ASSESSMENT OF RAILWAY TURNOUT ELEMENT RESTORATION USING MMA AND FCAW WELDING

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Abstract. Latvijas Dzelzceļš (LDz) (*Latvian Railway*) is restoring its railway turnout elements using MMA welding; however, even the elements restored following instructions developed by LDz have a short service life and the practice shows that shivers, separations and other types of damages of the renewed elements often appear even as soon as 1.5 months after the restoration. To evaluate the current practice and to establish the causes of problems, the restoration process in field conditions performed by welders of LDz was observed. After the observations made and the data collected were analyzed to prepare the conclusions and suggestions for improvement of the process. Furthermore, considering limitations of restoration with MMA welding, an additional experiment was conducted restoring the turnout element with FCAW. Both methods were compared and analyzed.

Keywords: quality of build-up welding, elements of railway turnout, metallographic examination, flux cored arc welding.

Introduction

There are 3200 railway turnouts in the infrastructure of Latvijas Dzelzceļš (LDz), a thousand of which are located on the main roads. 840 railway turnouts on the main railways are VARIO switches manufactured by the Austrian company VAE, which have better service properties as compared to the railway turnout elements manufactured in Russia and Ukraine. The sharpness of the frog core of the fixed frogs and wing rails, as well as ends of rails in connection points are exposed to particularly intense wear. The most frequent defects include the impact of locomotive wheels – skidding, separation, crumbling, flaking, wear of the lateral edge, etc. In 2009 the staff of the Institute of Railway Transport (IRT) of the Riga Technical University made a rail inspection and took photos of several tenths of frogs and rails with the aforementioned defects.

Railway turnout elements and rail ends in LDz are restored only the MMA method using welding equipment “PALLAS-403SX”. The restoration is performed in accordance with one of three instructions developed, namely: instruction C-013 of 28 January 1999 on restoration of rails [1], instruction C-016 of 5 January 2000 on restoration of rail blades and stock rails [2] and instruction C-020 of 8 February 2001 on restoration of railway frogs [3]. These instructions prescribe that restoration of worn and damaged surfaces must be performed using electrodes OK 86.28, OK 74.78, OK 83.28, OK 83.29, OK 84.42 produced by Esab. Each year LDz uses around 3.5 t of these electrodes and it is estimated that in 2015 Latvian Railway restored nearly 600 railway frogs and 2300 rail heads in joints.

Research quality of manual electric arc built-up welding of railway turnout elements

The research was made upon the order of LDz with a purpose to establish early damages of the built-up turnout welds. Irrespective of the fact that the welding is mainly performed according to the instruction requirements, the practice shows that shivers, separations and other types of damages of the renewed elements often appear. According to LDz statistics the welded layer serves from 1 month to 1.5 years, which is a very large interval and great difference of time taking into account that theoretically all elements are renewed according to the same technology and by observing the requirements of instructions. According to the statistics the weld of the turnout elements renewed for the second and third time has particularly short service life.

In 2009 LDz contracted the RTU IRT to clarify the reasons of damages of the restored turnout elements and rails with built-up welding, which were renewed pursuant to the instructions [1-3].

The following research stages were envisaged in LDz contract to establish the causes of damages of renovation involving built-up welding:

1. observation of the work of LDz staff while renovating the turnout elements and rails by built-up welding;

2. metallographic examination of the turnout elements restored by built-up welding;
3. description of the violations of LDz staff observed during renovation of the turnout elements by built-up welding;
4. upon their own initiative the staff of the RTU IRT made several experiments, which were not stipulated in the contract by using semi-automatic equipment and self-protecting flux cored electrode in renovation of the turnout elements by built-up welding.

At the beginning of November 2009 LDz staff revealed defects of the turnout No.3 in Garoza station, which had to be eliminated. The management of Jelgava Road distance decided to perform the first built-up welding of the turnout No.3 (which had VARIO frog) on 9 November 2009, where a wing rail with the wear of 3 mm and a 20 mm wide crack, as well as a frog core the wear of 6 mm were renovated (Fig. 1).

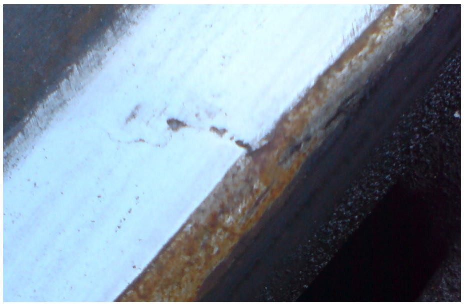

Fig. 1. **Defects of the frog core**

During the entire renovation process of the wing rail and frog core with built-up welding, the staff of the RTU IRT observed the renovation process and followed the instructions [1-3]. The observations in Garoza station continued during the second and third renovation with built-up welding of the turnout No.3.

