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WAYS TO REDUCE THE INFLUENCE OF HIGH FREQUENCY CURRENTS ON THE HUMAN BODY UNDER INDUCTION SURFACING

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Summary. *Devices with thermal and electromagnetic shields for induction heating and surfacing of machine parts using a ferrite magnetic circuit with a single-turn inductor, devices with double-turn and three-turn inductors, in which the surfacing zone is completely closed from the influence on workers are designed. This allows to improve the working conditions, as well as to develop new technological processes using high frequency currents. It is shown that the use of thermal and electromagnetic screens can reduce the surfacing time by 10–20 s and decrease the energy consumption by 15–20%, depending on the powdered hard alloy, taking into account health and safety issues.*

Key words: *induction heating and surfacing, thermal and electromagnetic shields, thin disks, labour safety, devices.*

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Modern welding processes and related technologies use various welding equipment, applying of which is accompanied by releasing harmful aerosols and gases into the air, as well as emitting thermal and electromagnetic fields which are dangerous to human health [1–3].

Technological processes that use high-frequency currents (for example, 440 kHz and 66 kHz, etc.) have a particularly significant effect on workers in various economic fields in the manufacture and restoration of working surfaces of machine parts and mechanisms using induction surfacing, heat treatment, etc. [4–6].

The results of modern research [7, 8] indicate high biological activity of electromagnetic fields (EMF) in all frequency bands. In particular, high frequency EMFs lead to heating of body tissues. The most EMF-sensitive systems of the body are nervous, immune, endocrine, sexual.

The biological effect of EMF in the conditions of long-term action accumulates, as a result of which the development of long-term consequences of degenerative processes in the central nervous system, tumours, hormonal diseases is possible. Children, pregnant women, people with cardiovascular, hormonal, nervous and immune disorders are especially sensitive to electromagnetic fields.

Due to the action of EMF on the human body, the transmission of nerve impulses is disrupted. As a result, there are autonomic dysfunctions (neurasthenic and asthenic syndrome), complaints of weakness, irritability, fatigue, sleep disorders, the highest nervous activity is impaired – memory disruptions, stressability. Disorders of this system are manifested, as a rule, lability of pulse and blood pressure, hypotension predisposition,

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heartache. In the blood there is a moderate decrease in the number of leukocytes and erythrocytes. It is established that under the action of EMF immunogenesis suppressed.

In the welding industry, a number of devices and methods have been developed to protect workers from the effects of high-frequency currents [9–10], but they do not meet modern requirements for production, so to reduce their shortcomings, the new tools need to be developed.

For this purpose, the authors have developed a number of devices and mechanisms to protect workers from the effects of high frequency currents when surfacing thin steel disks, both solid and toothed, with powdered hard alloys.

Figure 1 (a, b) shows the scheme (a) and the device made of metal (b) for induction surfacing of thin solid-shaped disks using a ferrite magnetic conductor, where the surfacing zone is completely closed from exposure to heat and electromagnetic fields [11].

The device consists of the lower 1 and the upper 2 clamping plates (Fig. 1 a, b) single-coiled inductor 3 (Fig. 1a) and (Fig. 2), which is mounted in the lower plate 1 (Fig. 1) and (Fig. 3) together with the magnetic circuit 4 (Fig. 1) and (Fig. 3). Fig. 4 shows the lower clamping plate 1 with the disk 10.

