TRANSVERSE MAGNETIC FIELD INPUT DEVICES FOR ARC WELDING AND SURFACING PROCESSES
(Review)

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Application of controlling longitudinal and transverse magnetic fields is promising in arc welding and surfacing, allowing improvement of efficiency of electrode wire melting, refining of the structure of weld metal (deposited bead) and reducing the depth of base metal penetration. In arc welding and surfacing the influence of transverse magnetic fields on geometrical dimensions of welds (beads) and electrode melting efficiency was mainly determined. These works either do not give the input device designs, or they are presented without discussion of the subject of optimality of the used designs, or dimensions of each element of these devices. The objective of this work was analysis of known designs of input devices to assess the effectiveness of their application in arc welding and surfacing. It is shown that the devices described in publications consist of an electric magnet with Π-shaped ferrite core with an air gap and windings. In some works just the transverse component of magnetic field B_x was measured, and longitudinal component of induction B_z induced by the applied input device, was not measured. However, the shape and dimensions of the cross-section of welds and deposited beads in this case could be influenced not only by transverse B_x, but also by longitudinal component of magnetic field B_z. Design features, as well as distribution of induction components B_x, B_z generated by known circuits of devices for application of transverse magnetic fields in the zone of welding arc and pool, were analyzed, and their disadvantages were noted. Urgency of development of new circuits is shown, as well as rationality of optimization of structural dimensions of known circuits of the devices to improve the effectiveness of arc welding and surfacing with application of transverse magnetic fields. 15 Ref., 5 Figures.

Keywords: *arc welding and surfacing, longitudinal and transverse magnetic field, magnetic field induction, input device for transverse magnetic field application*

Application of longitudinal (LMF) and transverse magnetic fields (TMF) in arc welding and surfacing mainly allows improving the efficiency of electrode wire melting, refinement of the structure of weld metal (deposited bead) and reducing base metal penetration depth. It should be noted that in all the works, where LMF or TMF are used at arc welding or surfacing, it is assumed that longitudinal component of induction B_z is directed along electrode axis, and transverse component of induction B_x (or B_y) is normal to electrode axis, i.e. is located in the plane of deposited item (plate).

Works [1, 2] deal with LMF input devices (ID) which consist of a solenoid with ferromagnetic core, presence of which considerably increases the longitudinal component of induction in the zone of the welding arc and liquid metal of the pool. In [3] optimum dimensions of solenoid with a round ferromagnetic core with an opening for welding wire passage are calculated for the case of modes of arc welding and surfacing with LMF impact.

Data on TMF ID designs for arc welding and surfacing are sparse. In some papers devoted mainly to consideration of TMF influence on the geometry of welds (beads) in arc welding (surfacing) no data on the design of applied TMF ID are given. Subject of their optimum application is not discussed in most of the publications. Let us consider in greater detail the currently available designs of TMF ID for the case of consumable electrode arc welding and surfacing.

Note that in [4–9] various aspects of the processes of arc welding and surfacing with TMF impact are studied, but they do not give any data on applied TMF ID designs. Studies [10–15] deal with TMF ID constructed by one and the same schematic — an electric magnet with Π-shaped ferromagnetic core with air gap and windings.

In one of the first works, devoted to investigation of the influence of an alternating TMF on butt weld geometry in submerged-arc welding of St.3 steel with Sv-08A wire and AN-348A flux, it is shown that a special electric magnet attached to ADS-1000 automatic welding machine is used

