International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

Study on Effect of Varying Rail Profiles on Fatigue Behaviour of Track Slabs

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Abstract— **Traditional ballasted track has a disadvantage of heavy demand for maintenance. Drainage deficiencies and weakness of the subgrade also leads to huge maintenance costs. This can be overcome by using slab track. In its simplest form, slab track consists of a continuous concrete slab with the rails supported directly on its upper surface using resilient pads. In this work, effect of two different rail profiles on fatigue behavior of track slab is studied. That is, effect of bull headed and flat footed rails are considered. Modal analysis is done to find out different modes of vibration and corresponding fundamental frequencies. High speed train pulses are applied to carry out transient analysis and fatigue analysis is done as the post processing of transient analysis. From fatigue results, damage and life of both the structures are compared.**

Keywords—Fatigue,Slab Track,Rail Profile, High Speed Train Pulse

I. INTRODUCTION

Modern railway track typically uses hot rolled steel with an asymmetrical rounded I-beam profile. If rails and the rest of track work are stronger, then tracks can carry heavier and faster trains. Bullhead rail, grooved rail and flat-bottomed rails are other types of rail profiles. Rail is graded in terms of its weight over a standard length. Heavier rails can support heavier axle loads and higher train speeds without much damage. In modern tracks, the rails are welded together by flash butt welding to form one continuous rail, about several kilometers long. This form of track is very strong and trains can travel on higher speeds and with less friction through it.

In bull headed rails, upper part of the rail is made a little stronger and thicker by adding more metal to it. In the case of flat footed rails, foot portion is made wider as compared to its head and it can be fixed directly to sleepers without any chairs or keys.

In this section, we set out to model slab track structure using ANSYS workbench. ANSYS is general purpose software, used to simulate interactions of all disciplines of physics, structural vibrations, fluid dynamics, and heat transfer for engineers.

In this work, fatigue life and damage of slab tracks with bull headed and flat footed rails are compared. Fig 1 shows a typical track slab structure and fig 2 shows bull headed and flat footed rail cross sections

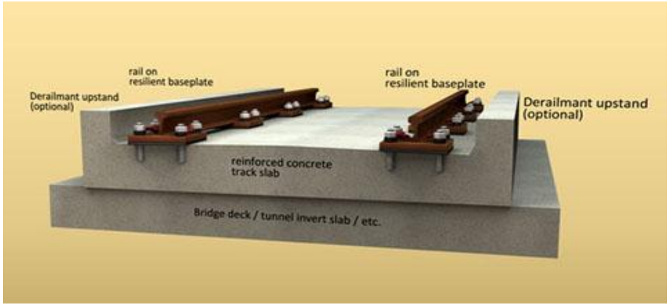

Fig 1: Slab track structure

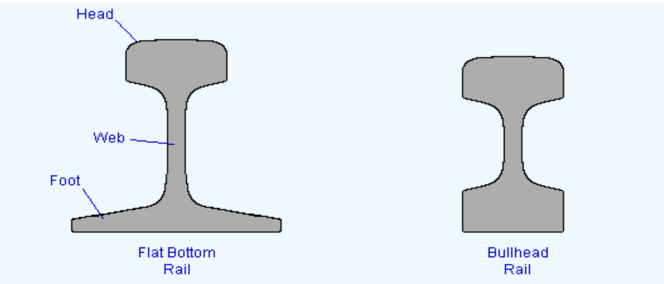

Fig 2: Rail profiles

II. LITERATURE REVIEW

G. Ruiz, E. Poveda (2013) [3]: They modeled a slab track system which comprises of three slabs and cylindrical bollards are used to separate neighboring slabs. They performed both modal analysis and transient analysis and fatigue analysis is done as the post processing of transient response. In this study, analysis is done using ANSYS software. For transient analysis, they use high speed train pulses of three different series of trains such as AVE class 103; Alvia class 120 etc and effect of all these train on track slab are compared.

Karthiga P, Dr. S. Elavenil et al,(2014) [4]: In their model, ballastless track comprises of a continuous concrete slab of 0.265m thickness, on which UIC 60 rails are supported and a Hydraulically Bounding layer was provided below the slab. They considered a maximum axle load of 170 kN and they use STAAD Pro software to perform analysis under different loading conditions. The obtained results are used for the manual design of concrete track slab.

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III. VALIDATION

To identify the correctness of the fatigue evaluation procedure, a validation process is essential. For validation, the considered test case is the fatigue evaluation of a rectangular bar with one end fixed and a force of 2x 10^6 N is applied on its other end. Bar size adopted is 20m x 1m x 1m.

