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Stress Analysis on Behaviour of Rails

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Abstract : It is axiomatic to say that the rails used nowadays have been subjected to heavier axle loads and high operating speeds. This may lead to derailment and eventually loss of life. In this paper Transient analysis (Dynamic analysis) for rail by using ANSYS 12.1 Software is discussed. In this analysis deflection and stress are compared with wheel diameter, load, speed and range of distribution of contact load. Result is analyzed by the effect of variation of these parameters.

Keywords: Stress on Rails, Analyzing rails stresses

1.Introduction

In October 2000 a high-speed train derailed less than one km south of Hatfield station near London in UK. Four passengers were killed and more than seventy people were injured. The cause of the accident was fracture and subsequent fragmentation of the outer rail on a curved section. The investigations revealed numerous fatigue cracks at the running corner. When one of these penetrated into the web and foot of the rail it resulted in a knock-on effect leading to the extension of adjacent cracks and, thereby, to the fracture of a complete rail section. Usually rail breakage will not have such drastic consequences. Nevertheless it is a paramount objective of every railway company worldwide to avoid rail breakages. Smith, collecting data from various sources, provides a comparison of the frequency of fracture events of various railway components in Great Britain at the end of the 19th and the end of the 20^{th}century. Although the list is certainly subject to some uncertainties, he is able to conclude: "…it is clear that whilst failures of wheels and axles have been reduced by a factor of 20 over the last century, failures of rails per train km have actually increased by a factor of more than 2". Reasons behind this trend are heavier axle loads, increased volumes of traffic and axial tensile stresses at low temperatures due to continuously welded rails.

Worldwide there were comparable numbers of rail breakages. Systems for heavy haul freight with their high axle loads are significantly more affected than systems with predominantly passenger transport, the authors [1] give an approximate figure of the economic costs of rail fracture and its avoidance: € 2000 million per year in the European Union alone. A positive trend found with respect to the mentioned British network was that, whilst the detection rate of damaged rails which then had to be removed, has been increased continually throughout the period under consideration, the number of breakages was virtually constant. This fact shows that countermeasures, such as non-destructive inspection and periodical grinding, have brought a significant improvement towards failure prevention. On the other hand, the requirements on the networks such as an increased volume of traffic and higher axle loads etc. are permanently increasing. Therefore, fatigue crack propagation in rails remains an important issue with respect to both the quantitative understanding of the Mechanisms and the development of analysis routines for practical application.

KittisakKuntiyawichai, Enrico Spacone and Minho Kwon, in their paper[2] presented an alternative way to derive the exact element stiffness matrix for a beam on Winkler foundation and the fixed-end force vector due to a linearly distributed load. The element flexibility matrix is derived first and forms the core of the exact element stiffness matrix. The governing differential compatibility of the problem is derived using the virtual force principle and solved to obtain the exact moment interpolation functions. The matrix virtual force equation is employed to obtain the exact element flexibility matrix using the exact moment interpolation functions. The so-called "natural" element stiffness matrix is obtained by inverting the exact element flexibility matrix.

Ulf Olofsson and Roger Lewis, in their book on Tribology of wheel rail contact[1], have focussed on the friction, wear, and lubrication of the tiny contact zone (roughly 1 cm2), where steel wheel meets steel rail, from a mechanical engineer's viewpoint

Ma Weihua and LuoShihui, in their Seminar given in the Conference of Intelligent Computation Technology and Computation on Analyses of Wheel/Rail Unsymmetrical Problem[3], have discussed about wheel surface damage. They discussed three types of surface damages: Wheel Tread sapling, Out of Round Wheel and Wheel flange wear. They presented that the unsymmetrical wheel/rail contact was an important reason which can leads to the wheel surface damage problem. They suggested that to improve the dynamic performance and the stability of the vehicle, the strong wheel/rail unsymmetrical contact must be avoided.

Zerbst, U., Lundén, R., Edel, K.O. and Smith, R.A in their book on Introduction to the Damage Tolerance Behavior of Railway Rails[4] introduce the most important questions regarding crack propagation and fracture of rails. These include the loading conditions: contact forces from the wheel and thermal stresses due to restrained elongation of continuously welded rails together with residual stresses from manufacturing and welding in the field. An overview of crack-type rail defects and potential failure scenarios has been provided.

