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Some comments on mechanical fatigue characterization of steel rails in Standards

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Abstract

Current Standards and recommendations on characterization of steel materials for rail production define tests for material supplying. As reported in technical literature, fatigue is the phenomenon which represent one of the main cause of rail damage and failure. Experimental testing of fatigue characterization according to Standards on different samples and with different surface roughness values, satisfying the Standard requirements, are performed. The results are then presented and discussed. Some nomenclature ambiguities are pointed out, which can lead to different loading conditions for fatigue testing.

Keywords: Fatigue; rails; Standard; Roughness

1. Introduction

Current international standards and recommendations on acceptance and qualification of materials for railway applications, and in particular for rails EN 13674-1 (2010), describe tests to characterize material and components supplies. Different Standards sometimes agree, sometimes do not and in some parts are ambiguous.

In these standards both the supplying requirements and testing are described.

For example in ASTM A1 (2010) dealing with material acceptance, chemical characterization and hardness measurements are required.

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In qualifying tests more requirements are prescribed.

The Standard EN 13674-1 (2010), defines the qualification requirements about the number of specimens, geometry and dimensions, where specimens are to be obtained in rail volume, test procedure and result processing. They consist in fracture toughness, fatigue crack growth rate, fatigue tests, residual stress measurements, geometrical parameters, hardness measurements, tensile strength and elongation, chemical parameters and surface quality.

The Standard ASTM A1 (2010) is referred to T steel tee rails. The requirements are limited to chemical composition, internal status, hardness and geometrical parameters. Control techniques are optical checks, hardness tests and ultrasounds.

Standard ISO 5003 (2016) indicates terms and definitions, dimension tolerances, technical requirements, inspection rules, identification, certification, for as-rolled and heat-treated steel rails for railways and is similar to EN 13674-1 (2010).

It must be noted that neither in AREMA (American Railway Engineering & Maintenance-of-Way Association) specifications AREMA (2010) nor in ASTM, specific Standards were found related to fatigue resistance of materials for railway applications, while these requirements are well defined for European Standards, even if in AREMA (2010), Lewis and Olofsson (2009) and other documents it is well documented that fatigue is one of the main cause of failure and damage of rails. In particular rolling contact fatigue, friction, thermal fatigue, wear are mentioned as the main failure causes for rails.

In Lewis and Olofsson (2009) it is described how rail fatigue and wear depend on the repeating contact loads. According to the authors, the main factors differentiating wear and fatigue of rail-wheel contact from failures in other mechanical components are that the cyclic loads are compressive. With gears, rails share highly concentrated non-conformal contacts, and the surfaces experience combined rolling and sliding relative motion.

Topic of this paper is pointing out some critical hints present in fatigue qualification tests Standards for rails.

Aim of the paper is to propose some modification to avoid ambiguities in interpretation and to improve qualifications of the materials for what concerns the definition of surface finish of specimens undergoing fatigue loading and the corresponding definitions of fatigue loading parameters.

2. Standards review

The first hint related to the EN 13674-1 (2010) is in the definition of qualification fatigue tests procedures: the nomenclature used in the definition of testing procedure is not univocal. The first point consists in that EN 13674-1 (2010) asks for “constant amplitude fatigue tests” to be “carried out in accordance with ISO 1099” (that is ISO 1099 (2006)) while a few lines later it states that “ the control variable shall be axial strain amplitude” requiring for a defined “total strain amplitude” to be applied to specimens. Actually, ISO 1099 (2006) requires stress controlled fatigue testing and defines how to apply stress to the specimen.

In EN 13674-1 (2010) neither the term “constant amplitude fatigue tests” is defined nor the term “total strain amplitude” and in the list of reference Standards no reference is given for the corresponding definitions. In ISO 1099 (2006) more definitions are available.

In §3.9 ISO 1099 (2006) the stress amplitude is defined as “one-half the algebraic difference between the maximum stress and the minimum stress in a stress cycle”, while in §3.10 ISO 1099 (2006) the stress range is defined as “arithmetic difference between the maximum and minimum stress”. The Standard then reports a figure which is not coherent with these definitions. On the other hand, these definitions correspond to the ones of ASTM E1823 (2013).

The ambiguity related to the definition of “constant amplitude” fatigue tests can be clarified thanks to §4.1 ISO 1099 (2006) where, in stating the general outline of tests, the Standard lists the possible test aims in which the “fatigue life at a specified stress amplitude” is reported.

To further clear the ambiguities related to the terms “amplitude” and “total strain” let us refer to other Standards about fatigue testing of steels.

ASTM standards gather many definitions in ASTM E1823 (2013) helping to clarify some terms.

For example, constant amplitude fatigue loading is defined as “a loading (straining) in which all of the peak forces (strains) are equal and all of the valley forces (strains) are equal.” Also force (load or strain) fatigue amplitude