The second built-up welding was performed 95 days after the first built-up welding in order to prevent the longitudinal cracks of the wing rail and core (Fig. 2). On 12 February 2010 the second built-up welding was carried out by applying the same technology and using the same tools and materials, which were used during the first built-up welding.

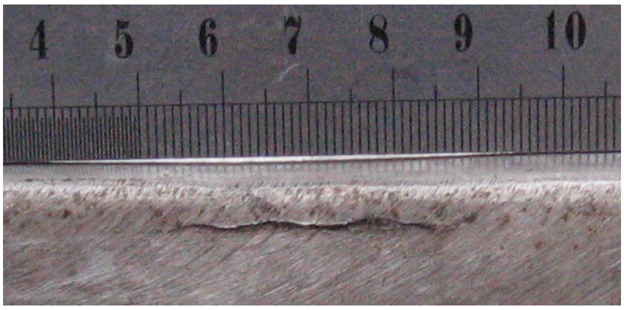

Fig. 2. **Longitudial crack after first build-up welding**

Same as during the first built-up welding, only observations were carried out during the second built-up welding without interfering in the welders’ work. At the beginning, built-up welding of the wing rail was performed and the following preparation works of the wing rail were carried out according to the renovation instruction: the crack was ground along the entire depth from the surface to be welded along the entire length.

In order to prevent the longitudinal cracks in the frog point and on the rolling surface, the third built-up welding was carried out in this turnout on 23 March 2010, namely, 39 days after the second built-up welding (Fig. 3).

After the third built-up welding just in 13 days the frog core was immediately replaced by a new one because longitudinal, penetrating cracks and shivers appeared in the frog core.

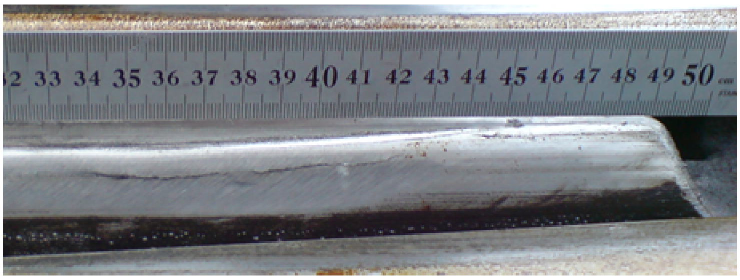

Fig. 3. **Longitudial cracks on frog point after second build-up welding**

Violations observed during the first built-up welding

1. During the first built-up welding of the frog core the welder made welds within the length of 250...300 mm. According to the instruction [3], when renovating steel with a high content of manganese by built-up welding, the welds should be made within the length of not more than 100 mm and the instruction that welding should be done from the opposite side each time was not observed. The welder performed built-up welding without making the frame welds, which must be made at the edges of the rolling surface of the frog core.
2. The amperage was not always chosen by the welder correctly. During the observations the welders chose the amperage 30A per 1 mm of the electrode diameter while welding the frog core by minimizing smoke release during the welding, although it is determined in the instruction [3] that built-up welding must be performed by choosing the amperage within the interval from 35 to 40 A per 1 mm of the electrode diameter.
3. Upon welding of the wing rail it should be remembered that the steel with the rate $C_{eqv} \geq 0.45$ is difficult to weld [4]. Wing rails are made of steel the C content of which is from 0.70 to 0.81 per cent. Such content of carbon determines the necessity to maintain constant temperature above 400 ºC but not less than 385 ºC during welding of steel because there is intense heat transfer from the rail. During the first built-up welding the wing rail was heated to 400 ºC, but afterwards it was not controlled and the temperature decreased to 250 ºC during the welding. At the temperature 250° - 270 ºC the welded layer forms a brittle martensite structure, which separates as a result of impacts of the rolling stock wheels and load [4].
4. While welding the frog core made of steel with a high content of manganese according to the instruction [3], it may not be heated more than 200 ºC so that not to change the austenite structure of this steel. By overheating above 200 ºC the steel loses its strength, hardness and wells form during the wheel load (Fig. 4).