P HosseiniTehrani, M Saket in their Seminar in Conference Modern Practice in Stress and Vibration Analysis[5] they have given study of multi-axial high-cycle fatigue initiation life prediction for railroad is done in this paper. Using ANSYS 11.0 software three dimensional elasto-plastic finite element model of rail/wheel contact was constructed and fine mesh technique in contact region is used to achieve both computational efficiency and accuracy. Stress analysis is performed and fatigue damage in railroad is evaluated numerically using multi-axial fatigue crack initiation model.

2.Sress Analysis on Rails

Dealing with a rail system loaded dynamically by assuming the load is being transmitted through the rail span as three progressive line contacts. The base result of the analysis includes the values of deflection and stress plotted against different loads, speeds and range of distribution of the contact load. The range of distribution of the contact load is demonstrated by transforming the three progressive line contacts loading as three sets of increased number of line contacts.

2.1 Modeling in ANSYS software:

The modeling of the rail is kept very simple, by creating an I-section as cross section (entity-area). The area entity is then extruded to create rail (entity-volume). The length of the extrusion is considered as 0.6 mt, which is a standard for Indian rail span [1].

2.2 Element used:

Element used for meshing the model is **"Solid45"**. SOLID45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes and orthotropic material properties having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

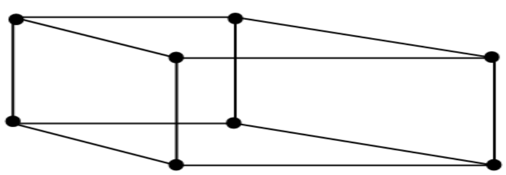

Figure1: element solid 45

The solution output associated with the element is in two forms:

- Nodal displacements included in the overall nodal solution
- Additional element output (stresses as the chapter uses)

2.3 Assumptions and Restrictions:

- Zero volume elements are not allowed.
- The element may not be twisted such that the element has two separate volumes. This occurs most frequently when the elements are not numbered properly.
- All elements must have eight nodes.

2.4 Model of the rail generated:

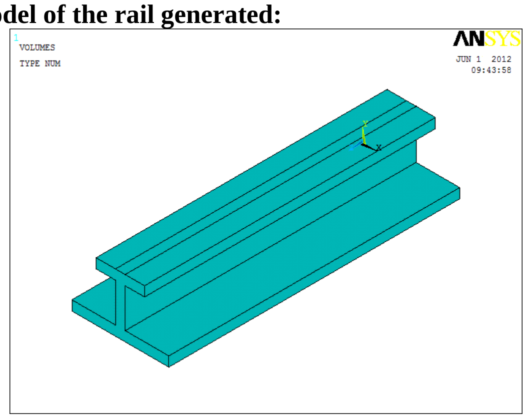

Figure 2: model used in ANSYS

The above figure shows the rail model used for the analysis the report. The I-section is created as an area entity, which is then extruded to a dimension of 0.6 m (600 mm). The cross-section details are listed below.

- Web length=100mm;
- Web thickness=20mm;
- Base length= 200mm;
- Base thickness=20mm;
- Head length=100mm; and
- Head thickness=20mm.

2.5 Meshing of the model generated:

The meshing of the model is done using hexagonal sweep. Element size used is 10 mm. The meshed elemental plot of the volume generated (along with the boundary conditions) is shown in the figure below:

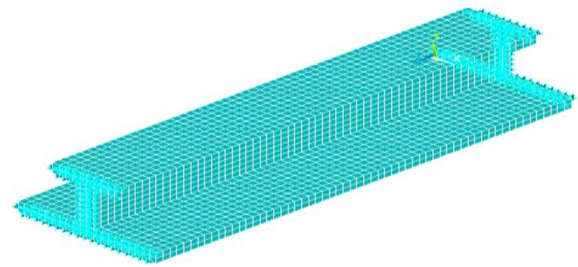

Figure3: element plot (with boundary conditions) of the model

2.6 Stress distribution along the rail span model:

The stress distribution and transmission for the rail model with the transmitting load along the length of the span is generated. These results are shown in the figures below in which the load is transfered along the span in three steps.