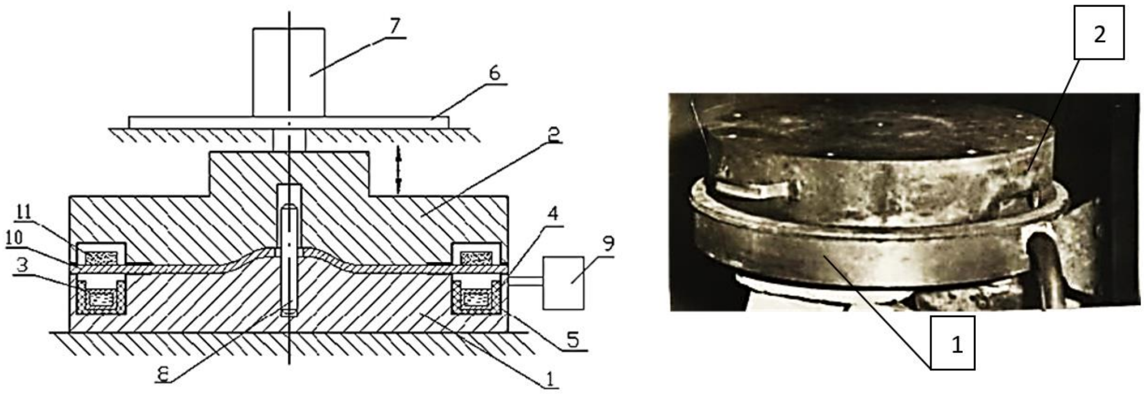


Figure 1. Device for surfacing disks using a ferrite magnetic circuit
(a – scheme, b – metal construction)

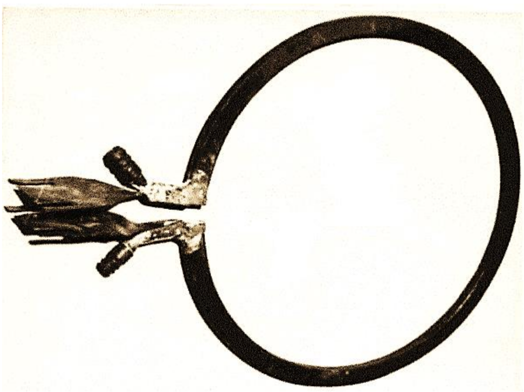


Figure 2. Single-coiled ring inductor

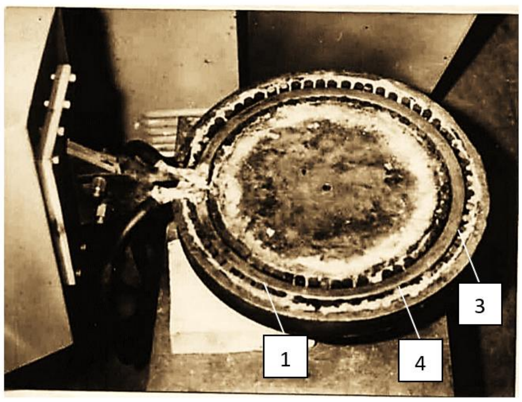


Figure 3. Lower clamping plate with ring inductor and ferrite magnetic circuit

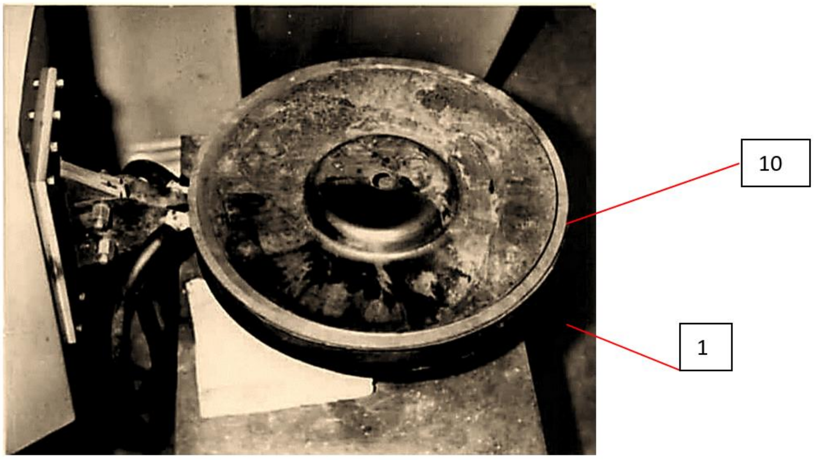


Figure 4. The design of a thin shaped solid disk: 1 – bottom plate; 10 – solid disk

Magnetic conductor 4 (Fig. 3) is made of U-shaped ferrites of 1000NMz type with maximum magnetic permeability μ_{MAX} = 2000. To eliminate the action of electromagnetic fields on the end clamping metal surfaces of plates, which is created by a single-coil ring inductor 3, end working surfaces were shielded with red copper 5 (Fig.1 a). To raise and lower the upper clamping plate 2, on the support 6 the pneumatic cylinder 7 was rigidly mounted (Fig. 1 a).

