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DESIGN FEATURES OF MOBILE RAIL WELDING MACHINES FOR FLASH BUTT WELDING

D.I. Malysheva, N.A. Vynogradov, V.Yu. Sysoyev

E.O. Paton Electric Welding Institute of the NASU
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine

ABSTRACT

The design features of mobile rail welding machines for flash butt welding produced by the companies, operating at the modern world market were studied. The studies provide an opportunity of highlighting the trends of further improvement of equipment with the growth of technological innovations.

KEY WORDS: seamless track, flash butt welding of rails, rail welding machine, upsetting, upsetting force, clamping, clamping force, continuous flashing, pulsating flashing, flash remover, current supply

INTRODUCTION

Seamless track is the most advanced and reliable design of a track for modern operating conditions. Rails, being a part of such a track, have no butt joints and this allows increasing the admissible speeds of trains to 160–200 km/h and more. At laying of seamless tracks and also during their repair, rails are welded in lengthy strings. Standard documents allow using only flash butt welding for joining rails in the main line, which provides an equal strength of welded joints with the base metal, including as well the values of fatigue strength [1]. Strings are welded either by stationary machines at rail welding plants and then delivered to the site of assembly, or on the track — by mobile rail welding complexes.

The global market of flash butt welding machines amounts to thousands of units of equipment and the profit market is millions of US dollars.

In 2020, the consulting Company QY Research published the report “Global rail welding machines market insights and forecast to 2027” [2]. According to the report, during the forecast period, the revenue of the mobile sector of rail welding machines will be about 70 % of the market share, and of a stationary is only 30 %. The use of stationary rail welding machines is constantly decreasing. Therefore, by 2027 the global market of mobile rail welding machines will reach 82 mln USD as compared to 54 mln USD in 2020 at an average annual growth rate of 2.9 % during 2021–2027.

From the point of view of the market, seamless railway tracks should be safe, and the costs of their laying and maintenance should be minimized. This issue sets increased requirements to the reliability of the equipment design, so it is relevant to carry out the analysis of the technical capabilities of mobile rail welding machines. The authors propose to analyze the design differences of mobile rail welding machines of different manufacturers.

QY Research focuses on the activities of the following companies that are represented at the market of mobile rail welding equipment: Chengdu Aigre Technology (China), Holland LP, Schlatter Group (Switzerland), Goldschmidt (Germany), Mirage Ltd (England), PJSC KZESO (Kakhovka Plant of Electric Welding Equipment) (Ukraine), Progress Rail (Caterpillar) (USA), Geismar (France), Gantrex (Belgium), BAIDIN GmbH (Germany), Vossloh (Germany), Plasser@Theurer (Austria), “Pskovelektrosvar” Company (Russia), Contrail Machinery (Romania), VAIA CAR SPA (Italy).

According to the design, mobile rail welding machines consist of fixed and movable clamps which fix rails with the help of clamping cylinders. The movable clamp can be moved relative to the fixed clamp by means of upsetting cylinders. Welding current from power sources, mounted on the machine, heats rails until a ductile state. Due to the rapid movement of clamped and heated rails, their joining — welding occurs. In this case, a part of the molten metal (flash) remains along the contour of welded rails. Standard documents [3], which determine the requirements for the method of flash butt welding in mobile rail welding machines, do not allow the presence of flash after welding, so in each machine, a device for its removal is provided.

We will not consider the products of Goldschmidt Company, as far as it is specialized on termite and arc welding, as well as Vossloh Company, because the welding head is very similar to the machine of Schlatter Group production.

The PJSC KZESO (Kakhovka Plant of Electric Welding Equipment) produces a wide assortment of mobile rail welding machines, designed at the PWI [1] for construction and repair of seamless high-speed main railways, tram and subway lines in field conditions [4]. The enterprise supplies to the market both welding machines K900 with a lever clamping scheme (Figure 1) as well as machines K920 (Fig-