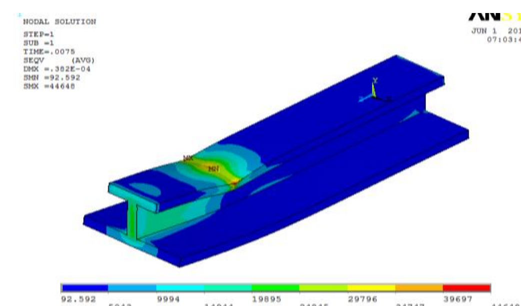

Figure 4:stress along the span at load step 1

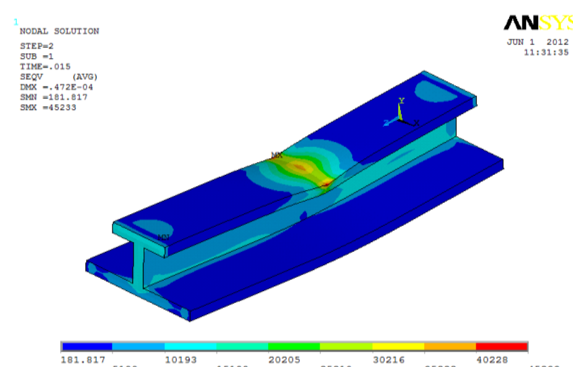

Figure 5:stress along the span at load step 3

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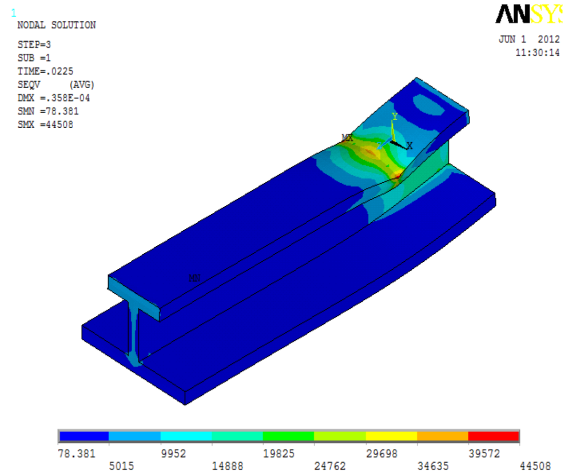

Figure 6:stress along the span at load step 2

2.7 Deflection along the span:

The variation of the deflection along the span with the transmission of the load (through the steps) is plotted in the figures below.

