

ULTRASONIC TESTING OF ALUMINOTHERMIC WELDED JOINTS OF RAIL TRACKS

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Resime The rails are an important and vital part of a railway system and are exposed, during service, to high stresses of different types, frequency and orientation and also to different environmental conditions. In Europe, rail quality and the acceptance criteria are regulated by international standard UIC 860 V, and EN 13674. The high external stresses are superimposed with the internal stresses, representing a serious load on rails and welding joints with the potential to extend existing flaws which may lead to rail fracture. In track, rails are joint, in generate, with aluminothermic welding process. The welds are weak points. Because, quality control of aluminothermic welding joints are very important. In this work, technique of aluminothermic welding of rails and quality control (special ultrasonic testing of welds are described). It has been found that by ultrasonic testing of rails, using different probes and frequencies, internal flaws such as cracks, non metallic inclusions can be successfully detected, and relevant examples are given.

1. INTRODUCTION

The rail tracks are extremely important part of the infrastructure of a railway system. Increase in the speed of trains, the axial loads of vehicles, the traffic density and ecological issues are intensifying the requirements for high quality of rails.

The quality of new rails is regulated by EU standard UIC 860 V - 1996 (four types of steel) and European Standard EN 13674 - 2003 (seven types of steels).

When in service, the rails are submitted to high internal and external stresses of various types, strength, frequency and direction.

The weak points on track are considered to be the welding points, which is the reason why the Long Rail (LR) is produced and installed.

The aluminothermic method is usually used for welding of the rails joints in service.

The welding of the rail tracks in service is required to be as short as possible in order to keep the disruption of traffic to the minimum.

The possible flaws that can occur in welded joints are of the following nature:

- human errors in execution
- deviation by chemical reaction and casting (metallurgical defects)

The rails have very complex configuration and its necessary to establish following:

- the critical points in cross section of the rail
- expected deviations (location, type and extent)

The ultrasonic testing represents the most suitable technique for discovering, locating and identifying the faults.

Some characteristic examples of the faults discovered by using ultrasound are included.

Also, in this work, technique of aluminothermic welding of rails and procedures of ultrasonic testing of welded joints of rails are presented.

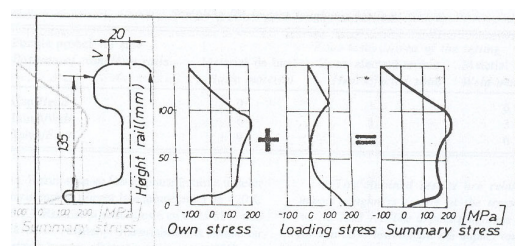


Fig. 1 Own internal stress and summary stress in the weld material

Figure 1 shows the disposition of own internal stresses, loading stress and summary stress in weld material over the rail height. The measurements of own stress have been carried out by measurement tapes finding in the area of rail foot and head the own stresses of axial direction.

2. ALUMINOTHERMIC WELDING OF RAILS

The basic principle on which the aluminothermic welding is based is the development of the chemical reaction of transforming the ferro oxides in iron. For chemical reaction development, the elementary aluminums, with affinity for oxygen stronger than iron, is used. The reaction is followed by the separation of the important amount of thermic energy. That means that the reaction is exothermic and the separated heat is used for the welding of the ends of two rails. The main chemical reaction is developed on following way:

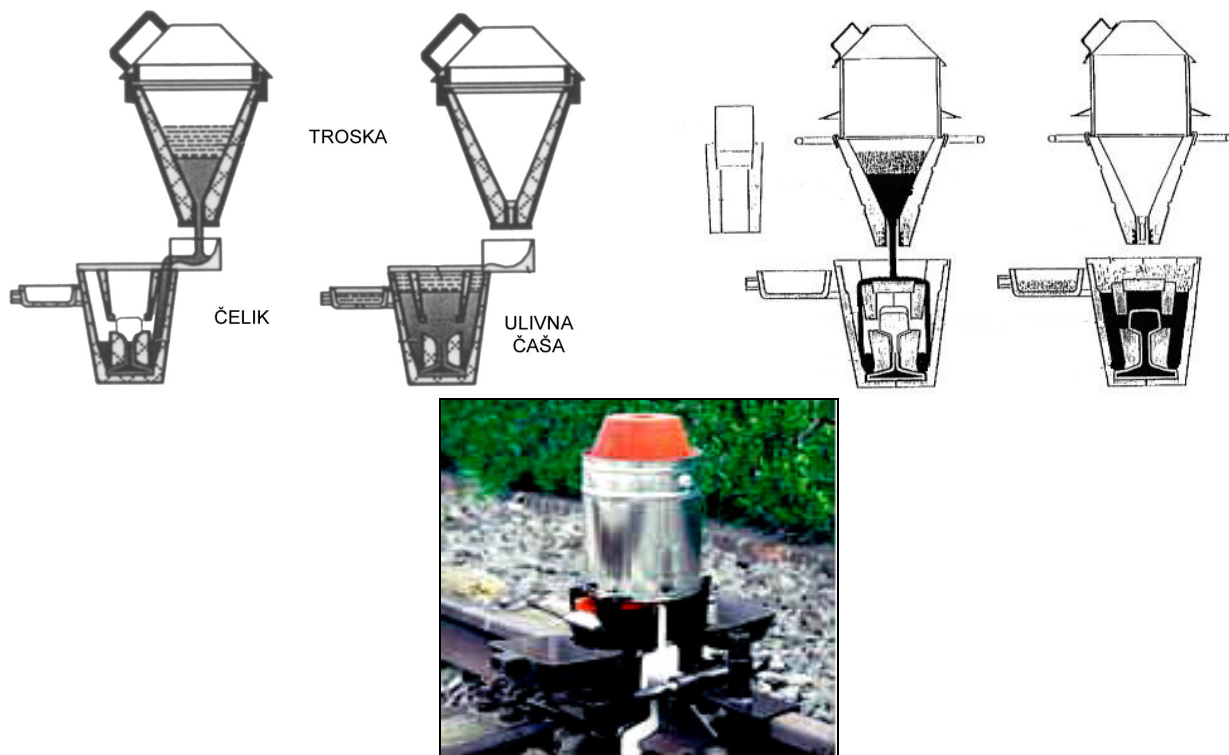
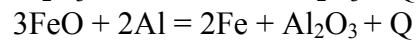
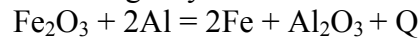


Fig. 2 Aluminothermic of rails (direct, indirect and ECO welding) [1]

In contrast to the gas and electro process of welding by melting, where the energy for melting of basic and additional materials is brought from outside, in this case the melting of basic materials is realized without the outside energy. In the mixture used for welding, the corresponding alloy elements are added depending on the rail type for which the mixtures are intended for.

To start the reaction it is necessary to provide so - called initial ignition. That means if the prepared mixture is ignited in "one point", the reaction will start with separation of important quantity of heat enabling the further reaction and the melting of rails ends. The process of reduction of ferro oxides is developed in melting pot, located above the welding pot. The pot is coated by fireproof material, the temperature in the pot increasing to 2200° C. During the mentioned process, the reaction products are iron and slag. The iron fall on the bottom of pot and the slag composed mainly of alumina oxides comes to the surface of pot.

It is necessary to provide the end of the chemical process, because in the contrary, the non activated part of the mixture with elementary aluminium could fall down in the interspace, space for welding and to disturb the compactness of the weld material. The distance between the two ends of rails is

also important because if this distance is not sufficient the error could occur - bad penetration or insufficient quantity of melt iron can not melt the contact parts of rails and do not provide the organic connection of weld material with the basic material.

Besides that, the important role has the quality of mixture preparation, as the enrichment of particular components in mixture, their purity humidity, etc. Before the carrying out the casting operation it is necessary to carry out the preheating operation of the rails end that should be welded. The period of time for rails and preheating depends on several conditions such as the type of rails, dilation distance, flame regulation as well as on the weather conditions.

The preheating of rails of normal quality is up to the temperature of 950° C, and for the rails of quality 900 A and 900 B up to 1050° C. If the aluminothermy welding is not carried out correct, in this cause can appear different faults.

There are different causes for it such as:

- add too big pieces of steel in aluminothermic mixtures;
- bad preparation of the pot;
- unsuitable distance between ends of rails;
- bad preheating operation of the rails ends;
- earlier beginning of casting i.e. before finish of chemical reaction;
- earlier taking off a mold;
- unsuitable post - welding operations;

After the ignition of the aluminothermic mixture the chemical process is realized with reduction of ferro oxides in the specially constructed pot (fig. 2).

The pot is coated with fireproof material. After the welding the weld is worked in two stages:

- rough working of weld in hot conditions
- fine grinding of weld.

After the fine machine grinding of weld the final working of weld is realized:

- cleaning from sand and cast (surplus);
- painting of welded joint by the mineral oil;
- providing of slow cooling of weld part of rail for obtaining of convenient microstructure.