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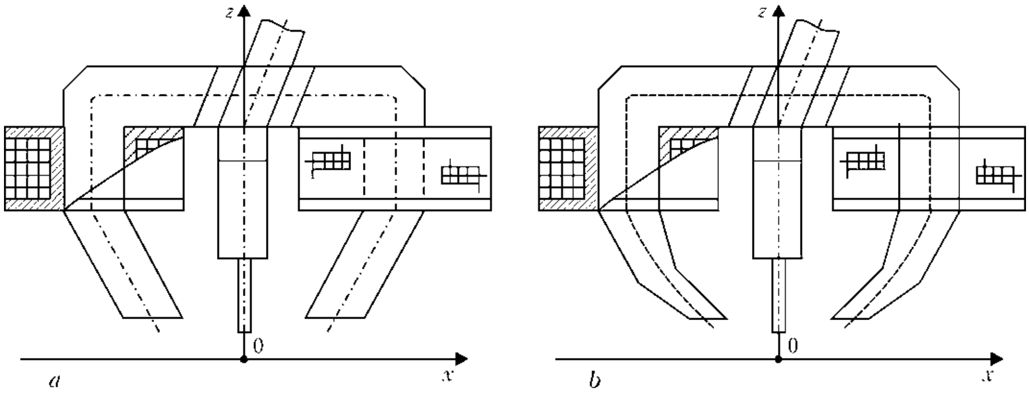

Figure 1. Schematic of electric magnets with constant (*a*) and variable (*b*) pole section [11]

for generating TMF [10]. It is established that at transition from a square-edge plate to a grooved plate magnetic induction decreased 4–7 times. TMF application in submerged-arc surfacing promoted lowering of penetration depth by 10–50 % and increase of weld width by 20–25 %. However, this paper does not give the design of the applied TMF ID.

Work [11] deals with TMF ID in the form of a П-shaped electric magnet with two coils, placed on rods with constant (Figure 1, *a*) and variable (Figure 1, *b*) pole cross-section, for the case of DC submerged-arc welding with Sv-08GA wire and AN-348A flux of circumferential roll butt joints of steel pipes (11–12 mm wall thickness).

It is established that sound formation was ensured at ampere-turn number of 3000–7500 and magnet core section of 25 × 25 mm with 20–30 mm air gap between the poles. This device with electric magnets of a constant cross-section, at other conditions being equal, ensured a higher magnetic field induction than the device with variable cross-section rods, tapering towards the poles. Note that in this work just the transverse component of magnetic field B_x was measured in the butt zone. However, in the same zone the magnitude of longitudinal component of induction B_z, which was not measured, is considerable. Weld shape in this case could be influenced not only by transverse, but also by longitudinal component of magnetic field induction.

Study [12] presents TMF ID for surfacing cylindrical samples of 76 mm diameter from steel 45, which consists of electric magnet with П-shaped core (Figure 2), which was used in submerged-arc surfacing with Np-30KhSGA wire. It is shown that TMF impact leads to a change of the coefficient of electrode wire melting. This device, however, is applied only at surfacing of

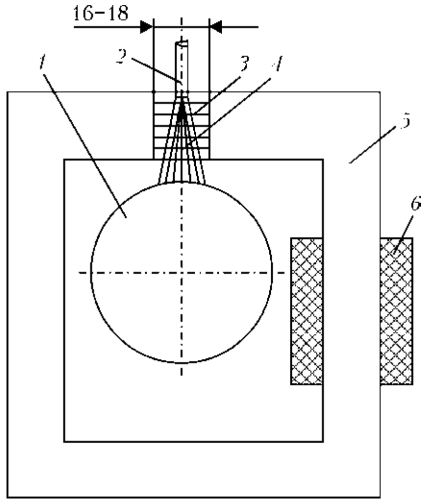

Figure 2. Schematic of ID for TMF application to arcing zone in welding [12]: *1* — surfaced sample; *2* — electrode wire; *3* — magnetic lines of force; *4* — welding arc column; *5* — electric magnet core; *6* — coil

