International Journal of Future Generation Communication and Networking
Vol. 13, No. 3s, (2020), pp. 1212–1217

Identifying the Non-linear Stiffness of Elastic Rail Clip using Different Loading Conditions

Sandeep Valji Shinde[1], Dr. S. S. Sarawade[2], Prof. S. K. Agarwal[3]

1. *Student, Sinhgad College of Engineering, Vadgaon(Bk), Pune,*
2. *Professor, Mechanical Engineering Department, M.E.S. College of Engineering, Pune, Maharashtra, India*
3. *Bridge Engineering Department, IRICEN, Pune, Maharashtra, India*

Abstract:

The Railway Track is a Continuous Beam Structure [consists of (i) Super-Structure - the Rail, Fastening System and Sleepers; (ii) Sub-Structure - Non-Cohesive Granular Materials viz Stone Ballast] that is supported on the Elastic Foundation having Sleepers, Rail Pad, Liners and Elastic Clips tied to the Rail. Extensive research has been carried out for understanding the behavior of rail fasteners, comprised of the Fastening Clips, Fastening Plate, Rail Pad. Those mostly concentrates on the dynamic behavior of the fastening system, and its predictive life. This study shows the non-linear behavior of the elastic rail clip. To demonstrate the behavior of the fastening clip, a simplified model, is simulated using Finite Elements, 1-D Beam Elements. It successfully demonstrates the non-linear behavior of the elastic rail clip. Also, the study presents the stiffness calculations based on its non-linear behavior, to discuss the influence of the loading of the elastic rail clip, with respect to the stiffness of the clip.

Keywords: *Rail Fastening System, elastic rail clip, spring clip, FEM*

1. Introduction: What is Fastening System?

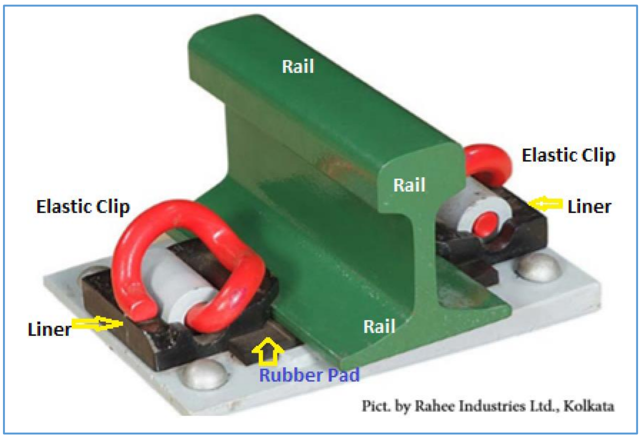


Fig.1 A schematic of Rail Track and Rail Fastening System
[Source: http://www.pandrolrahee.com/]

The structure of the Railway Track consists of (i) Super-Structure - the Rail, Fastening System and Sleepers; (ii) Sub-Structure - Non-Cohesive Granular Materials viz Stone Ballast. A wide variety of the fastening system are designed based on the needs, and conditions of the track. Apart from the suppressing the vibrations due to traffic impact, Preserving the transverse slope and the gauge are the primary functions of the fastening systems (Esveld, 2001; Lichtberger, 2005).

Spring Clips are classified based on the flexibility, i) Rigid and ii) Elastic. Those are further classified as fixation type, i) direct and ii) in-direct.

The fastenings used in concrete sleepers must be elastic in both tension and compression. The basic component of all types of fastenings consists of an elastic steel rod or plate, named spring clip, or spring plate. The clip functions as a system with a “compatible” elastic pad. The clip, as a spring, develops the elastic clamping force of the fastening on the rail foot. The load-deflection curve of the clip characterizes the static stiffness of the clip and consequently of the fastening. Some clips present only one type of static stiffness, but the most advanced present a secondary static stiffness also. In resilient fastenings, apart from the clip –acting on the upper part of the rail foot– there is a second spring the

ISSN: 2233-7857 IJFGCN

resilient pad, which is made of elastic material compatible to the fastening's steel clip and it is acting under the rail foot.
With increasing axial load, speed of trains, the fastening system needs to be able to preserve the connecting between the rails to the sleepers.