3. TESTING OF WELDED JOINTS OF RAILS

Each group of aluminothermic mixtures needs be subject to following features:

- chemical analysis;
- ultrasonic testing;
- determination of strength properties;
- determination of toughness;
- determination of hardness;
- microstructure testing

If results of above mentioned examination are good in this case manufacturers can get suitable certificates.

In service each welded joints of rails are checked by visual and ultrasonic methods.

3.1 Ultrasonic testing

Aluminothermic welded joints have micro and macro structure of cast steel and in the same time, rails have structure of plastic deformation (pearlite steel).

After welding, it is carried out mechanical preparation surface of head of rails.



Fig. 3 Geometry of ultrasonic testing

Welded joints of rails have very complex forms as rails. Complex configuration of welds makes difficult to simply testing due to refraction and transformation ultrasonic waves.

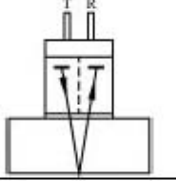
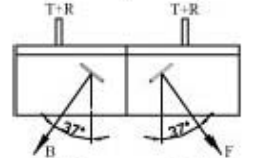
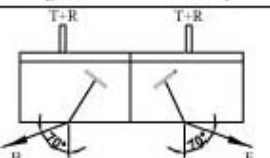
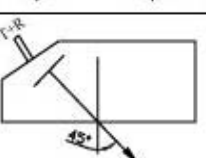
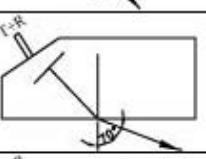
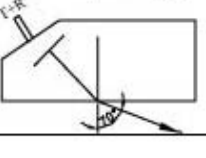
Sl. No	PROBE ANGLE	BEAM PATH	APPLICATION
1	0° 4 MHz DOUBLE CRYSTAL		1. LONGITUDINAL HORIZONTAL DEFECTS IN HEAD WEB AND FOOT
2	37° FORWARD (F) AND BACK WARD (B) 2MHz SINGLE CRYSTAL		1. STAR CRACK IN WEB (BOLTHOLE)
3	70° TORWARD (F) AND BACK WARD (B) 2MHz SINGLE CRYSTAL		1. TRANSVERSE DEFECTS IN RAIL HEAD
4	45° 2MHz SINGLE CRYSTAL		1. TRANSVERSE DEFECTS IN HEAD PORTIONS OF F.B. AND G.P. WELDED JOINT 2. HALFMOON DEFECTS IN A.T. WELDS BELOW WEB - FOOT JUNCTION
5	70° 2 MHz (20 mm CIRCULAR OR 20mm X 20mm SQUARE CRYSTAL) SINGLE CRYSTAL		1. DEFECTS OF A.T. WELDED JOINTS IN FLANGE LOCATION
6	70° 2 MHz SINGLE CRYSTAL (8 mm X 8 mm)		1. HALFMOON DEFECTS IN A.T. WELDED JOINTS IN FLANGE LOCATION BELOW WEB - FOOT JUNCTION

Fig 4: Detail of probes used for testing of rail and welds

In particular, examination should pay attention to critical areas, where the stresses concentration in welds is high and where possible defects may propagation and lead to fracture and stopped of traffic.

It is important to precisely those areas thoroughly investigate and detect any possible defects (fig. 3). Actually set the optimal geometry of the critical research areas.

It is important to know which types of defects can be expected. The most common defects are cracks, porosity, metal and nonmetallic inclusions (slag), blow holes (fig. 5).

Before each examination is necessary to determine sensitivity equipment, i. e. to determine the ability of detecting small defects.

Sensitivity is determined by the detection of artificial defects ($\varnothing$ 3mm), i.e. calibration ultrasonic system for testing.

It is used following probes (lead zincronate- titanate crystal) [8]

- normal (0°) 2 MHz, 18 mm. $\varnothing$ Double crystal
- 45° / 2 MHz, 20 mm. dia. or 20 mm x 20 mm (square) crystal size, Single crystal - 1 no
- 70° / 2 MHz, 20 mm. dia or 20 mm x 20 mm (square) crystal size, Single crystal - 1 no
- 70° / 2 MHz, 8 mm x 8 mm crystal size, Single crystal - 1 no
- 45° / 2 MHz probe.

This scan is used to inspect the bottom of weld foot to detect half moon shaped defect.

Place 45° / 2 MHz probe on the rail head surface at a distance equal to height of rail from the centre of the ATA weld.

