Engineering Failure Analysis 85 (2018) 97–103

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Embrittlement of welded joints of tram rails in city environments

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ARTICLE INFO

Keywords:
Welded joints
Tram rails
Environments
Thermite welding
Brittle cracking
Fracture testing

ABSTRACT

This paper concerns the issue of cracking of thermite-welded tram rails. The work presents cases of rail cracking revealed directly after welding or after a short period of track operation. The results of static strength tests, resistance to brittle cracking tests, microstructure and chemical composition examinations of a rail that cracked after thermite welding are discussed. It is emphasised that the main cause of occurrence of cracks in the area of rail web is thermal (welding) stresses. Non-metallic inclusions, the presence of hydrogen in the rail and the influence of an active environment were pointed out as factors conducive to the occurrence of brittle cracks.

1. Introduction

Railway and tram rails have been thermite-welded for over one hundred years. It was in the last year of the 19th century that tram rails were first welded using this method; five years later, the same was done with railway rails [1]. Such order of events is not accidental – tram rails are more stable and are subject to lower loads than railway rails, also, vehicles travelling on tram rails develop lower speeds than those travelling on railway rails. Despite considerable development in the realm of thermite welding of rails, especially in terms of rail material, thermite mixtures, welding technology, equipment and weld control [2–4], the instances of rail cracking still occur in the course welding or rail operation [5–6]. Fig. 1 shows two fragments of tram rails with welded joints, cut out of a newly built track. Halfway the height of the rail web, one can see a horizontal crack (Fig. 1a). The crack was discovered right after thermite welding of the track. The crack in the joint shown in Fig. 1b is located in the very same place. This crack was discovered in the course of rail operation. Originally, an attempt was made to fix the joint. The crack was welded, and openings were drilled at its ends. In the end, the joint was cut out of the track. Such cases are not incidental. For instance, around the turn of the year 2015–2016, the traffic was being repeatedly held up at newly build tram lines in three Polish cities – Łódź, Olsztyn and Szczecin – because rails cracked under a passing tram. Fortunately, no passenger suffered any harm. However, after these events, non-destructive tests were conducted all along the trackage and they revealed over 200 cracks in total. In each of the cities, the cracks were horizontal for the most part and located more or less halfway the height of the rail, at the spot where the rails were welded. These incidents inspired the authors to undertake research on the reasons why thermite-welded tram rail crack. The findings presented in the article concern the rails used in Szczecin.

2. Item and method of testing, samples

While constructing a trackage, rails that are 18 m long are permanently joined together by means of welding, e.g. thermite welding, which produces a jointless tram track. Such a track ensures passenger comfort while riding on a tram. Unfortunately, welded

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https://doi.org/10.1016/j.engfailanal.2017.12.011
Received 1 June 2017; Received in revised form 10 September 2017; Accepted 6 December 2017
Available online 07 December 2017

Nomenclature

R_m	tensile strength
$R_{p0,2}$	yield strength
A	elongation
HBW	Brinell hardness
K_{Ic}	fracture toughness
P_q	tensile force
M_b	bending moment
HAZ	Heat Affected Zone

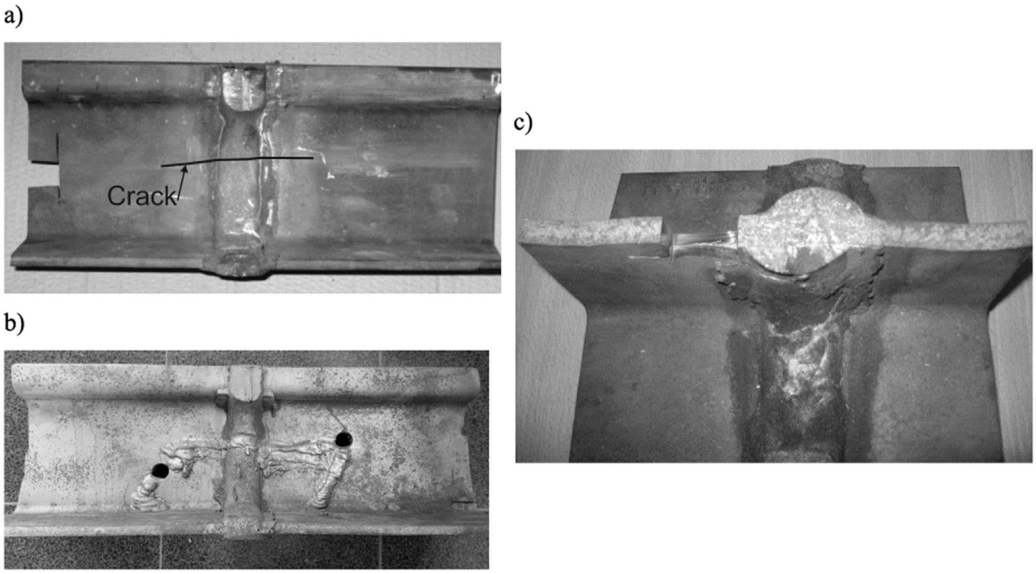

Fig. 1. Sections of grooved tram rails: a) cracked right after thermite welding, b) cracked in the course of operation, c) bottom surface of the rail crack (Fig. 1a).

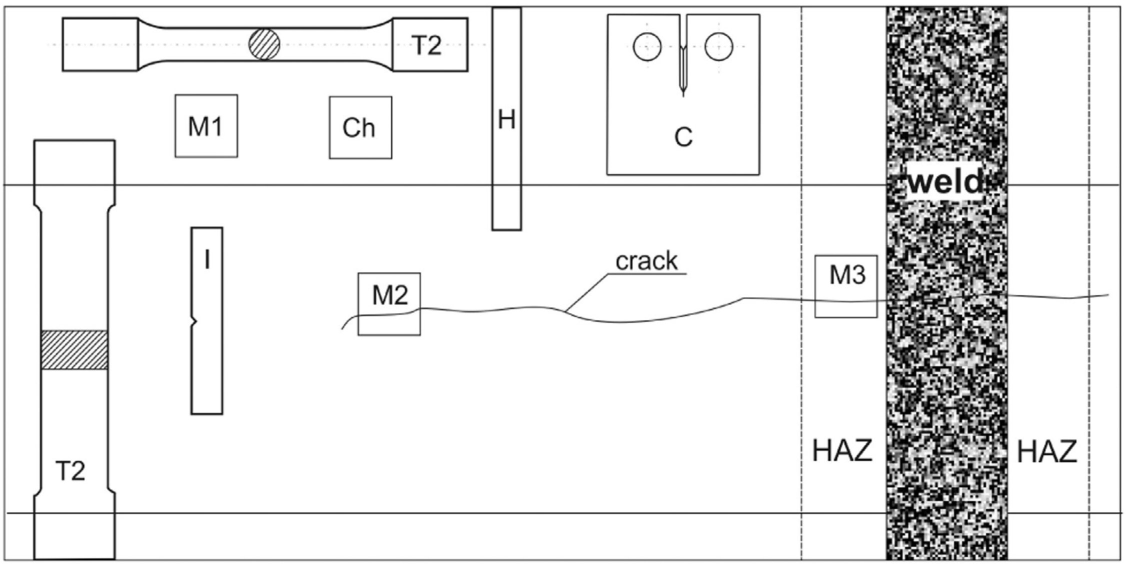

Fig. 2. Test sites for testing the properties of the R260 steel tram rails.