2. Literature Review: Fastening System

Deshimaru et. al. (1, 2017) mentioned that it is important for the design and verification of rail fastening system performance to clarify the permissible lateral force it can tolerate. The validity of the method was confirmed with the relationship between the applied loads and stress on the rail clip, established in laboratory tests. The fatigue life of the rail clip was then estimated using the proposed method and the permissible lateral force for a conventional fastening system was derived using this estimation.
Mohammadzadeh et. al. (2, 2014) presented stress-based approach to develop comprehensive method for fatigue reliability analysis of the fastening spring clip. The Axle load, speed, and material properties are assumed to be random variables. From the dynamic analysis of the track and trains, the load in terms of the displacement time histories is applied to fastening clips. Using the Miler's Rule and Monte Carlo Simulation, the reliability and sensitivities are plotted. It further concluded that the stress range and material parameters have significant effect on the fatigue crack.
Kantantinos (3, 2001) proved that One pair of clips per rail, acting on the upper part of the rail foot, together with one "compatible" resilient pad, underneath the rail's seating surface, function as one ensemble. The pad provides elasticity (springs) under the rail's seating surface, it is produced from elastic material and it must be compatible to the clip. The compatibility is assured through the Load – Deflection curves of both the clip and the elastic pad. The clip's Load-Deflection curve must be relatively flat so that the clamping force remains adequate over the years. Some clips present only one type of static stiffness, but the most advanced also develop a secondary static stiffness. The clip, as a spring, develops an elastic clamping force on the upper surface of the rail foot, the toe-load, due to its tightening after mounting.
Zhao [6] et al analyzed the influence of fastening model on the high frequency dynamic contact forces at singular rail surface defects. J. A. Casado et al [8] conducted a fatigue test on the fastener systems and proposed a model for the identification of the critical conditions based on the evolution of various parameters during the fatigue process, such as displacement, stiffness and temperature. Xiao Hong et al (5, 2018) evaluated the performance and predict the fatigue life of the e-clip (a widely used e-clip in the railway system) under cyclic loading, with twelve loading conditions. D.J. Thompson et al [9-10] measured the vertical and lateral dynamic stiffness of rail fastener systems under preload in the range 100-1000 Hz and clarified the influence of vibration at higher frequencies on the stiffness of fastener systems. Shang [11] analyzed the effect of rail corrugations on the maximum equivalent stress of rail fastening clip. Luo [12] et al analyzed the forces of e-type fastening clips using the finite element method and studied the effects. J. Smutny et al [18] developed a new method using time and frequency related transformations to evaluate the response signals obtained by rail fastening analysis.

3.Finite Element Modeling of Fastening System

Xiao Hong et al [5] considered the Elastic Clip, Rail Fastening Plate, gauge aprons. and the Contact between the Center Leg and Fastening Plate. This paper provides a simplified model of the elastic rail clip is generated which can be easily swept while modelling in 3D. The scope of this paper is to analyse the simplified model, 1-D Beam Elements, elastic rail clip with different boundary conditions. The nomenclature of the elastic rail clip is as follows. The Beam Representation in 3-D format is shown in the figure 2 below.

ISSN: 2233-7857 IJFGCN

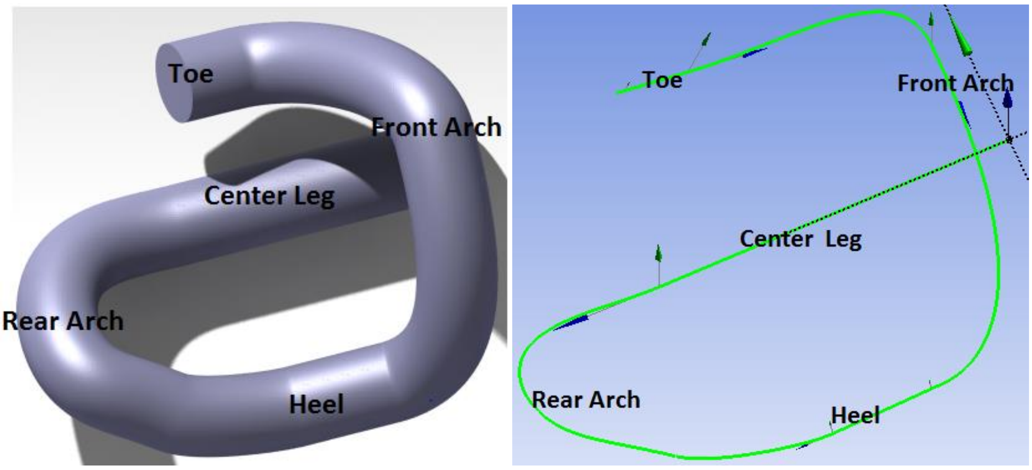


Fig.2 A Simplified model of Elastic Fastening Clip

This model is analysed in Ansys. It has two boundary conditions. The 1st Case considers the Fixed Support at Centre Leg, and Fixed Support at the Heel, Force as a load on the Toe,
as shown in fig.3. The 2nd Case considers the Fixed Support at Centre Leg, and Fixed Support at the Toe, Force as a load on the Heel, as shown in fig.4.

