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ANALYSIS OF FACTORS AFFECTING FRACTURES OF RAILS WELDED BY ALUMINO-THERMIC WELDING

Summary. On Latvian Railway the use of the alumino-thermic welding is widespread using the Elektro-Thermit Company technology. Today it is a basic method for rail joints on railway switches. The analysis of the metal structure in the thermic welding and in the thermic welded zone of rails showed that the weld metal had inclusions small pores and nonmetallics. Pores and nonmetallics are not reduce hardness but it is concentrators of stresses and sources of cracks development.

АНАЛИЗ ФАКТОРОВ, ВЛИЯЮЩИХ НА ИЗЛОМЫ РЕЛЬСОВ, СВАРЕННЫХ АЛЮМИНО-ТЕРМИТНОЙ СВАРКОЙ

Резюме. На Латвийской железной дороге, использование алюмино-термитной сварки широко распространено, используя технологию фирмы Elektro-Thermit. Сегодня это - основной метод для сварки рельсов на железнодорожных стрелочных переводах. Анализ металлической структуры в термитном сварнном шве и околошовной зоны рельсов показал, что металл сварки имеет малые поры и неметаллические включения. Поры и неметаллические включения не влияют на твёрдость сварного соединения но, являются концентраторами напряжений и источниками развития трещин.

To heat metal during the (alumino) thermic welding process, a powdery mixture of metallic aluminum (Al~22%) and iron scale (Fe_3O_4~78%) is used as a thermite.

The thermic welding of rails is carried out in the following sequence: a mould is placed on the rails to be joined; a crucible is mounted on a special bracket; a portion of thermite is charged; the rail ends are pre-heated and thermite is ignited by a special ignition primer. After a thermic reaction has been completed (20-25 s), a crucible plug is open and thermic steel in the liquid state is discharged into the mould. During the process of fused thermic steel casting into the joint gap, the rail ends are penetrated and welded. On completion of steel crystallization (3-5 min), the equipment is removed, the fin is trimmed and the welding joint on the rail head is grounded.

During the process of oxidizing, aluminum is able to release 378 kcal/mole of heat, while 198.5 kcal/mole are absorbed to reduce iron Fe from oxide Fe_2O_3. During this reaction 179.5 kcal/mole difference of the heat balance is obtained which is used for welding. Thus during the process of thermic reaction aluminum reduces iron oxides Fe_2O_3, Fe O – Fe forming iron and the components in the crucible are heated up to 2600^0C.

On Latvian Railway, the use of the thermic welding is widespread using the Elektro-Thermit Company technology. Today it is a basic method for rail joints.

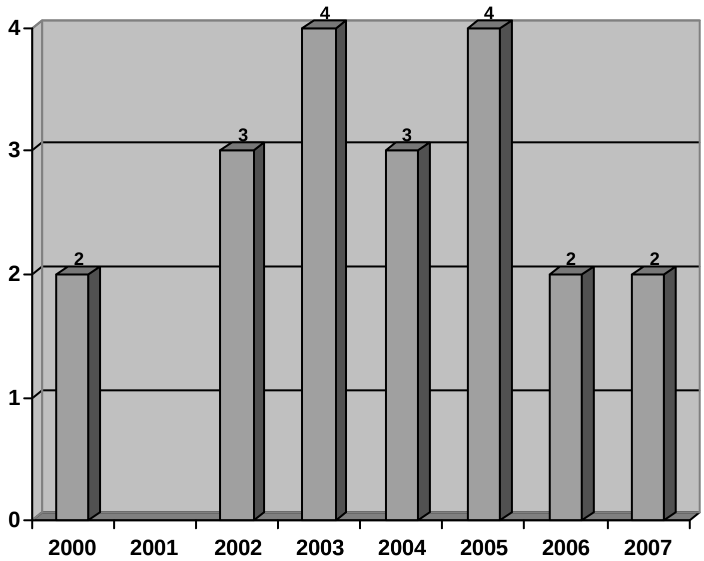


Fig. 1. Thermic weld fracture on Latvian Railway
Рис. 1. Изломы термитной сварки на Латвийской железной дороге

Experience of the operation of rails welded by the thermic welding showed that every year occur from 2 to 3 fractures of thermic joints on the main tracks between stations of Latvian Railway. In more cases these fractures of thermic joints are as shown in fig. 2.