Fixation of pressure plates in the process of surfacing was performed using a guide 8, which is rigidly fixed to the lower plate 1 (Fig. 1 a). As a power source a tube generator 9 of VCHG-60/0,44 type was used. This design of the device reduces the dissipation of electromagnetic and thermal fields, which significantly reduces their impact on the performance of welder workers.

Thus, the obtained research results showed that the use of ferrite magnetic circuit reduces the surfacing time by 10 s and reduces energy consumption by 20% compared to the technology of surfacing without ferrite magnetic circuit.

Disk 10 was surfaced using a powdered hard alloy 11 (PG-C1) (Fig. 1 a), which was previously spilled on the surface of the disk with the appropriate width and thickness.

For reducing of dissipation of thermal and electromagnetic fields that affect workers, when surfacing, thin disks with solid work surface as well a device [12], which is shown in Fig. 5 was developed. It has the additional ring inductors for surfacing, built in the working surface of the table concentrically to the main inductor in order to heat the surface of the disk outside the surfacing zone. The power of each inductor is proportional to its diameter

The device works as follows. The disk 6 is mounted on a fixed table 1. After that, the surfacing charge11 is spilled on the part 6. The upper plate 10 under the action of the drive 12 mounted on the plate 13, moves down and is pressed to the top of the disk 6, which is fixed on the guide 2. The power source 9 is connected with flexible conductive hoses 7, through the switching unit 8 and voltage is applied to the inductors 3, 4, 5. This is followed by surfacing, with simultaneous heating along the entire periphery and width of the surfaced and non-surfaced area. The part is heated by inductors 4 and 5 to the temperatures lower than the surfacing temperature by inductor 3. The heating temperature decreases as it approaches the center of the disk. After surfacing according to the previously set mode, the parts are cooled by the inductors surfaces, in which water is constantly circulating.

Creating temperature modes with several inductors (in this case three) create the conditions for maintenance of the set form, the sizes, quality of a surfacing area are created. This allows to increase productivity of surfacing of one-piece disks due to elimination of additional operations and equipment for straightening of parts, as well as protection welder workers (thermistors) from being affected by thermal and electromagnetic radiation.