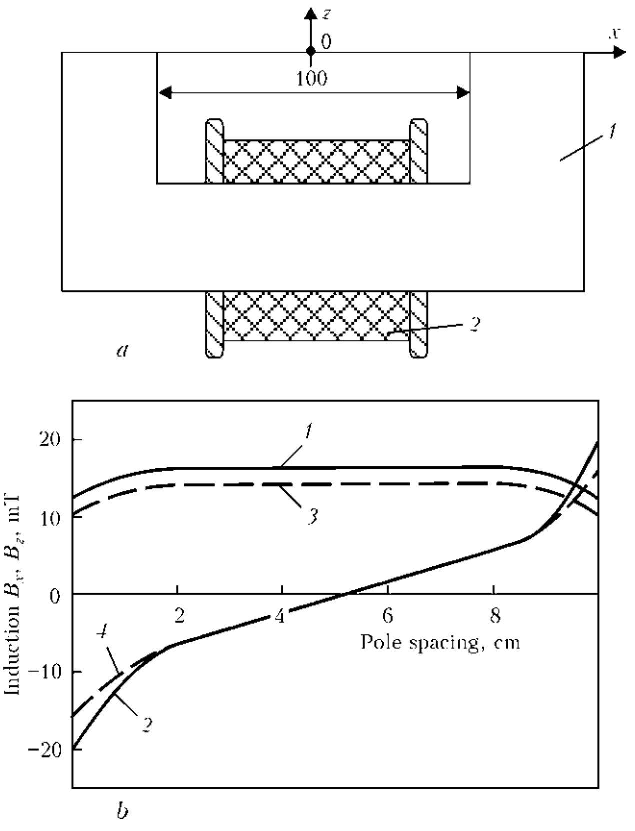

Figure 3. Schematic of electromagnetic input device (*a*) and induction distribution between its poles (*b*): *1*, *3* — B_x; *2*, *4* — B_z; *1*, *2* — $y = 0$; *3*, *4* — 10 mm