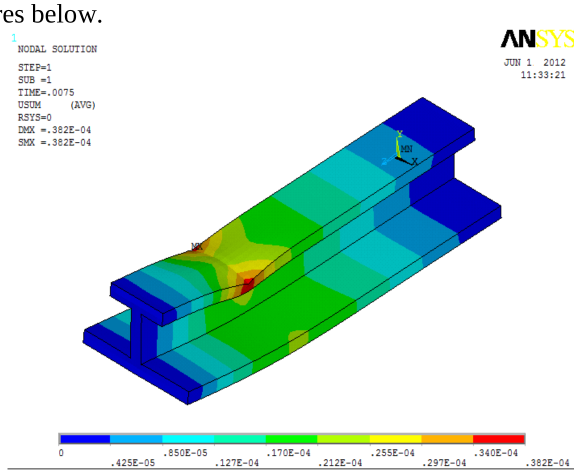

Figure 7: deflection along the span at load step 1

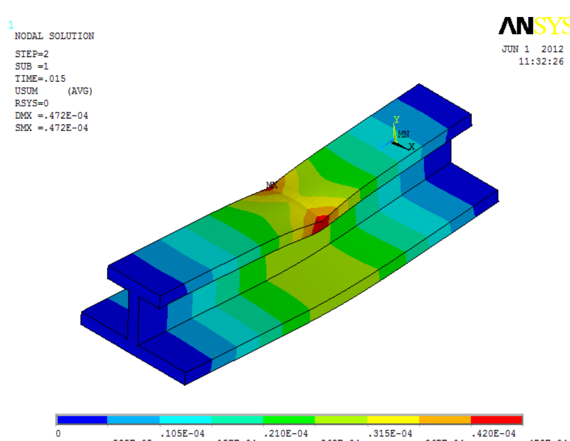

Figure 8: deflection along the span at middle

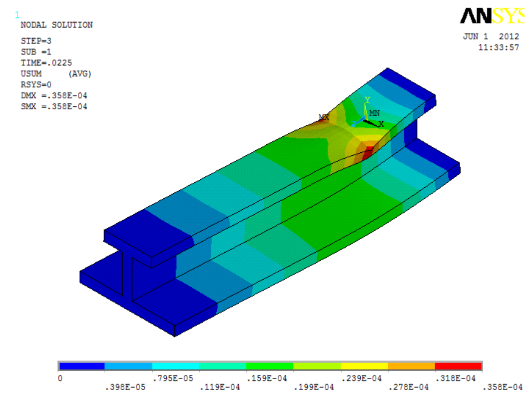

Figure 9: deflection along the span at load step 3

2.8 Load vs. stress curves:

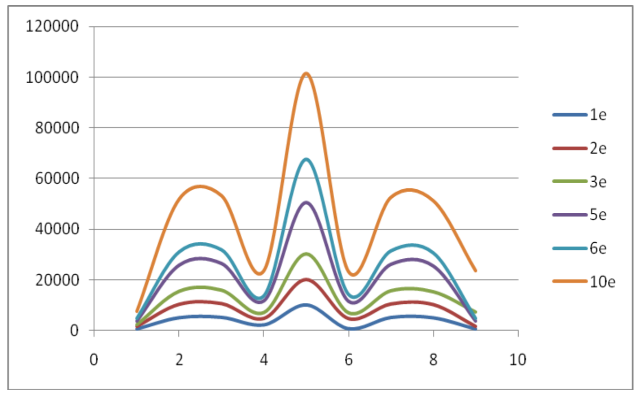

Figure 10:variation of stress along the span with varying load

In the above fig. the graph shows variation of the stress along the span for different loading conditions. The graph gives a clear idea about how the curves are offset with the varying load without actually changing the nature of the response.

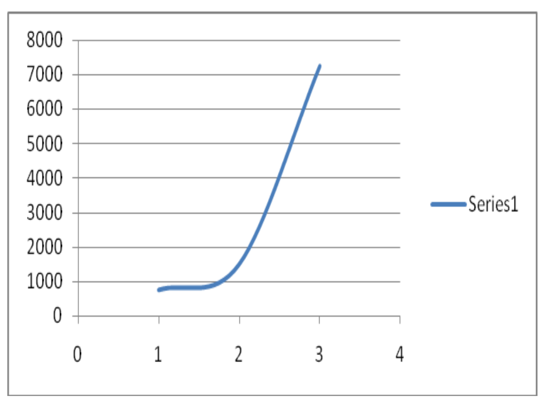

Figure 11: variation of the stress at a point with varying load

In the above fig depicts a graph between increase of load (x-axis) and stress (y-axis) at a given node and as expected stress also increases with increase of load.

2.9 Speed vs stress curves:

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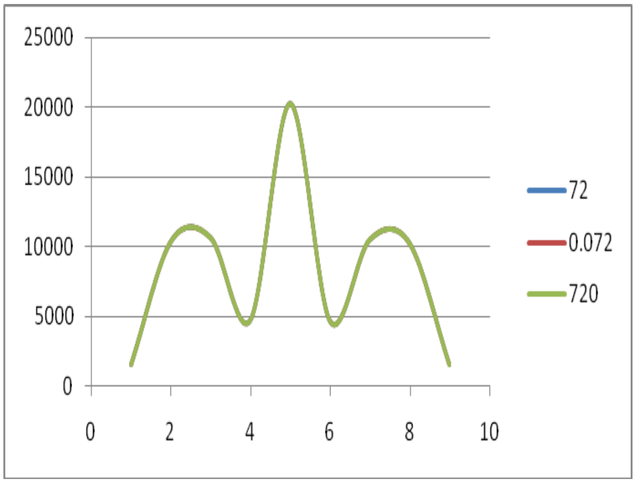

Figure 12: graph showing independence of the stress with the speed (timing of loading)

In the above fig. a graph is drawn between length of the rail span (x-axis) and stress (y-axis), for varying speeds (transmission of the loads). From this curve it can be pragmatically observed that for same loading condition with change of speed there is no change of stress distribution (both in nature and magnitude). But it is a general notion that with the increase in speed the stresses in the rail do increase, not only a notion but also proven in many test results. The only difference between the practical results and the results shown above is that absence of the traction force. With this the thesis comes to a conclusion that the variation in stress with the variation in the speed is only associated with the traction force between the wheel and the rail, as the modeling of the rail in this thesis does not include the contact detail of the wheel and the rail. To highlight the effect of the speed, the speed variations are made highly exaggerated (0.072 to 720 Kmph).