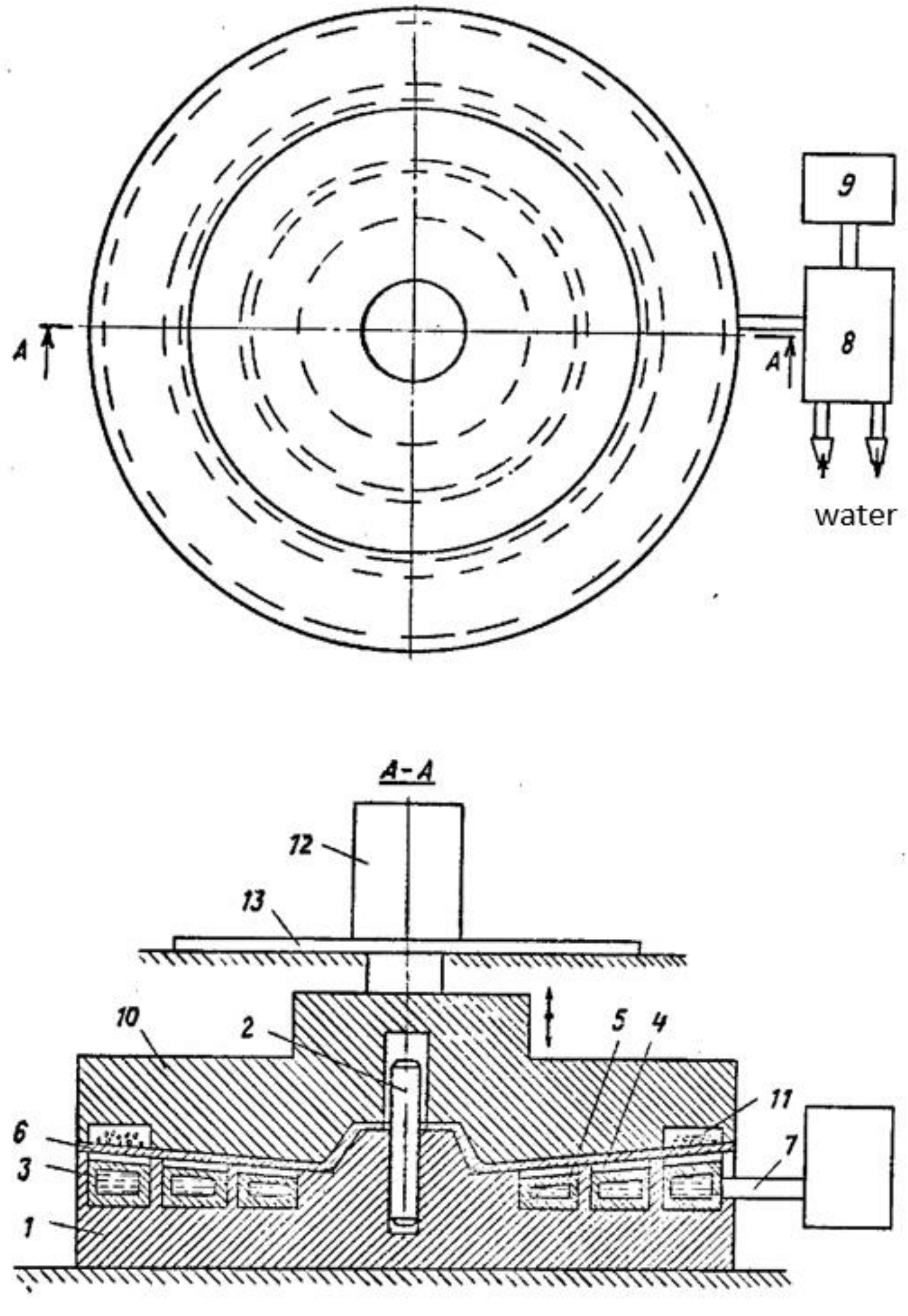


Figure 5. Device for surfacing of thin shaped disks with reduced dissipation of thermal and electromagnetic fields

Also, to reduce the impact of thermal and electromagnetic fields on workers and reduce energy costs and increase the efficiency of the surfacing process device [13], which is shown in Fig. 6 a, b, c was developed.

It consists of two clamping plates, lower 1 and upper 2, the working end surfaces of which are made according to the configuration of the part to be surfaced. The lower plate 1 is U-shaped with the inverted base down, in the end of the upper part of which a groove is made. The surface of the groove is covered with shielding 3 and heat-insulating material 4, and the cavity of the groove is filled with heat-resistant dielectric material 5, for example, alumina Al_2O_3, which has a dielectric constant $\varepsilon \cong 10$, low conductivity $\sigma < 1$ and melting point around 2000°C. In the mass of material 5 annular coils 6 of the inductor are placed.

The upper clamping plate 2 also has an annular recess, the surface of which is covered with shielding 3 and heat-insulating 4 materials as well. In the upper plate there are through holes 7 for the exit of gases from the weld zone. To ensure uniform temperature distribution on the welded surface of the part 8, the working end surfaces of the clamping plates are covered with heat insulating material 9. The coils 6 of the inductor are connected to terminals 10 in parallel with fittings 11 for supply and drainage of cooling water, as it is shown in Fig. 6 a.