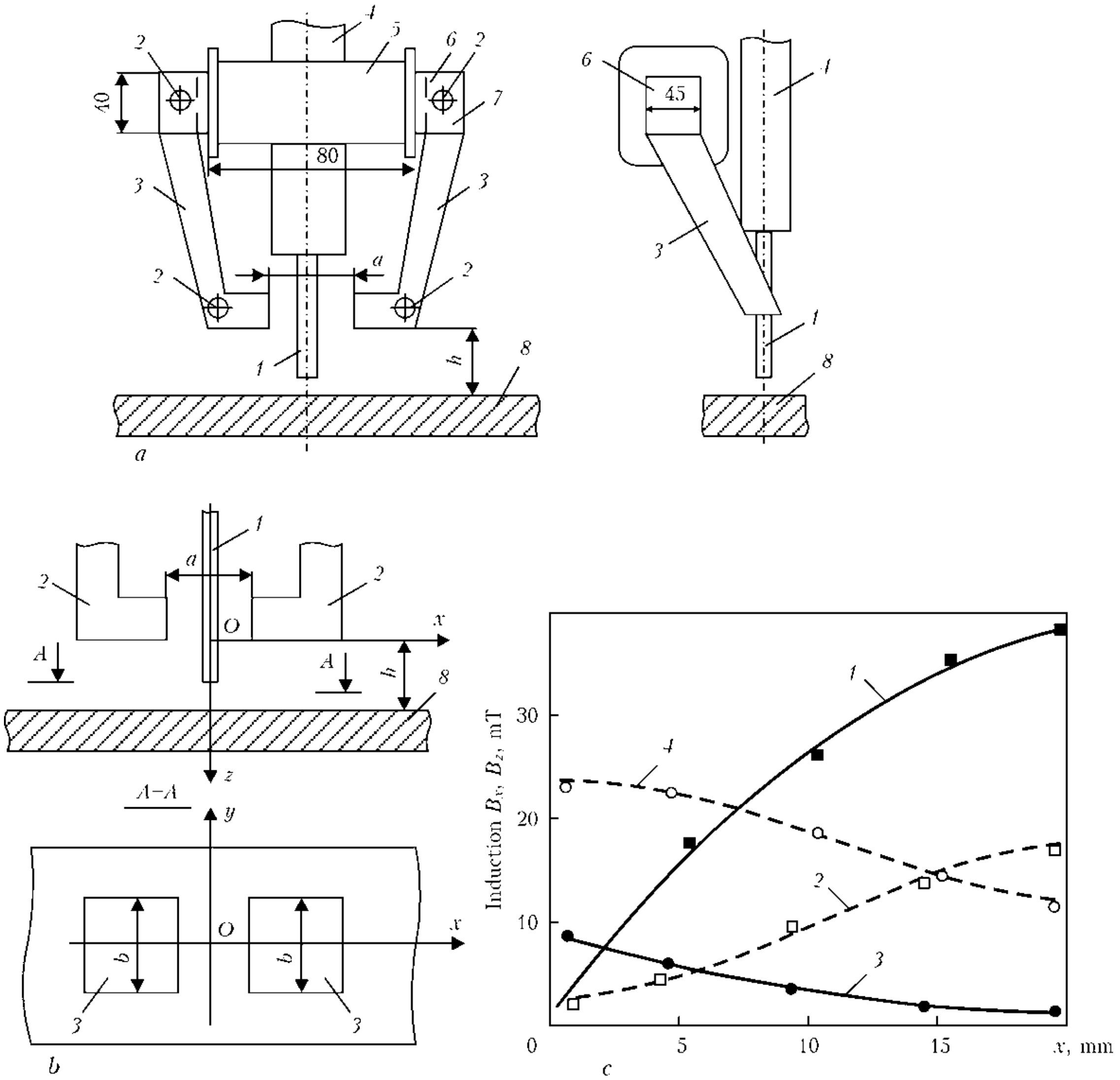

Figure 4. Schematic of device for inducing TMF (*a*), coordinate system at measurement of magnetic field induction (*b*) (for designations see the text) and distribution of TMF induction components B_z, B_x in the direction of axis Ox (*c*) [14]: *1*, *2* — induction B_z; *3*, *4* — induction B_x; *1*, *3* — ferromagnetic item; *2*, *4* — item from nonmagnetic material ($y = 0$, $h = 20$ mm, $I_w = 1920$ A)

components of a cylindrical shape and is not applied for surfacing of flat items. Another advantage of such a device is a limited diameter of items which can be reconditioned by surfacing.

In [13] the impact of TMF on the arc in submerged-arc surfacing with wire was made at application of a device consisting of П-shaped magnet core *1* (steel 45) and coil from insulated copper wire *2* (turn number $w = 120$) (Figure 3, *a*). Surfaced plates from nonmagnetic 12Kh18N10T steel 15–20 mm thick were placed on poles of this П-shaped magnet core. With such a design of the input device, the transverse component of magnetic field induction B_x along the central part between the poles (at the surfaced plate surface) was uniformly distributed, and was higher than the normal component of induction B_z (Figure 3, *b*). It is shown that the impact of alternating TMF leads to widening of deposited beads. At TMF frequency of 50 Hz bead widening proceeds in proportion to induction B_x. However, such a design of TMF ID can be applied for research purposes and only for welding nonmagnetic materials and alloys.

Work [4] shows a device (Figure 4, *a*), consisting of magnet core *7*, assembled from sheets of electric steel and frame of coil *5* with turn number $w = 480$, placed on magnet core *6*. Rods of magnet core *3* (25 × 25 mm section) had a gap of width *a*, through which electrode wire *1* passed. Magnet core rods were connected by bolts *2*. Device was attached to nozzle *4* of automatic welding machine by yokes (not shown in Figure 4, *a*).