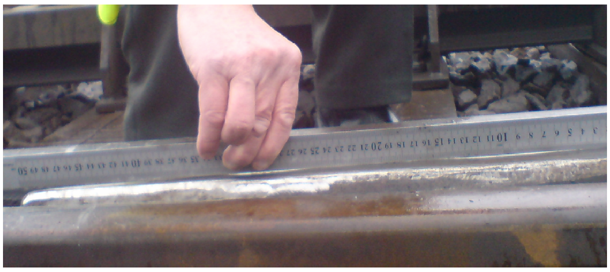

Fig. 4. **Wells formed during the wheel load**

5. The welders use non-contact laser thermometers for measuring the temperature of the welded object, which may misleadingly decrease the measured temperature by 20 ºC depending on the ray direction. That is very dangerous while welding the frog core where the temperature during welding may not exceed 200 ºC. Therefore, the temperature measurements during welding must be made with contact thermometers in order to determine the temperature of the objects precisely, which is particularly important when renovating the frog core.
6. One more reason of non-observance of the temperature mode is an insufficient “gap” – a time interval which is provided for the renovation works to be performed in field conditions. Therefore, the welders and grinders are in a hurry and do not meet all the requirements set in the instruction.

7. It was observed during all three renovations of the turnout No.3 that each time the welders supplement the electrode drying cabinet with new electrodes without using the existing electrodes as a result of which the electrode cover is overdried and the protective functions of its welding arc and crater are being lost. According to the standards an electrode may not be dried for more than twice, however, some parts of electrodes are dried for several times due to which the coating loses its capabilities to protect the welding crater from nitrogen and oxygen. As a result, iron nitrides Fe_4N appear in the welded material, which fix steel but considerably decrease plasticity and impact resistance. The nitrogen, which has not managed to connect to iron, is released from metal forms gas abscesses – pores [5].
8. Non-observance of the grinding temperature. According to the instruction the temperature during grinding may not exceed 70 ºC, especially while grinding the weld of the frog core. However, it was observed that the temperature during grinding reaches 90 ºC. By increasing the temperature above 80 ºC the material of the welded layer loses hardness, due to which wells form under the impact of the rolling stock (Fig. 4).
9. During the second built-up welding, which took place in February when the outside temperature was minus 3 ºC, it was snowing and gusty wind was blowing, the welder's post was not protected from the snow covering the welding area (Fig. 5). The humidity in the welding crater is the reason of the presence of oxygen and hydrogen. Oxygen reacts to iron and forms iron oxides, while the hydrogen forms pores by remaining in the welded metal. That all is the reason of appearing of cracks and spalling in the welded layer under the impact of the rolling stock wheels (Fig. 6).

Fig. 5. **Insufficient coverage of the welding area**

Fig. 6. **Spallings in the welded area**

Therefore, the welding area must be well protected with a high quality tent during snow and rain, while the gases releasing during the welding shall be discharged by means of a fan. Gas discharge from the tent is necessary so that the welder could see the welding crater well and had not to breathe gases.

After these observations a presentation was given to the LDz specialists during which the staff of the RTU IRT introduced their findings on violations of the welding process and explained their adverse impact on the weld resistance. As a result of this presentation LDz does not assign welders with average certification results to perform the renovation works of turnout elements by assigning less responsible works to them. Thereby, after welding of the first VARIO frog core and wing rail of the switch No.3 the service life of it has been extended by 157 days, namely, 5 months in the station Garoza.

During the second stage of the contract metallographic examination of the frog core and rail welds was performed in the laboratory of the RTU IRT, which is equipped with modern devices by cutting out 10 mm thick templates of the damaged frog core. This was carried out by using the cooling liquid in order to prevent increase of the temperature of the frog and the change of the material structure during sawing. Afterwards, thin cuts were made of these templates; their cutting was made by using the cooling liquid due to the same reason. The cuts were pressed in plastic forms, grinded and polished in order to make high quality metallographic research of the samples. The metallographic examination was made with a microscope and magnification from 50 to 200 times. During the metallographic examination inclusions and pores, non-fusion of the welded layer and basic metal were found in the samples of the damaged areas of the frog core, namely, poor quality of the weld, which is the reason of the weld damages of these elements.

During the metallographic examination it was established that approximately 25 % of the welded layers have poor quality and inclusions, pores, as well as other defects, but in general the welded layers have good quality (Fig. 7).

a) b) c)

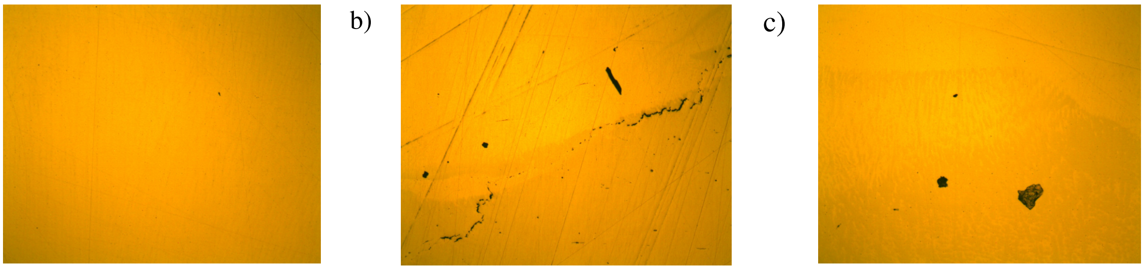

Fig. 7. **MMA welded layers (x100):** a – good fusion; b – non-fusion; c – inclusions

