International Journal of Advance Research in Science and Engineering
Vol. No.5, Issue No. 04, April 2016
www.ijarse.com
IJARSE
ISSN 2319 - 8354

FATIGUE ANALYSIS ON STEEL RAIL SECTION

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ABSTRACT

Fatigue analysis and crack propagation ina 52kg standard rail section (used for Broad Gauge tracks in Indian Railways) is carried out under the axle load of 28.56 tonnes(maximum axle load for broad gauge) with the help of CASCA and FRANC2D. Results are useful for estimating the fatigue life of the rail and to estimate the length of the crack at the end of the life.

Keywords: 52kg standard steel rail section, CASCA, Fatigue, Fracture Mechanics, FRANC2D.

I. INTRODUCTION

Railways are an important lifeline to any country's economy, thus it becomes important to avoid accidents and keep their running smooth. One of the major reason causing accidents is rail failure, which make it imperative to maintain good condition of rails. Rail failure before their expected life is generally caused due to unnoticed propagation of crack at the junction of foot and web under cyclic loads, thus the fatigue analysis and crack propagation of the rails become a necessity. Rails laid in the grade of 1:20 are subjected to heavy bending force causing simultaneous tension and compression. In this paper a Fracture Mechanics based approach is adopted for the determination of the crack length versus number of cycle using Paris' Law for a 52kg standard rail section.

Fracture mechanics is a branch of solid mechanics that deals with study of stress and strain fields around existing cracks in a structure and tries to describe the behaviour of the structure under effect of existing and propagating cracks. A structural component may fail under the effect of cyclic loads which may be of much smaller magnitude than the static failure loads. Such a failure of a component is termed as fatigue failure.

Fracture mechanics however has a drawback in that it requires an existence of a crack in structure. Thus, if a new structure is to be designed, a probable location and size of the crack must be anticipated in order to employ the principles of fracture mechanics; and thereby understand the crack propagation behaviour. The probable location from where the crack may emanate are called hot-spots. The determination of hotspots is vital for accurate description of fatigue failure in structural components. Since the analysis is carried out using finite element method, the crackpropagation problem becomes mesh sensitive.

Fatigue is degradation of material and subsequent crack propagation under the influence of repeated cyclic loads on a structure. Commonly, the fatigue of a component can be described by the well-known Paris' law (Dahlberg and Ekberg, 2006) [1]. Paris law requires two material constants for characterization of the crack propagation behaviour; viz., m and C. Experiments are required for determination of m and C (Anderson, 2005) [2]. Alimitation with the Paris' law is that it describes the crack propagation phase, but the description of crack initiation phase must be done either by experimental observation or by other appropriate fracture models (Prashant Kumar, 1999) [3]. Pungo et al. (2006) [4] extended the Paris' law to take into consideration some of the deviations from the power-law regime using SN curves for materials. This approach is suggested to be more generalized from of Paris' law and may be more suitable for fatigue characterization.

FRANC2D has been adopted here for the computational simulation of crack growth. The aim of present study is to estimate the fatigue life and the length of the crack at the end of the life.

II. MODELING AND ANALYSIS

Thedetails of a typical52kg standard rail section considered for the current study is as per Fig.1 where, R is the radius of the arc and all dimensions in mm [5]. The details of the figure are modeled using CASCA. The rail is considered to be isotropic and having Young's Modulus of Elasticity E = 2 × 10^5 MPa.The CASCA modelis as shown in the Fig.2.

For the determination of the location from where the crack may emanate, a preliminary analysis of the joint has been carried out. The finite element mesh of 6-noded linear strain triangular elements along with von Mises equivalent stresses computed using FRANC2D have been shown in Fig.3. FRANC2D is a two dimensional, finite element based program for simulating crack propagation in planar structures. The von Misses equivalent stress values in the plot are in MPa. The critical location of crack was recognized from the plane stress in Y-direction at the junction of foot and web of the rail, shown encircled in the Fig.3.