In Figure 4 are shown schematically probes and wave propagation directions depending on the place of search (head, neck, foot) and that defects is usually reveal. (probe angle, beam path and application).

Also, give examples of defects found by ultrasound. After a certain time some defects were discovered adequate in visible cracks (fig. 5).

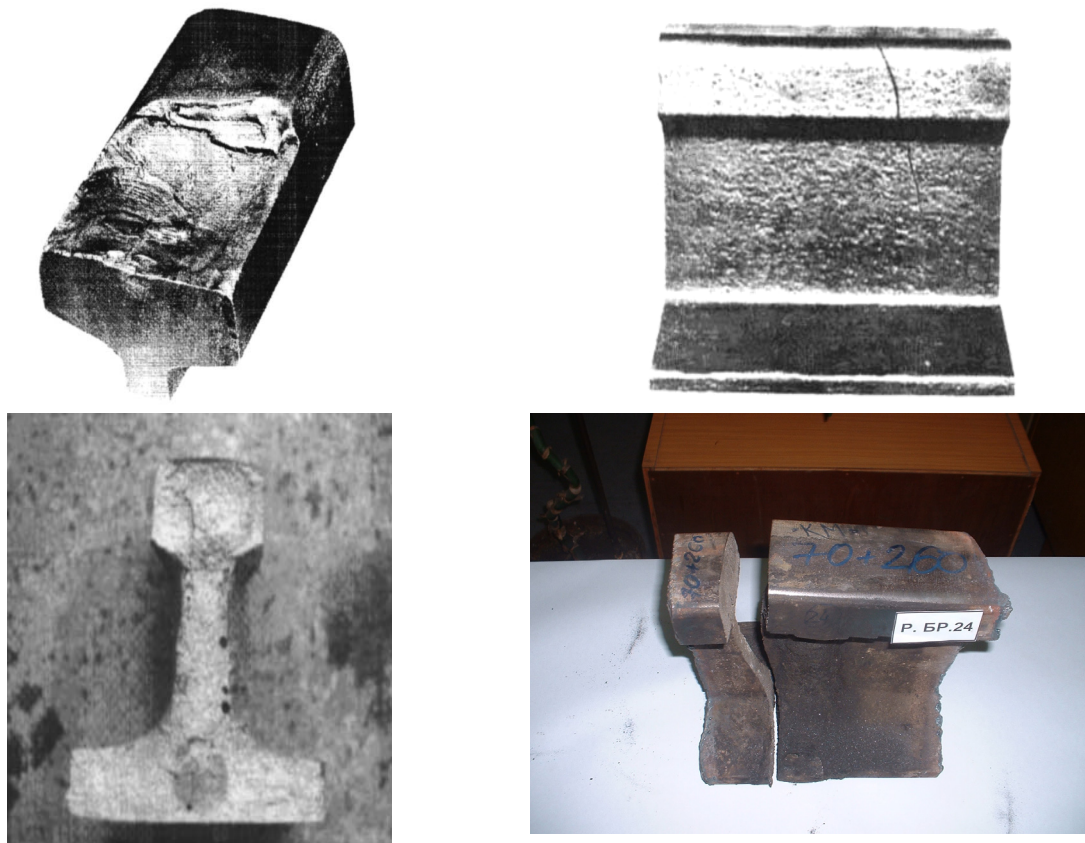


Fig. 5: Examples of fractures of welded rails

4. CONCLUSIONS

Based on literature data and own research can be concluded the following:

- Rails are very important part of the railway infrastructure
- During the exploitation of rails are exposed to large stresses of different types, frequency and direction
- Quality of rails is regulated by the standards of the International Union of Railway UIC 860 (four types perlite steels) and the European norms EN 13674 (seven types perlite steels)
- Welding of rails in the tracks is done in two ways:
 - aluminothermic welding
 - electrical - resistant welding
- In this paper, quality of welded rail joints aluminothermic procedure is described
- It is very important that the quality of mixtures for welding corresponds of types and class of rails
- Basic types of faults in aluminothermic welds rails can be following:
 - faults occurring in the welding process mistake
 - metallurgical defects (error in casting)

The most common defects are cracks, porosity, metal and nonmetallic inclusions (slag), blow holes

- Ultrasonic testing is the most suitable method of determining the homogeneity of welded rails joints

- It is recommended that the sensitivity of ultrasonic system (apparatuses, cables and probes) determine with artificial faults $\varnothing$ 3 mm (head, web, foot)

- For ultrasonic testing is used straight beam unit and angle beam unit (40°, 60°, 70°) frequency 2, 4 MHz

5. LITERATURE

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