Figure 1. Mobile rail welding head K900

ure 2), K922-1, K945 and K950 with a horizontal arrangement of clamping cylinders to generate a constant force, that does not depend on wear of tongs. According to the standard documents [5], welding of rails can be carried out in two ways: with a tension of rail string and with a preliminary bending. In welding rails with a preliminary bending, a part of a string is loosen, raised and bent in a horizontal plane until alignment of the ends. In the process of welding, the bend of a string is straightened under the action of longitudinal force, created by a welding machine. Machines K922 (Figure 3), K945, K950 generate an upsetting force of 1200 kN. This makes it possible to eliminate the bend by performing welding of rails into a track with the tension of a string and minimizing the length of a rail, which is removed from sleepers. This simplifies the process of welding, as well as enables the operation of “last welding”, that is, welding and equalization of stresses in rails per one operation. Machines [6] consist of two tong clamping devices, manufactured in the form of two double levers, which are mounted on a common central axis and isolated from each other. Two tong clamping devices are made with the possibility of moving along the axis relative to each other using two hydraulic upsetting cylinders, the rods of which bind them. As a source of heating rails, two AC transformers are used, which are built into the machine. An original design of the welding circuit, where as a conductive elements, the power units of the machine are used, which allows reducing the power consumed during welding. Clamping is



Figure 2. Rail welding head K920-1



Figure 3. Welding machine K922-1

carried out behind the web of rails. If in the machine K900 a flash is removed by travel of the moving column (a throw-on flash remover is used), then in the machines K922, K945 (Figure 4) and K950, in addition to the throw-on, a flash remover with a drive from built-in autonomous hydraulic cylinders is provided. This allows removing flash in a clamped state and maintaining the butt during the period required for cooling. The designing feature of these machines is the presence of clamping multipliers built into the cylinders that increase the pressure, and, accordingly, the clamping force by 2 and more times (the maximum clamping force at the highest working pressure is 2900 kN) to avoid slipping of columns during upsetting. Machines K945 and K950 have an increased travel of upsetting cylinders being 400 and 250 mm, respectively, which eliminates the possibility of a tear in a heated butt during unclamping [7]. All the machines are designed and manufactured, taking into account the features of a pulsed flashing technology, developed at the PWI. The weight of the welding head does not exceed 3500 kg.

Machines are included in a mobile rail welding complex in the form of a 20-foot container, designed for mounting on a base of a cargo car and a railway platform.

It should be noted that the key players at the market of mobile rail welding machines, such as Chengdu Aigre Technology (China), Holland LP, Progress Rail (Caterpillar), Geismar, Gantrex, Contrail Machinery,



Figure 4. Welding machine K945



Figure 5. Container system Multiflex for welding rails with welding head AMS60

VAIA CAR SPA, as a welding head in their machines use the equipment that was in different years designed at the PWI and manufactured at the PJSC KZESO.

Schlatter Company offers mobile rail welding machines AMS60, AMS100 and AMS200 in different configurations, that differ with each other by a rail alignment (centering) system and operating range [8].

The AMS60 and AMS200 machines contain a body and a slider that have the ability of linear movement. Clamping systems are mounted in the body and the slider. The eccentric clamping system, activated by clamping cylinders has an ability of self-slipping, which allows increasing the clamping force while adding upsetting force. Clamping is carried out behind the web of rails. By means of the double lever, the upsetting cylinder, located over the axis of rail clamping, can move the slider. Before clamping, an integrated lifting hydraulic device clamps both ends of rails until the rests to carry out vertical alignment (centering) of rails along the rolling surface.

During designing of the AMS60 machine (Figure 5), the main attention was paid to centering — an accurate combination of ends of the rails on the side edge (it is possible to choose from left or right) and the rolling surface. Therefore, this machine is the best used in the situations, where accurate alignment is required, for example for high-speed railways (for rails of up to 68 kg/m). AMS60 has an upsetting force of 6000 kN. The weight of AMS60 is about 6200 kg.

The AMS100 machine (Figure 6) is designed for welding rails of a large cross-section. AMS100 has an upsetting force of 1000 kN and can weld heavy and even tram groove rails. It is often used for welding track of cargo transportation with an axle load of up to 75 kg/m. However, AMS100 was also used for welding high-speed railways. As to kinematic scheme, the welding head AMS100 is identical to K920 machine (design of the PWI).

AMS200 (Figure 7) [9] is a mobile rail welding machine of a new generation that allows performing welding and tension without an additional stretching



Figure 6. Welding head AMS100

device, as well as the operation “last welding”. The tension and upsetting forces are 1400 kN. The machine has a necessary force to pull up rails to the required calculation length. A full travel of clamping cylinders is 300 mm. If necessary, checking and adjustment of accurate side alignment of rails is carried out using an electronic measurement system. The current supply is completely independent of clamping and is carried out on the outer side of the head of rails and their foot. The mass and dimensions of the AMS200 machine does not exceed the mass of AMS60 machine.

The presented machines are available in two variants:

- Supra Road flex is a self-travelling system based on a cargo car, which is designed for fully autonomous operation with the possibility of moving from one site to another by the track or outside it;
- Supra Multiflex allows all equipment to be placed in a container and mounted on the railway platform. For standard complete set, a compact 30-foot container is used.