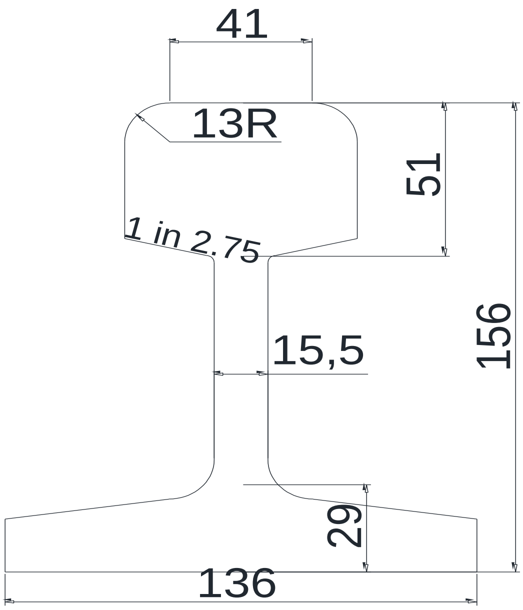

Figure 1:Schematics of 52kg standard rail section

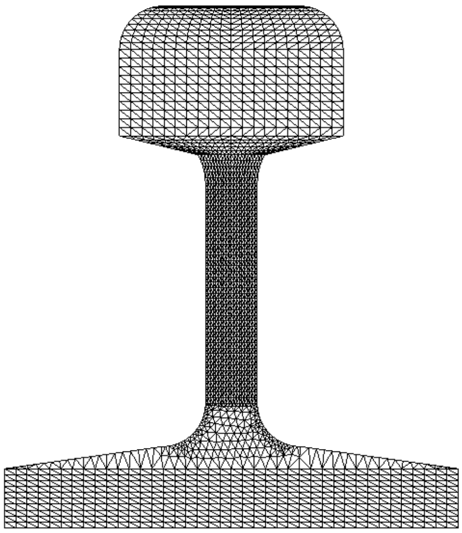

Figure 2: CASCA model

After finalizing the location, initial crack of length 0.25mm was introduced at the location. The material properties and Paris' law constants used for the rail section are: modulus of elasticity (E) = 200000 N/mm^2, thickness = 1mm, Fracture toughness KIc = 29[6], m = 3 and C = 10^{-12}[3].

The crack was propagated in FRANC2D simulation and the initial and final configuration if crack is as shown in Fig.6.

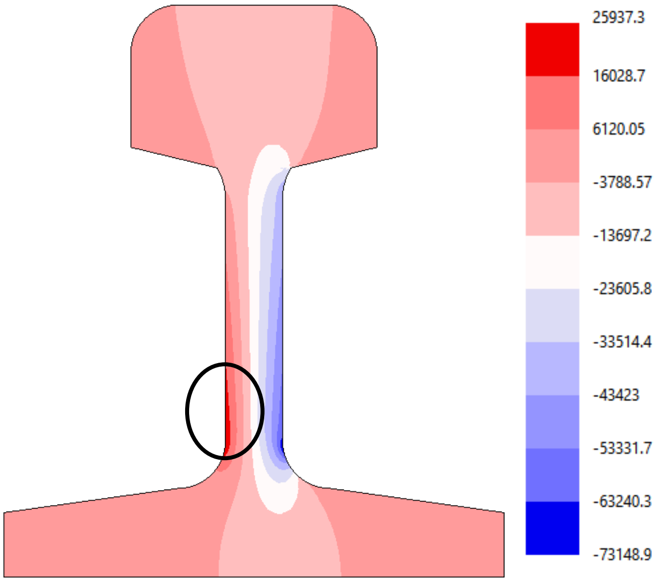

Figure 3:Stress contours of plane stress in Y-direction (non-cracked section)

As shown in Fig.4. the crack moves horizontally and then take the vertical path as the compression regime is encountered.

The crack propagation simulation is carried upto 20 mm. Of course the rail should not be taken in service till such large crack length and would be ideal to change after 7mm length of crack i.e. 17×10^7 cycles (Fig.5)