The results from ANSYS FE model were compared against analytical results. Comparison of results is shown in table 1. The results obtained from ANSYS are approximately equal to the calculated values and the percentage of error is negligible

TABLE 1: FATIGUE RESULTS FOR VALIDATION MODEL

Results	Target	Mechanical	Error (%)
Life	3335.1049	3329.9	-0.156
Damage	299.8406	300.31	0.157
Safety Factor	0.019	0.019025	0.132

IV. FATIGUE EVALUATION OF TRACK SLABS WITH DIFFERENT RAIL PROFILES

A. Geometry

Taking advantage of the track line symmetry (x-axis), half of the slab track geometry is represented. The slab track structure consists of concrete track slab, CA mortar layer, concrete roadbed, fastening cushions, soil subgrade and UIC 60 flat footed rail or bull headed rail and the length of the track structure considered is 7.15m. For modeling this structure, proper elements are selected from ANSYS element library. Fig 3 shows geometry in ANSYS and table 2 shows its dimensions.

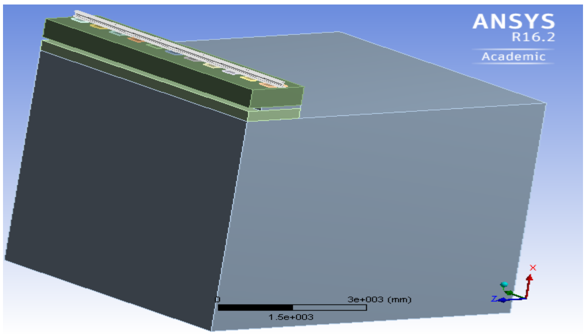

Fig 3: Geometry in ANSYS with flat footed rail

TABLE 2: DIMENSIONS OF THE FEM MODEL

Layer	Vertical dimensions (z axis)(m)	Transversal dimensions (y axis)(m)
Slab track	0.55	1.3
CA mortar	0.10	1
Concrete roadbed	0.30	1.3
Fastening cushion	0.02	0.45
Soil subgrade	6.3	7.55

B. Boundary Conditions and meshing

After modeling slab track system, symmetry boundary conditions are imposed on its both ends. Such boundary conditions are also imposed equally on concrete road bed, concrete asphalt mortar layer and soil subgrade. Out of plane movements in soil subgrade are also restricted at two side surfaces parallel to the track line and at the bottom of the track. To reduce computational time, mesh size has been carefully designed. Table 3 shows the material properties of various component parts of the track structure [1].

TABLE 3: MATERIAL PROPERTIES

	E (GPa)	γ	ρ (Kg/m^3)	ζ (%)
Concrete slab	35	0.2	2500	1
CA mortar	0.1	0.3	1700	10
Concrete roadbed	35	0.2	2500	1
UIC 60 rail	200	0.3	7850	0.1
Fastening cushion	0.006	0.3	800	10

C. Loadings

Here, various loads applied on the track structure are standard earth gravity and high speed train loads. A value of 9.81m/s^2 is given as standard earth gravity and for transient analysis high speed train pulses are applied [1]. Fig 4 shows the load pulse of a high-speed train (type ETR-Y), which is composed of two locomotives and ten coaches and has a total length of 224.2 m. The train runs with a speed of 300 km/h.

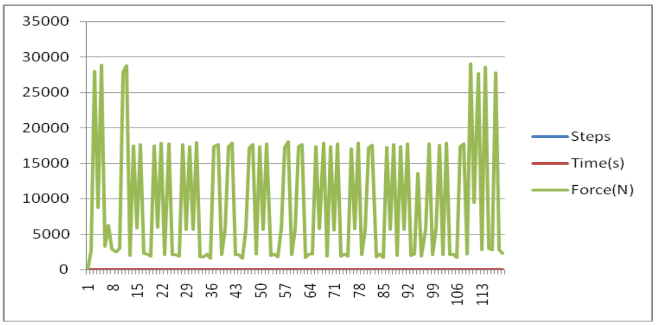

Fig 4: Applied train pulse

D. Results and Discussions

In this work, results considered are total deformation, fatigue life and fatigue damage. Total deformation is the vector sum of all directional displacements of the structure. Fatigue life plot shows the available life of the structure for the given fatigue analysis and fatigue damage is a contour plot of the damage due to fatigue, at a given design life.

- Total Deformation

Total deformation values are more in the case of bull headed rails as compared to flat footed rails. This may be because, flat footed rails have wider foot area than that of bull headed rail and thus it can transfer train load over a wider area. Fig 5 and fig 6 shows the total deformations of track slab with flat footed rail and bull headed rail respectively. The total deformation for track slab with flat footed rail is 0.049971mm and the total deformation for track slab with bull headed rail is 0.052538mm. Thus bull headed rails create more deformations in the track slab.