2.10 Range of distribution of contact load vs. stress:

The distribution of the contact load is increased by increasing the number of the lines of the nodes included in point loading (not by making the loading as the pressure loading). Care must be taken regarding making the point load magnitude only a fraction as the range of the distribution increases (to maintain the total load constant). The figure below shows the increased distribution of the load (in comparison to the loading of the nodes along a single line). This can be associated to the situations like, with the decrease in the stiffness of the wheel the distribution of the load does increase (due to increased deformation), increase in diameter of the wheel also increases the distribution of the loading (as the line contact gradually tends to be area contact).

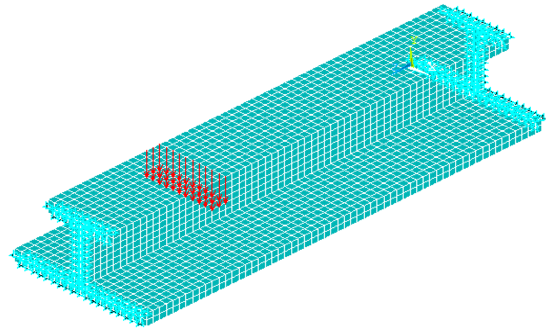

Figure 13: range of the distribution of the contact load (increased distribution)

The stepped loading along the three steps is carried out with the same number of the steps but the distribution of the loading is increased (by increasing the number of the lines through which the nodes used for point loading is increased), as mentioned in the above mentioned passage.The results show that with the increase in the distribution of the loading the nature of the stress response hardly changes, even the magnitude remains mostly constant, except for the region where the peak amplitude comes into the picture, the change is predominantly a preferred change, as the peak of the stress value gets reduced, i.e.; the maximum value of the stress along the span of the rail gets reduced. With this the report concludes that with the increase in range of the distribution of the load the response plot does not alter for most of the span of the rail, but the peak definitely becomes low.

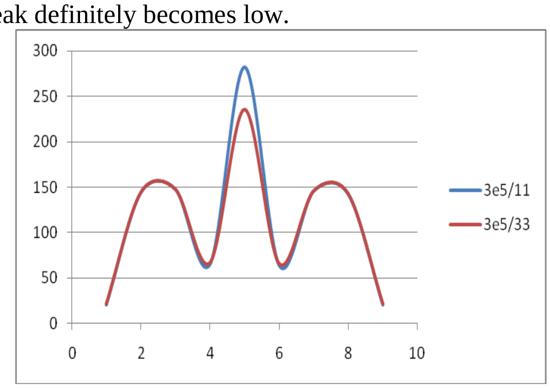

Figure 141: variation of the stress along the span of the rail with increased distribution of the contact load

2.11 Load vs. maximum deflection:

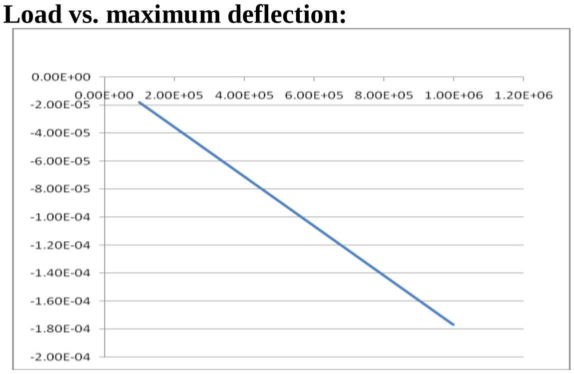

Figure 15: variation of maximum deflection in span with variation in load

International Journal of Engineering Research ISSN:2319-6890)(online),2347-5013(print)
Volume No.4, Issue No.1, pp : 4 - 8 01 Jan. 2015

In the above figure, a graph is drawn between load (x-axis) and maximum deflection along the span of the rail (y-axis), the observation shows that as expected, with increase of load the maximum deflection also increases. The increment obtained is linear.