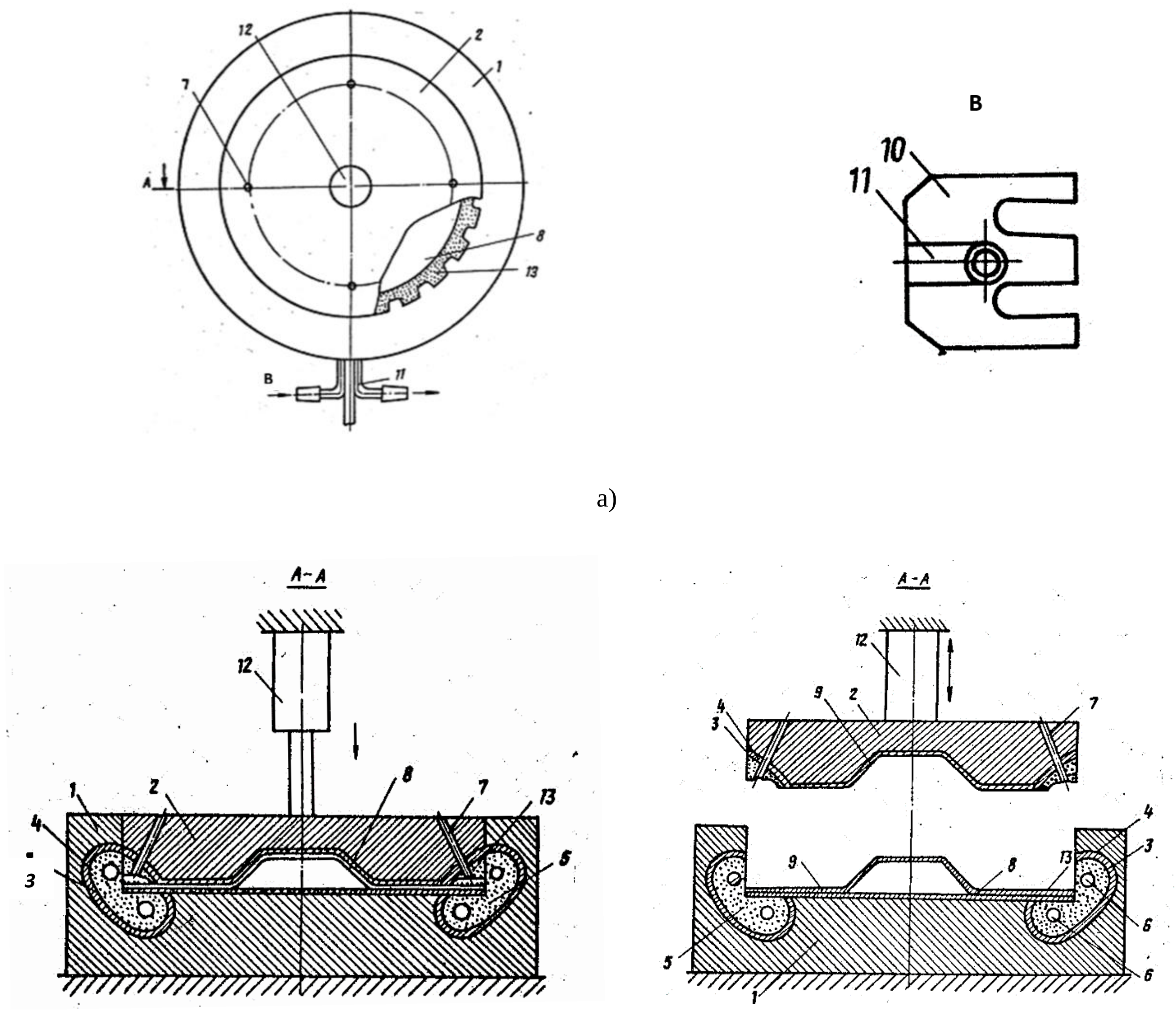
The current in the coils 6 is directed opposite (antiphase) to the current and magnetic flux. There is a pneumatic cylinder 12 for clamping of part 8 with plates 1 and 2.

The device works as follows. Part 8 (knife-cutter) with pre-application of the charge 13 with a special mechanism is installed on the lower plate 1. Then by means of the drive 12 the upper clamping plate 2 is lowered. Annular recesses with coils 6 of the inductor form a closed waveguide, which covers the surfacing area. When switching on the microwave unit (not shown in Fig.), simultaneous surfacing is carried out over the entire working zone of the part 8. After surfacing, the upper clamping plate 2 is moved up and the part is fed into the container for further processing, such as sharpening.

In the waveguide, by means of two coils 6 under the action of high-frequency multidirectional currents in them there occurs a concentrated electromagnetic field of high power, which contributes to Foucault currents, which provide uniform heating of gears, high-quality surfacing (more uniform thickness of the surfacing metal) and reduce energy consumption.

The energy supplied from the coils 6 of the inductor to the welded part in the proposed design of the waveguide 5 is not dissipated into the environment, but is concentrated in a closed space, thereby increasing the efficiency of the inductor and the device as a whole and also eliminate its effect of electromagnetic field on human body.