It is established that tangential component of induction B_x at the surface of ferromagnetic plate is maximum in the system center and decreases in the direction from electrode axis to electric magnet poles (Figure 4, *c*). Presence of a ferromagnetic item significantly (approximately by

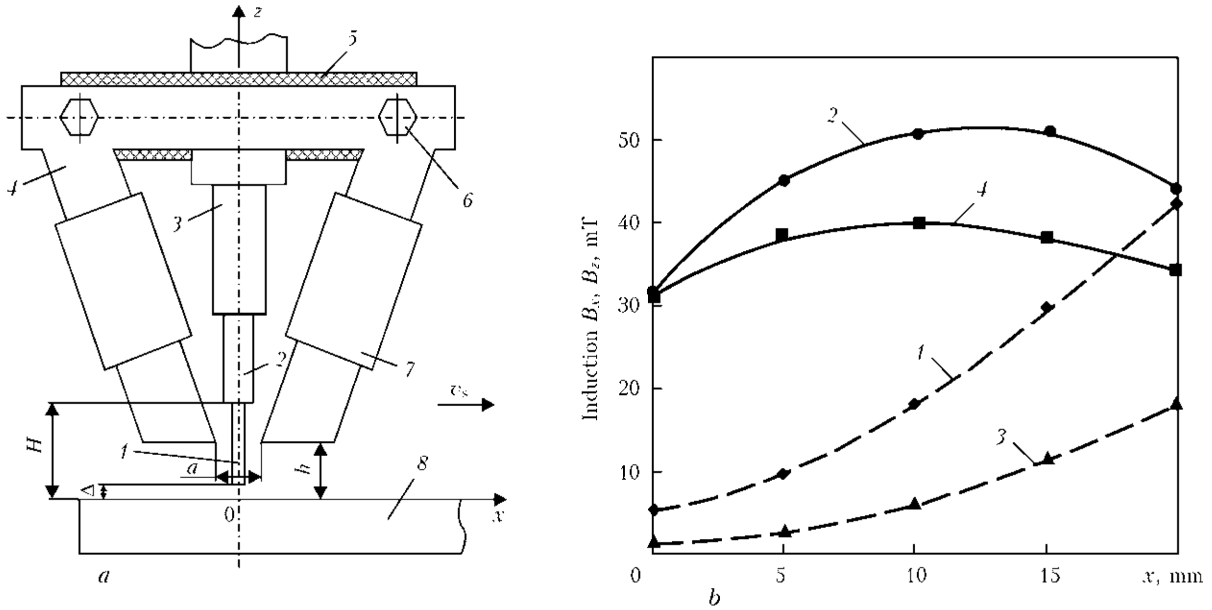

Figure 5. Schematic of the device for inducing TMF (*a*) (for designations see the text) and distribution of TMF induction components B_z, B_x along axis *Ox* ($z = 0$, $y = 0$, $I_c = 60$ A) [15]: *1*, *3* — induction B_z; *2*, *4* — induction B_x; *1*, *2* — constant TMF; *3*, *4* — variable TMF of 50 Hz frequency

4–6 times) lowers B_x and increases the normal component of induction B_z at ferromagnet surface (see Figure 4, *c*) that is associated with weakening action of ferromagnetics on the tangential (transverse) component of TMF induction.

In [15] a device, the schematic of which is given in Figure 5, *a*, was developed for inducing controlling TMF. The device is magnet core *4*, consisting of three sections: two inclined sections, on which coils *7* are located, as well as a horizontal section connected to inclined sections by bolted joints *6*. Magnet core is assembled from plates of electric steel 0.5 mm thick. Pack cross-section is 30 × 20 mm. Number of turns of one coil was $w = 70$. Device generating TMF was attached to automatic welding machine of ADS-1002 type using yokes. Magnet core *4* was insulated from automatic machine by insulator *5*. Automatic machine allows varying parameter *H* (electrode extension), i.e. distance between current-conducting jaws *2* and plate *8*, as well as distance *h* from end faces of magnet core *4* to surface of plate *8*. Device design allows measuring the distance between magnet core lower sections at electrode tip (parameter *a*). Electrode wire *1* passed through nozzle *3* (Figure 5, *a* gives the system of coordinates accepted for magnetic field investigation, with the origin of coordinates being located on plate surface under electrode axis).