2.12 Speed vs. deflection:

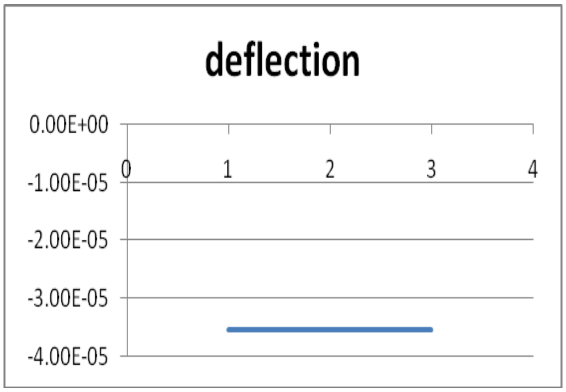

Figure 16: variation of maximum deflection with variation of wheel speed

The graph shown above is a plot between speed of the wheel (x-axis) and maximum deflection the span of the rail (y-axis). This result clearly supports the conclusion from the graph shown in figure 12, which states that the stress is unaffected by the speed of the wheel (unless the contact is defined). The above statement will hold true only if the deflection also behaves unaffected by the changing rate of wheel speed. Hence, the above result clarifies the point that deflection is unaffected by the changing wheel speed.

2.13 Range of distribution of contact load vs. deflection:

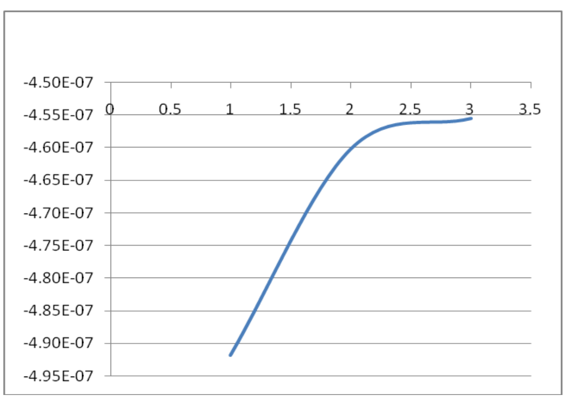

Figure 17: variation of maximum deflection with the variation of distribution in the range of the contact load

In the above figure a graph between range of distribution of contact load and deflection is drawn, the observation shows that with increase in the range of distribution of contact load, the deflection value decreases, but with further increase of range of distribution of contact load, the decrement in the deflection value is getting saturated.

4 Conclusion:

Variation of the rail speed is the interesting result we have obtained. As, both the results of the variation with the stress and maximum deflection get the thesis to a common conclusion that when the analysis does not include contact details, physically referring to tractive details between wheel and rail, along with the details of thermal and residual stresses, the variation is independent of the wheel speed. With this the thesis concludes that the reason for the variation in practical results can be due to any one of the above mentioned causes or even all of them intact.

1. The results of the variation of the stress and maximum deflection with the variation of the load magnitude is mostly as expected that with the increase in the magnitude of the load, both the parameters do increase. But, the heart of the point of the load variation is that the increase of the deflection is linear.
2. The results using the variation in the range of distribution of the contact load are unique from most analysis of the others, as the variationin its value can be assigned to the variation in any of the following:
   a. Variation in diameter of the wheel;
   b. Variation in deformation at the point of contact; or
   c. Due to any of the reasons resulting in the variation contact.

These results conclude that the stress is mostly unaffected by the variation of the range of the distribution of the contact load, but the peak is definitely reducing. At the same time the variation of the maximum deflection gets to saturation after some increment in the range of the distribution of the contact force (before which the magnitude of the maximum deflection does decrease).

REFERENCES:

i. *A book by Ulf Olofsson and Roger Lewis, "Hand book of railway vehicle dynamics" Published in 2006 by CRC Press.*

ii. *A paper by SuchartLimkatanyu, KittisakKuntiyawichai, Enrico Spacone and Minho Kwon,"Natural stiffness matrix for beams on Winkler foundation: exact force-based derivation".Structural Engineering and Mechanics, Vol. 42, No. 1 (2012) 39-53.*

iii. *A paper by Ma WeihuaLuoShihui, Song Rongrong,"Analyses of Wheel/rail Unsymmetrical Contact Problem". International Conference on Intelligent Computation Technology and Automation 2008.*

iv. *A paper by Zerbst, U.; Lunden, R.; Edel, K.-O.; Smith, R.A."Introduction to the damage tolerance behaviour of railway rails".In Engineering Fracture Mechanics (2009) Elsevier.*

v. *A paper by P HosseiniTehrani, M Saket." Fatigue crack initiation life prediction of railroad". 7th International Conference on Modern Practice in Stress and Vibration Analysis. Journal of Physics: Conference Series 181 (2009) 012038.*