In order to reduce the influence of electromagnetic fields, as well as increase the productivity of the surfacing process by automating the process of filling the charge, another device was developed [12], which is shown in Fig. 7 a, b, c, in which the charge dispenser has a drive shutter, the drive rod of which is fixed with a clamping mechanism made of two hollow cones inserted inside each other, while the inner cone is rigidly fixed to its top with the shutter drive rod (dispenser). The outer end is mounted on this rod with a gap and is made so as to cover the surface to be welded, which has a conical funnel turned by a socket to the dispenser.



a)

b)

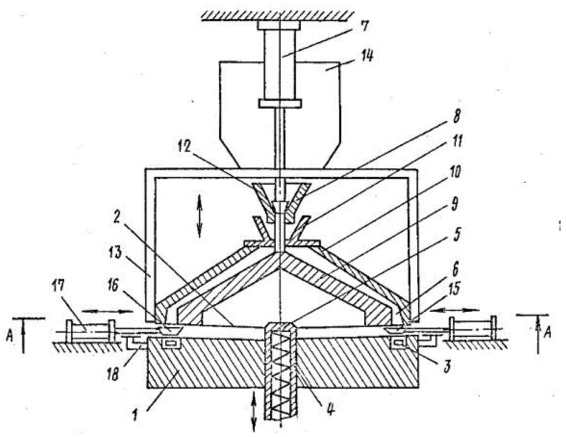
c)

Figure 6. Device for induction surfacing of thin-shaped disks:
a – general view; b – section A-A; c – section on A-A when lifting the upper clamping plate

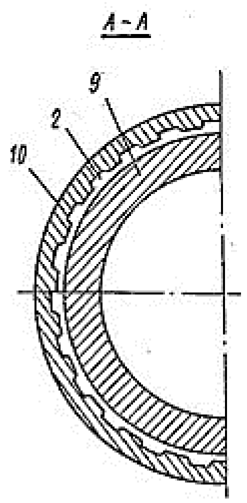
In the upper position of the rod between the inner and outer cones, a closed cavity is formed, the volume of which is equal to the volume of dispenser. In addition, in order to save surfacing materials, the device is equipped with two horizontally movable semi-annular trays mounted on the guides made on the table to install the product.

The device works as follows. In the initial position, the clamping mechanism in the form of two cones 9 and 10 is at some distance from the surface of the table 1. With a special additional device, part 2 is fed to a spring-movable vertical-motion shaft 4 and is mounted on its end at certain distance from the table surface 1. At this point, the shutter 8 of the dispenser 12 is above the hole made in the bottom of the dispenser 12, forming a gap for the passage of the portion of powder necessary for simultaneous spilling on the surface of the part. The powder is fed through a conical funnel 11, which is in the upper part of the outer cone 10, in a closed cavity formed between the inner cone 9 and the outer cone 10. By turning on the hydraulic drive 7, the inner cone 9 and the outer cone 10 together with the gate 8 wove down and the opening of the dispenser 12 is closed by the cone 11. Since the outer cone is made so that it covers the disk to be sufaced, and the inner one is firmly pressed against the surface of the disk by its weight, the probability of pouring the charge 6 on the inductor 3 when filling the charge on the surface of the disk 2 is eliminated. With the possible partial pouring of powder (charge) through the gaps formed between the end of the part 2 and the cone 10 (due to inaccuracies in the manufacture of the part), it falls into two movable semi-annular trays 15, 16, which move horizontally along the guides 18 by means of two drives 17. The semi-annular trays 15 and 16 move simultaneously under the part at the moment when of coverage of the part 2 by the outer cone 10. After filling the charge 6, on the surface to be surfaced, the trays 15 and 16 move reciprocally; and when turn on the hydraulic drive 7, the part 2 moves down together with the plate and the dispenser 12, which can move vertically before the end part of the table 1 touches the lower surface of the part. The dispenser 12 is mounted on the frame 13. When supplying high frequency current to the inductor 3, the part 2 is a simultaneously surfaced over the entire working area.