At measurements of TMF induction the following values were kept constant: distance from electrode tip to plate surface $\Delta = 5$ mm, value of electrode extension $H = 25$ mm, parameter $h = 25$ mm, distance between lower end faces of magnet core along the horizontal $a = 35$ mm. When studying magnetic field induction, Sv-12Kh18N10T wire of 4 mm diameter was used, and base metal was 12Kh18N10T steel plates.

Distribution of inductance B_z of constant and alternating TMF of 50 Hz frequency rises when moving away from axis *Oz* towards device poles along axis *Ox* (Figure 5, *b*, curves *1*, *3*). It is characteristic that induction component B_z is much smaller than component B_x in the zone under electrode tip (Figure 5, *b*, curves *2*, *4*). In addition, at running of direct current in TMF ID coils, induction component B_x is greater than at running of alternating current of 50 Hz frequency. This is, apparently, due to the fact that at application of alternating current of 50 Hz frequency losses for eddy currents and hysteresis curve occur in the device magnet core.

It should be noted that data given in Figures 4, *c* and 5, *b* on the nature of distribution of induction B_x along axis *Ox* are different. This is associated, in our opinion, with the influence of the shape of TMF ID rods on distribution of induction B_x along axis *Ox*. In the considered papers this question was not discussed and requires further study.

Considering the data of [14] showing that in the presence of an item from ferromagnetic steel longitudinal component of induction B_z in the weld pool zone is practically by an order of magnitude higher than transverse component of induction B_x of TMF (see curves *1*, *3* in Figure 4, *c*), it can be assumed that established in works [10–12] effects of TMF influence on geometrical dimensions of cross-sections of welds and deposited beads are due to the impact of not just the transverse, but also the longitudinal component of TMF induction.

Thus, earlier published works on investigation of TMF influence on geometrical dimensions of welds in arc welding and surfacing did not allow for the features of TMF ID design. This task is believed to be urgent for arc welding and surfacing processes.

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Received 24.10.2012

NEWS

Laser Cutting of Metallic and Non-Metallic Materials

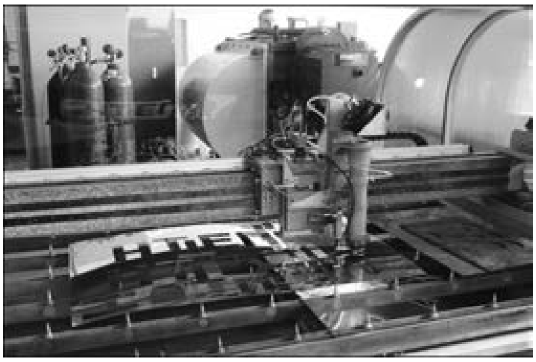
The pattern cutting of sheet material according to any preset contour is realized using a program-controlled cutting by a laser radiation of up to 1 kW power. Here, the products of erosion are removed from the zone of radiation action by a jet of air-oxygen mixture. The installation for cutting includes a fast-flowing laser, a three-coordinate manipulator, mirror of optic track, cutter with a focusing lens. Dimensions of the sheet being cut depend on sizes of a manipulator and lie usually within 1–2 m. One of the operating installations is shown in the Figure.

Field of application

- cutting of «ferrous» and stainless steels of up to 6 mm thickness;
- cutting of wood, cardboard, plywood of up to 20–30 mm thickness;
- cutting of plastics and organic glass of up to 40 mm thickness;
- cutting of rubber, hard-alloy and other structural materials.

Technical-economical advantages

- as compared with a microplasma cutting the accuracy (up to ±0.01 mm) is much increased, there is no cut conicity;
- cut width does not exceed 0.7 mm, that reduces greatly the amount of wastes, making technology ecological;



Process of laser cutting

- labor conditions are improved, there are no such harmful factors, typical for plasma cutting, as noise, illumination of electric arc, exhaustion of harmful aerosols is much reduced;
- there appears a feasibility to cut non-electroconductive thick materials.

Efficiency

- up to 500 mm/min in cutting of 6 mm thick black steel;
- up to 2000 mm/min in cutting of 1 mm thick stainless steel.