As an alternative, a system consisting of two 20-foot containers is also available.

Mobile rail-welding machines of the Austrian **Plasser@Theurer** Company of APT500 series are based on the welding head of the PWI design. The new development of the company is a fully automated robot APT 1500R [10]. This means that a welding robot needs only to be lowered to the welding zone, and then the process



Figure 7. Mobile machine AMS200



Figure 8. Welding machine of container type ART1500RC

runs automatically. The design of APT 1500R provides a separate application of welding current and clamping of rails. Rails are lifted from sleepers with the help of lifting devices, centered as to their height and aligned relative to the working edge, and the special measurement system is constantly monitoring this process. Upsetting cylinders clamp the web of a rail until the rests with the force of 3500 kN. Clamping cylinders, upsetting cylinders are located in a one plane passing through a neutral axis of a rail [11]. Such a design solution protects the machine from undesirable loads. The design of the machine allows tension and upsetting of rails — the tension force is 1500 kN. The travel of upsetting cylinder is 200 mm.

The feature of the welding robot is the fact, that it uses an AC source with a frequency of 1000 Hz. The power source consists of AC transformers, whose voltage is rectified by diodes, and then a direct voltage is transformed by inverters back to the alternating but with a frequency of 1000 Hz. This allows using compact transformers, and on the other hand, such a welding voltage has a low residual pulsation, which positively affects the quality of welding [10]. Current conductors are clamped to rails with the use of separate hydraulic cylinders. Current supply is carried out on the bottom part of the head and the top side of the foot of a rail. In the design of the robot, a flash remover with hydraulic cylinders is built-in. Cylinders load a welded butt joint in the direction of compression of a butt (according to the requirements of the standard EN14587-2



Figure 9. Machine B120AC

[3]) and do not need unclamping. A continuous contactless measurement of temperature of rails provides a precise cooling of a rail in accordance with a set temperature characteristic using pulses of repeated heating. The weight of the welding head is 5500 kg.

The welding robot welds rails laid in a string, and can produce closing and final welded butt joints.

There are three modifications of a welding robot:

- Machine for flash butt welding APT 1500 RA. This four-axle machine is built into a railway rolling stock of a standard design;

- ART1500RC is a container-type welding machine (Figure 8);

- ART 1500RL is a welding robot on the automobile platform. Moreover, the limit mass of the structure does not exceed 32 t for transportation on the roads of Europe.

The German Company **BAIDIN GmbH** produces rail welding machines for flash butt welding of rails [12]. The main products of this company is a container complex on the base of welding heads K355AM, which as to the kinematic scheme is identical to the machine K900A and B120AC (Figure 9), which as to its design is the same as K920. All these machines are based on the developments of PWI. For power supply of welding transformers, in this case power inverter transformers are used, which transform a three-phase voltage of a diesel generator into a single-phase sinusoidal voltage with a frequency of 50 Hz. According to the manufacturer, this solution provides a uniform load (without voltage unbalance) on a diesel generator plant and stabilizes the voltage of welding transformers. The upsetting force is 1200 kN, and the maximum clamping force is 2800 kN. The weight of the welding head is 3800 kg.

As to its design, the universal head A150DC for welding rails resembles a welding head ART1500R of the Plasser@Theurer Company and differs by the fact that it has eight clamping cylinders, which are arranged opposite one another relative to the longitudinal axis. Such a layout allows performing an accurate centering of rails during clamping, because the piston cavities of the counter cylinders are joined in pairs. Flashing of rails in it is carried out by a direct current using two rectified units. The travel of clamping cylinders is 250 mm, which allows performing the operation of “last welding”. The maximum clamping force is 4000 kN, the upsetting force is 1500 kN. The weight of welding head is 4200 kg.

In 2019, at the exhibition RailLive 2019, an induction welding machine of **Mirage Rail** Company was demonstrated, which was designed for Network Rail, Great Britain [13]. Unlike flash butt welding, in induction welding, the ends of rails are not heated until a molten metal and maintained in a solid state. Heating



Figure 10. Induction welding robot of Mirage Rail Company of rails is carried out throughout the whole perimeter by the currents of magnetic induction with the help of inductors. The power consumption is 150 kVA.

The device consists of a support [14], where two modules are built-in: movable and fixed. Each module includes three separate clamping heads and two heads of vertical lifting. Clamping and lifting heads are of a lever type with double levers. When designing the device, the attention was paid to the accurate alignment of rails in three projections. This is necessary to reduce the stress in welded rails during the process. After welding, flash remover built into the device is moved using two autonomous hydraulic cylinders and removes a flash.