Considering the observations made during the restoration experiments with MMA described above and in search for more economic and effective solution for restoration of railway turnout elements, two additional experiments were performed restoring the railway turnout element surface with build-up with self-protecting powder wire and flux-cored arc welding (FCAW). During the experiment, which was conducted in premises, the frog point and frame rail were restored. When restoring railway turnout elements with FCAW using semi-automat the same instructions [1-3], which were used when restoring railway turnout elements with MMA, were used. Considering the specific chemical characteristics of each restored element, different wire marks were used for restoration.

When comparing FCAW with MMA, the economic benefits of FCAW must be noted. FCAW allows to perform restoration three times faster and twice as cheaper than applying MMA, especially in relation to use of materials (powder wire during FCAW is used entirely, while during MMA electrodes can be used only partially: only ¾ are used, while the remaining part is unusable). Furthermore, human work hours spent for FCAW are considerably less than for MMA [6].

Results and discussion

Metallographic examination was conducted for both types of performed build-up: MMA and FCAW, revealing good quality of the weld without inclusions, pores and with good fusion of the welded layer and base metal (Fig. 8). The main prerequisite for high quality build up is precise compliance with the technological process, i.e. maintenance of constant temperature during all welding process. During the experiments with the FCAW method the temperature of the frame rail was constantly monitored and the process was interrupted every time when the temperature decreased to 380 ºC. The rail was heated up again up to 400 ºC – 440 ºC. Considering that this prerequisite was complied with during the experiment, the quality of the weld was very good. Whereas, as evidenced by MMA experiments conducted earlier, if the temperature of the element falls below 300 ºC – 270 ºC, micro cracks can appear in the thermal heat area and the build-up layer thus causing the defects [7].

a) b)

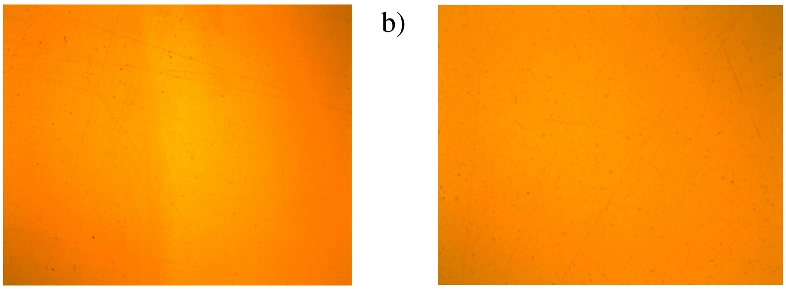

Fig. 8. **FCAW (with semi automat) welded layer (x100):** a, b – good fusion

Furthermore, welding with self-protecting powder wire ensures stable and metal spatter free arc. The shape of the weld is with good penetration and is smoothly coated, which excludes such welding defects as inclusions and pores, as well as slag impurities. The fast curing and brittle slag crust can be easily removed revealing smooth rutile weld. When applying spray arc defects characteristic of positional welding, as well as fusion defects and brittle slag can be eliminated. The chemical composition of the wire ensures fast drying slag that during positional welding with electrodes holds welding bath thus ensuring high metal investment coefficient that is not possible to obtain during welding with electrodes or monolite wire, thus causing it to become the most productive material that is well suited for hand arc welding in this position.

Conclusions

1. In order to ensure high quality restoration of the surfaces of the worn turnout elements and make a good fusion of the basic layer and built-up weld the requirements of restoration instructions involving built-up welding should be strictly observed during the entire renovation process.
2. Upon performing the restoration works in field conditions by welding the frog core and wing rails, the “gap” of three hours – the period provided for restoration during which one welder and one grinder work, is not sufficient. According to the observations in Garoza station the restoration period should last for at least four hours.
3. While restoring the railway turnout elements by built-up welding in unfavorable weather conditions the welders do not have sufficient tents or shields to protect the welding area from humidity.
4. Unlike MMA, FCAW does not form harmful substances by preventing the formation of inclusions in the welding area and a high quality fusion is made.
5. FCAW is more efficient than MMA because it ensures 1.5 - 4 times larger economy of materials and time, therefore, it is recommended to use the semi-automatic equipment and self-protecting flux cored electrode for renovation of the switch elements in stationary conditions.

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