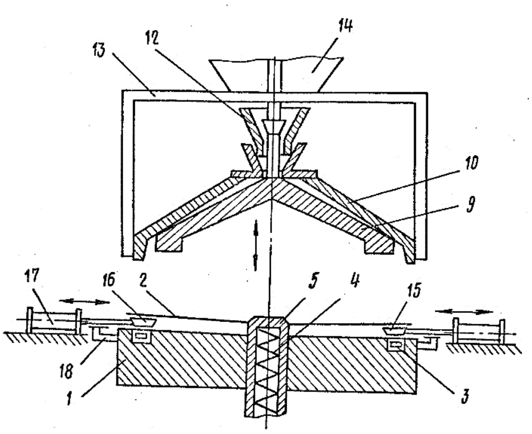
After surfacing, the plate with the workpiece 2 and the dispenser 12 is moved vertically upwards by means of a vertically movable spring shaft 5 to the upper limit movement of the dispenser 12 when the hydraulic drive 7 is switched on. By means of the hydraulic drive, the inner cone 9 is moved vertically upwards until it collides with the outer cone 10, forming a closed cavity with it while opening the the dispenser. When the shutter 8 is raised to the appropriate level, the powder is poured out, and the welded part is transported to the loading container with a special additional device. The powder is supplied from the container 14 to the dispenser 12 when pressing the part 2 to the table 1. The developed design of the device for surfacing disks also protects the welder-workers from the effects of thermal and electromagnetic fields.



a)



b)



c)

Figure 7. Device for induction surfacing of thin disks with simultaneous filling of the charge: a – general view of the device; b – section A-A; c – also at the time of charge dosing

The authors also developed other designs of mechanisms to protect workers from electromagnetic and thermal fields with movable relative to each other, as well as rigidly interconnected thermal and electromagnetic screens, which were described and published in [14]. These developments increase energy savings by 15–20% depending on the use of powdered hard alloys, due to the concentration of electromagnetic fields from the inductor in the surfacing zone.

Conclusions. The use of thermal and electromagnetic screens using high frequency currents can improve thermal and electromagnetic safety of workers, increase technological and energy efficiency of induction heating and surfacing of machine parts and mechanisms, based on the needs of technology

To implement the benefits, there were developed the devices for induction heating, including surfacing of thin elements, in the construction of which thermal and electromagnetic screens are used for protecting workers from being hurt by thermal and electromagnetic fields.

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ШЛЯХИ ЗНИЖЕННЯ ВПЛИВУ СТРУМІВ ВИСОКОЇ ЧАСТОТИ НА ОРГАНІЗМ ЛЮДИНИ ПРИ ІНДУКЦІЙНОМУ НАПЛАВЛЕННІ

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Резюме. *Розроблено ряд пристроїв і механізмів для захисту робітників від впливу струмів високої частоти при наплавленні тонких сталевих дисків як суцільної, так і зубчастої форми, порошкоподібними твердими сплавами. Показано, що при наплавленні суцільних дисків із використанням феритного магнітопроводу типу 1000 НМЗ П-подібної форми з магнітною проникністю* μ_{max}*=2000 дозволяє зменшити час наплавлення на 10 с та знизити витрати електроенергії на 20% у порівнянні з технологією наплавлення без феритного магнітопроводу. Встановлено, що в іншому пристрої для наплавлення суцільних дисків, у робочу поверхню стола якого концентрично основному індуктору для наплавлення, встановлено додаткові кільцеві індуктори для підігрівання поверхні диска за межами наплавлювальної зони. Створення температурних режимів за допомогою застосування додаткових індукторів створюють умови для забезпечення заданої форми, розмірів та якості наплавлюваної поверхні, які дозволяють підвищити продуктивність процесу наплавлення суцільних дисків, а також захист робітників наплавлювальників від ураження тепловим та електромагнітним випромінюванням. Досліджено також пристрої з тепловими та електромагнітними екранами для індукційного нагрівання та наплавлення деталей машин із використанням магнітопроводу з одновиткового індуктора, пристрої з двовитковими і тривитковими індукторами, в яких зона наплавлення повністю закрита, тобто повністю ізольований вплив теплових і електромагнітних полів на робітників, які дозволяють покращити умови праці, а також розробляти нові технологічні процеси наплавлення з використанням струмів високої частоти. Показано, що застосування теплових та електромагнітних екранів забезпечує рівномірне кероване виділення тепла в зоні наплавлення, що дозволяє скоротити час наплавлення з 32 до 22 с і зменшити витрати електроенергії на 15–20% залежно від порошкоподібного твердого сплаву та підвищує його експлуатаційні властивості.*

Ключові слова: *індукційне нагрівання та наплавлення, теплові та електромагнітні екрани, тонкі диски, безпека праці, пристрої.*

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