The device is designed for welding rails CEN 56 and 60. The time of welding is 6 min, the mass of the device is 2200 kg (Figure 10).

Russian Company “Pskovelektrosvar” [15] is represented at the market by two mobile machines: MSR-80.01 (Figure 11) and MSR-12001A (Figure 12), designed for continuous or pulsating flash butt welding of rails R50 and R65.

Machine MRS-80.01 [16] consists of fixed and movable bodies. Each body contains power and electrode levers with different leverage systems. Power levers per-



Figure 11. Mobile machine MSR-80.01



Figure 12. Mobile machine MSR-12001.01

form clamping of rails. The clamping force is 2100 kN. Electrode levers perform centering of rail ends and supply current to the web of a rail. The upsetting force is 800 kN. The weight of the machine is 3800 kg.

Unlike MRS-80.01, in MRS 12001A [17] between the power and electrode levers, the combination mechanism is located, the levers of which are joined to the power levers, and the electrodes have the ability to rotate in two projections with self-positioning over the web of a rail and provide a reliable electrical contact. The mechanism of combination is designed to increase the accuracy of rail centering. Machine MSR-12001A can perform welding of rails with a tension with the flash removal directly after welding. The rated clamping force is 2800 kN, and the upsetting force is 1200 kN. The weight of the welding head is 3750 kg.

These machines are designed for operation in the composition of complexes of type PRSM.

The authors would like to draw the attention of readers to the new development of the PWI (Figure 13) [18]. The design feature of this machine is the fact that a number of axes joining clamping tong-type devices between each other was reduced from three to one. This allowed reducing a number of upsetting cylinders to one. The upsetting force of the machine is 65 kN. The machine is positioned as a machine for welding rails in hard-to-reach places, as well as for welding rails in the string in field conditions and on mobile rail welding plants. This machine requires

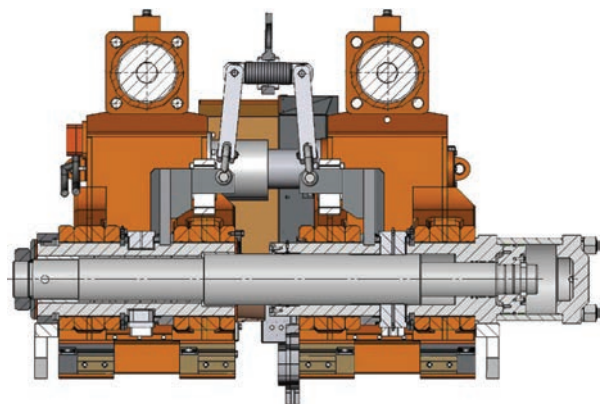


Figure 13. Universal rail welding machine

only a 215 mm gap to the nearest rail, which allows using it even for welding of switching transfers.

All mobile machines independently of the manufacturer have control systems that are manufactured based on an industrial computer and provide tasks and control of welding process parameters, providing the operator with up-to-date information on the technological process of welding with a subsequent issuing passport for each welded butt joint. Simultaneously in the built-in PC, the results of welding works are archived.

Therefore, modern technical products acquire the features of the investment project and a designer has a task not only to create the new equipment, but also to optimize expenses for all stages of manufacturing products, such as designing, development and manufacturing. The analysis of the gained experience of design and operation of welding machines allows outlining the further ways of improving and developing equipment designs, taking into account also economic components.

CONCLUSIONS

1. The trend of the development of the world market of rail welding machines is featured by an increase in the share of mobile equipment for using in field conditions during construction and repair of railways.

2. Mobile machines for welding rails vary by a kinematic scheme, according to which clamping and upsetting by centering and heating method of rails are performed. Each technical solution has its advantages and disadvantages.

3. Basic designing solutions of mobile rail welding machines, presented at the market, are developed at the PWI and used by domestic and foreign manufacturers of this industry, each of which improves individual assemblies and mechanisms in order to expand the technological characteristics.

4. The latest development of the PWI in the field of mobile rail welding machines is positioned as a machine for welding rails in hard-to-reach places, as well as for welding rails in the string in field conditions and at mobile rail welding plants.

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ORCID

D.I. Malysheva: 0000-0001-9058-1053

CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

D.I. Malysheva

E.O. Paton Electric Welding Institute of the NASU
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine
E-mail: dep26kb@paton.kiev.ua

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