Unlike the pump, the compressor system doesn't require conversion of the working agent into liquid phase on its outlet from the turbine.

The installation (fig. 1) consists of the reservoir filled with a working agent, the pump, the evaporator, the turbo generator and the condenser. The coolant Freon R22 (the chlorinedifluoromethane) is considered as a working body. This Freon is the most suitable to the given system under its physical and chemical characteristics and it is widely used in the modern refrigerating equipment.

The system working cycle diagram shows four sections (fig. 2). The first section *1–2* shows the feeding of the working agent to the evaporator, thus increasing the Freon pressure in the system and slightly raising the temperature because of the losses in friction. The second section *2–3* shows the evaporation and overheating of the working agent in the evaporator at a constant pressure