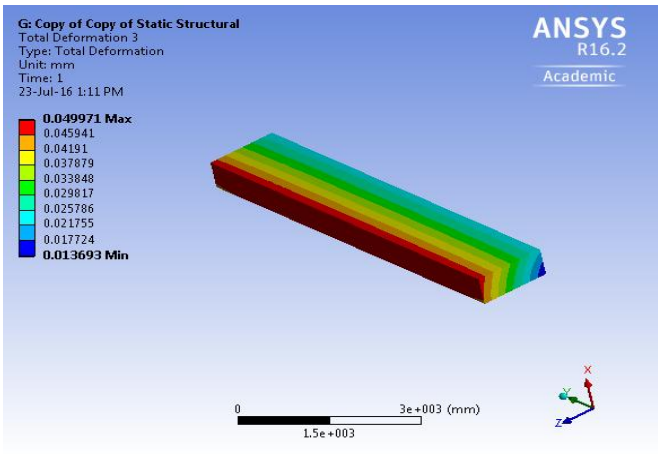

Fig 5: Total deformation of track slab with flat footed rail

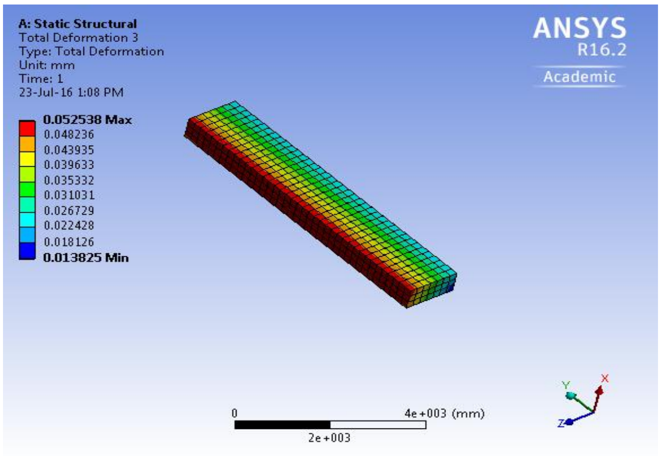

Fig 6: Total deformation of track slab with bull headed rail

- Fatigue Evaluation

Fig 7 and fig 8 shows the fatigue damages of track slabs with flat footed and bull headed rails respectively. Fatigue life is more and damage is less for track slabs with flat footed rails

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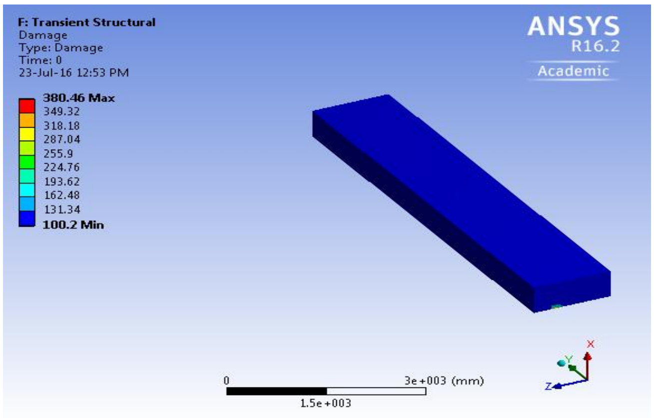

Fig 7: Damage of slab track with flat footed rail

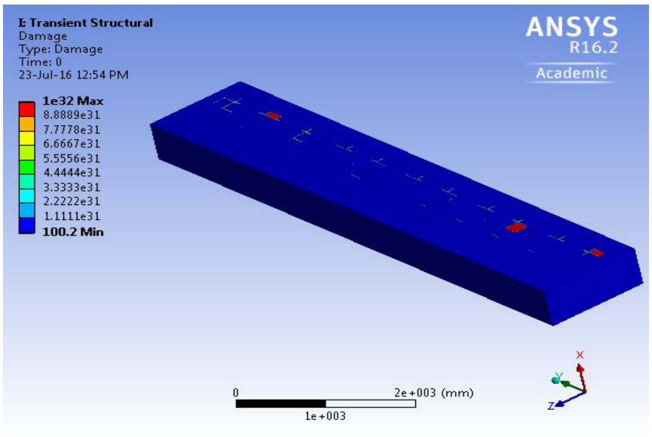

Fig 8: Damage of slab track with bull headed rail

Table 4 shows the fatigue damage and life of track slabs with flat footed rail and bull headed rails

TABLE 4: Fatigue result

	Track slabs with	
	Flat footed rail	Bull headed rail
Damage (maximum)	380.46	10^{32}
Life (cycles) (minimum)	2.6284 x 10^{6}	0

V. CONCLUSION

In this study, modal analysis and transient analysis are done. Real high speed train pulses are applied to carry out transient analysis. Fatigue analysis is done as a post processing of transient analysis. Fatigue life and fatigue damage are the fatigue results considered in this work. Also the effect of two different rail profiles (flat footed rail and bull headed rail) on fatigue behavior is studied.

From the results, we can conclude that track slabs with flat footed rails shows good performance as compared to track slabs with bull headed rails.

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