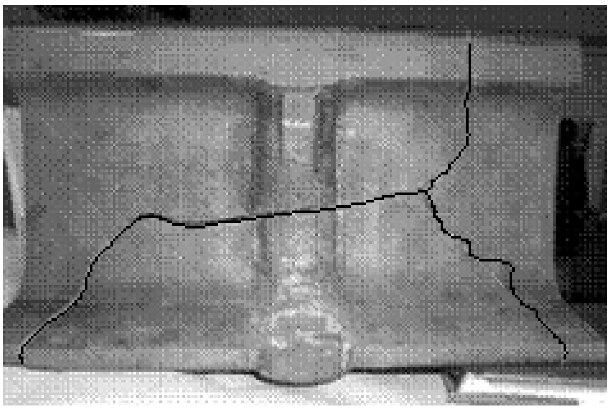


Fig. 2. View of a thermic weld fracture
Рис. 2. Вид излома сварного термитного шва

For the purposes of revealing stresses in the thermic weld, some scores were made transverse to the thermic weld along the horizontal axis of 6 rails 1.2 m of length with thermic joint in the centre.

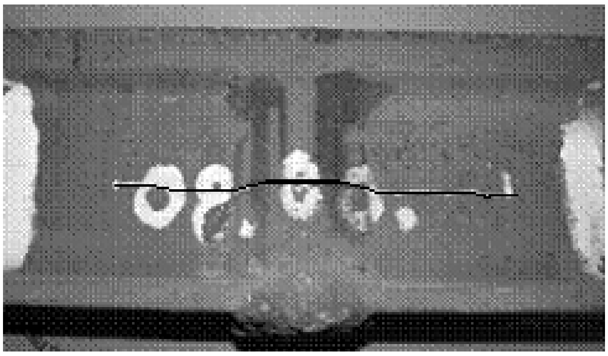


Fig. 3. View of a thermic weld score and cracks revealed
Рис. 3. Вид надпила термитного шва и появившейся трещины

Rails for test were removed from the main railway network in service for more than 1 year. Continuous welded rails were welded using volumetric tempered rails P65 and UIC60 type with unhardened foot. All 6 rail joints welded by the thermic welding had through cracks of 200-300 mm of length on both sides of the weld joint alongside a score (see Fig. 3). No load was applied to the rails with scores made on the lugs of the weld joint.

Such emergence of cracks in the weld joint alongside the scores indicates of great residual stresses in the weld joints made by the thermic welding.

In order to reveal the causes of fractures of the rail thermic joints, an analysis of the weld metal structure at the fractured thermic joints was carried out. For the purposes of the metal structure analysis, the section metallographic specimens were cut out from the thermic weld in the region of the rail head, web and foot.

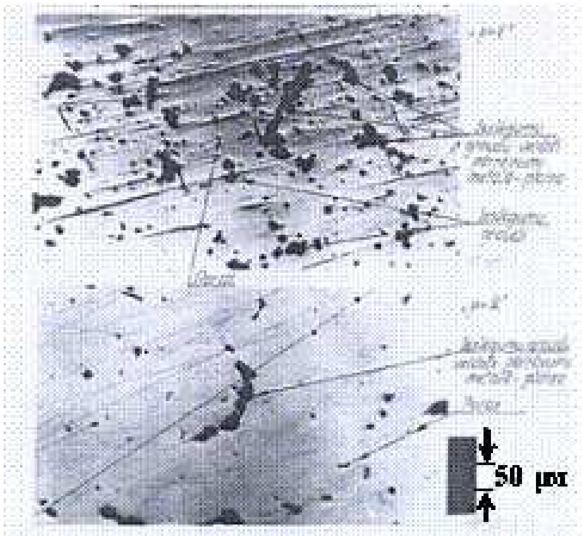


Fig. 4. Structure of the thermic weld metal in the rail head
Рис. 4. Струтура металла термитного шва в головке рельса

The analysis of the metal structure in the thermic welded zone of rails showed that the weld metal had inclusions of iron oxides infused (FeO, Fe_2O_3, and Fe_3O_4) and small pores (see Fig. 4). The emergence of pores was caused by ingress of moisture into the thermite during the welding process on rails. Pores and infused oxides are concentrators of stresses and sources of cracks development. Pores and infused oxides reduce hardness of the weld joint under the action of tensile forces.