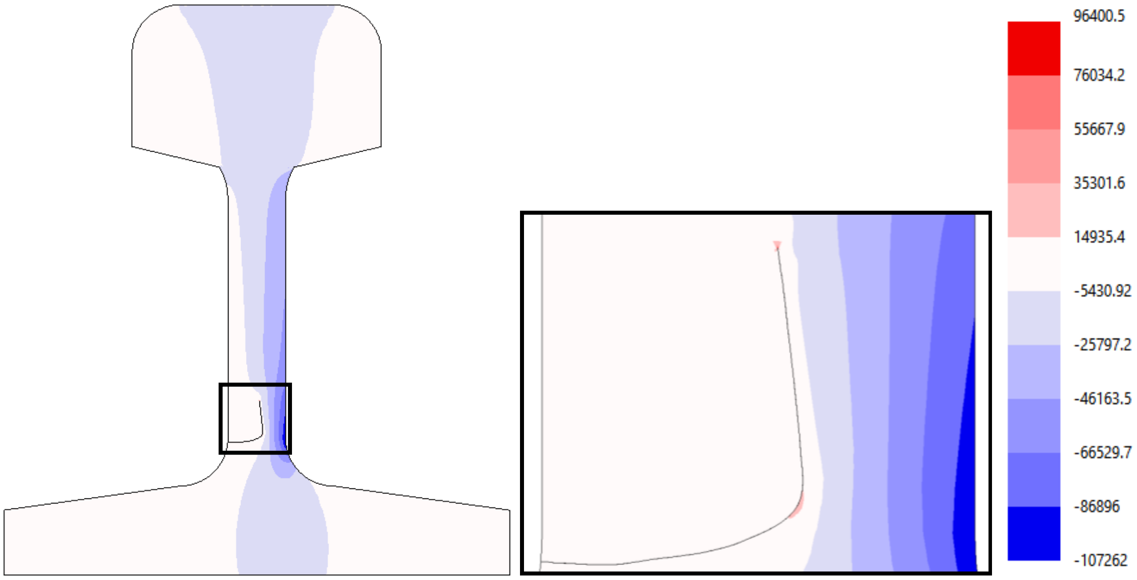

Figure 4. Stress contours of plane stress in Y-direction (cracked section)

The decision whether this life span is sufficient depends upon GMT (Gross Metric Tonne) of the particular region.

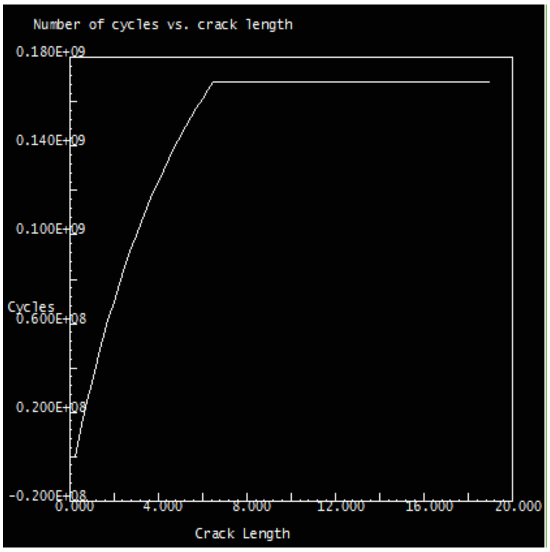

Figure 5. Crack length v/s Number of Cycles

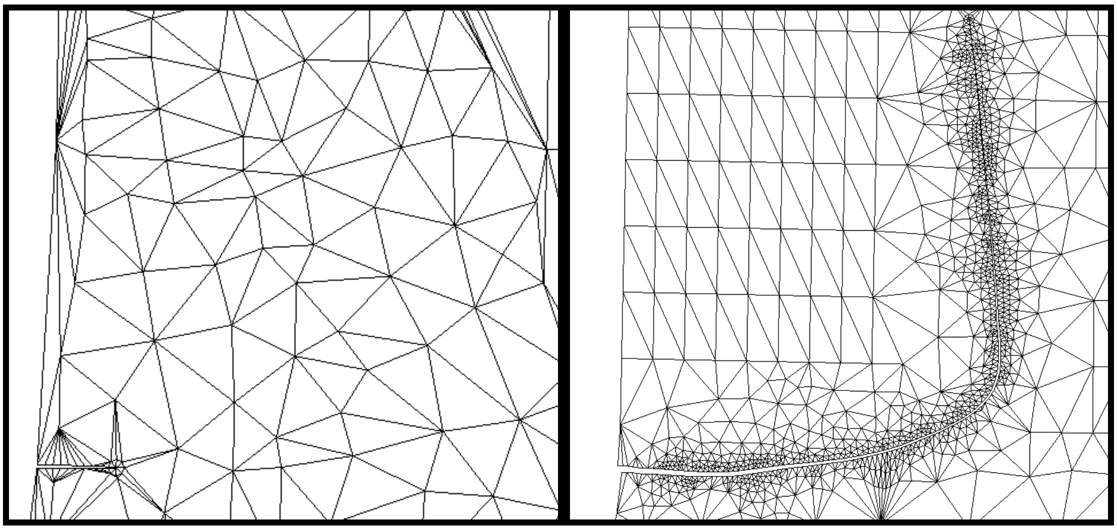

Figure 6. Initial and final configuration and crack.

III. CONCLUSION

The above fracture mechanics analysis gives a clear picture of the fatigue life in the rail section. The process of analysis using FRANC2D is found to be successful for rail section. Fracture based analysis should be adopted in the design procedure for clearer description of crack propagation and estimate of life of the rail section.

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