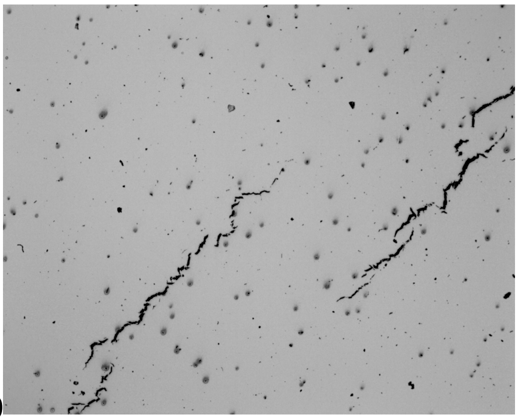
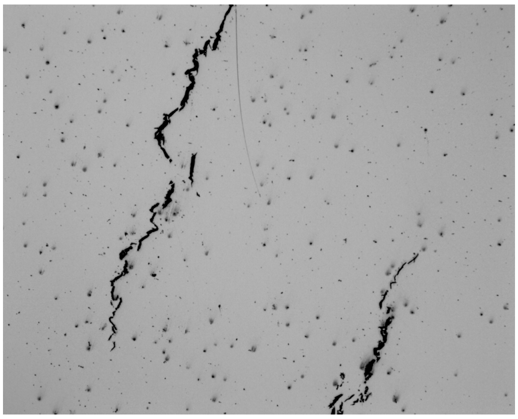
a)  b) 

Fig. 5. Cracks in the structure of the rail, 5x
Рис. 5. Трещины в металле основного рельса, 5x

The analysis of the thermite structure showed that some elements of iron scale Fe_3O_4 and Fe_2O_3 have dimensions of 5-6 mm (Fig. 6), while, according to the standard, their dimensions should not exceed 1-2 mm.

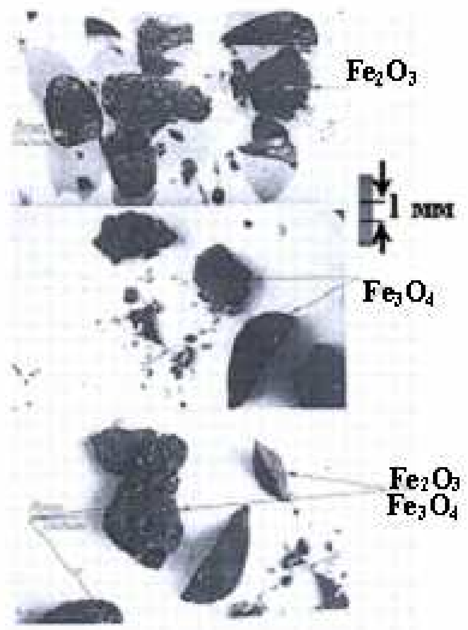


Fig. 6. Structure of the thermite
Рис. 6. Структура термита

Only at such conditions iron oxides have time to fuse at the temperature of 2600^0C. Just iron oxides remaining in the weld joint originate cracks formation in the weld metal and reduce its strength.

As a result of the examination of the factors which affect joints fractures of the rails welded to the thermic welding, the following was established:

- high internal residual stresses are concentrating at the zone of the thermic joint in volumetric tempered rails,
- there are pores and infused iron oxides in the thermic weld which originate cracks formation and reduces weld strength,

- some part of iron oxides (FeO, Fe_2O_3 and $Fe_3O_{4)}$ of the thermite produced by the ELECTRO-THERMIT Company have dimensions of 5-6 mm and not always may be fused during the thermic welding of rails.

Bibliography

1. Sliežu termīta metināšana. Tehniskie noteikumi., Rīga, 2002.
2. Malkin B.V., Vorobjev A.A.: Termitnaja svarka. Moscow, Mashgiz, 1963.

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