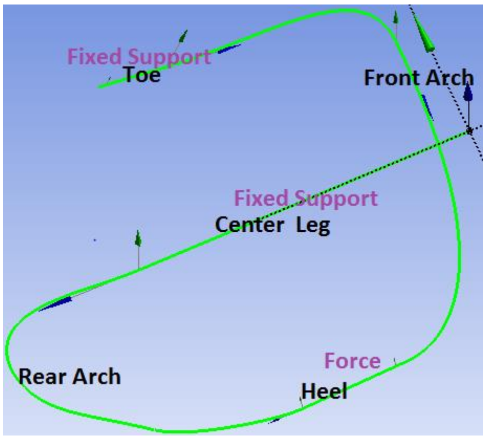


Fig.3 Boundary Conditions - 1st Case

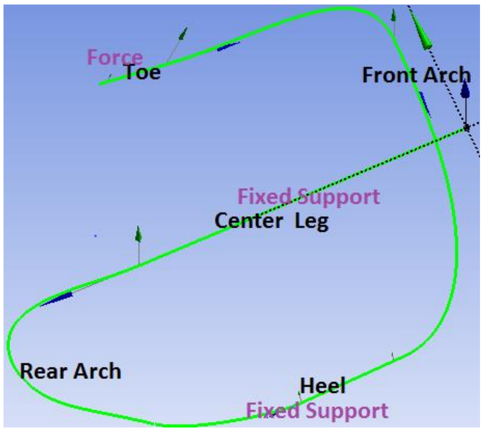


Fig.4 Boundary Conditions - 2nd Case

The Elastic Rail Clip is modelled as Structural Steel which follows the Elasto-Platic Material Model, Bilinear Isotropic Hardening with 1e8 Pa and 1e10 Pa

4.Results and Conclusion:
Interpreting the results of the 1st Case - Fig.5, and the 2nd Case - Fig.6, the Total Deformation, Axial Force, Total Bending Moment and Total Shear Force are plotted that confirms that the Elastic Clip failure occurs at the point where the Center Leg and Rear Arch meet. Also, the Force vs. Deflection, which stabilizes after few iterations and follow single curve rather than following different curves every time.

ISSN: 2233-7857 IJFGCN

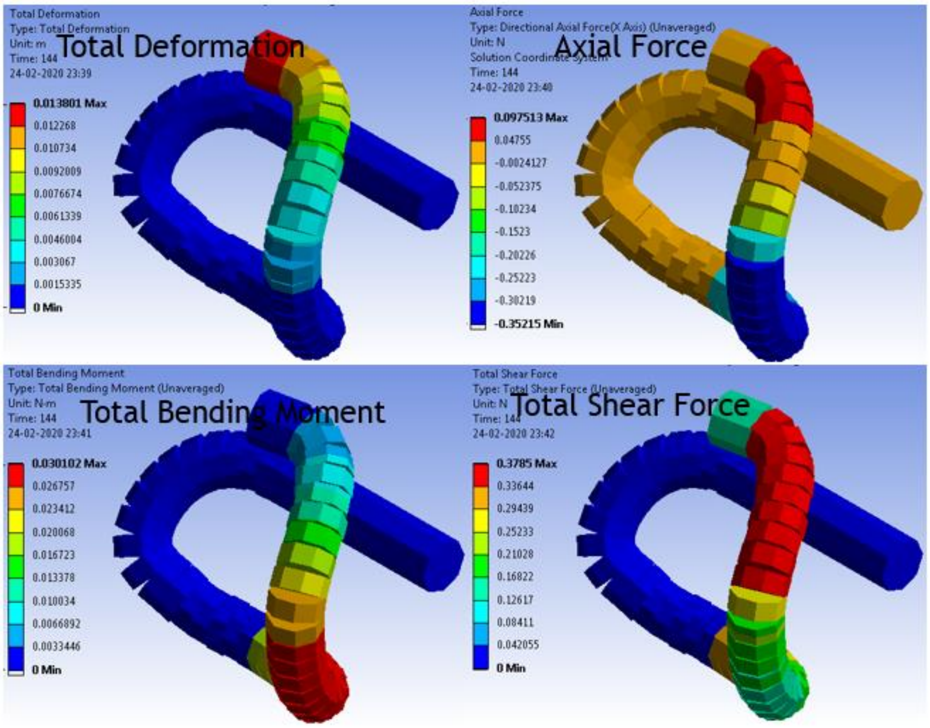


Fig.5. 1st Case
Total Deformation, Axial Force, Total Bending Moment and Total Shear

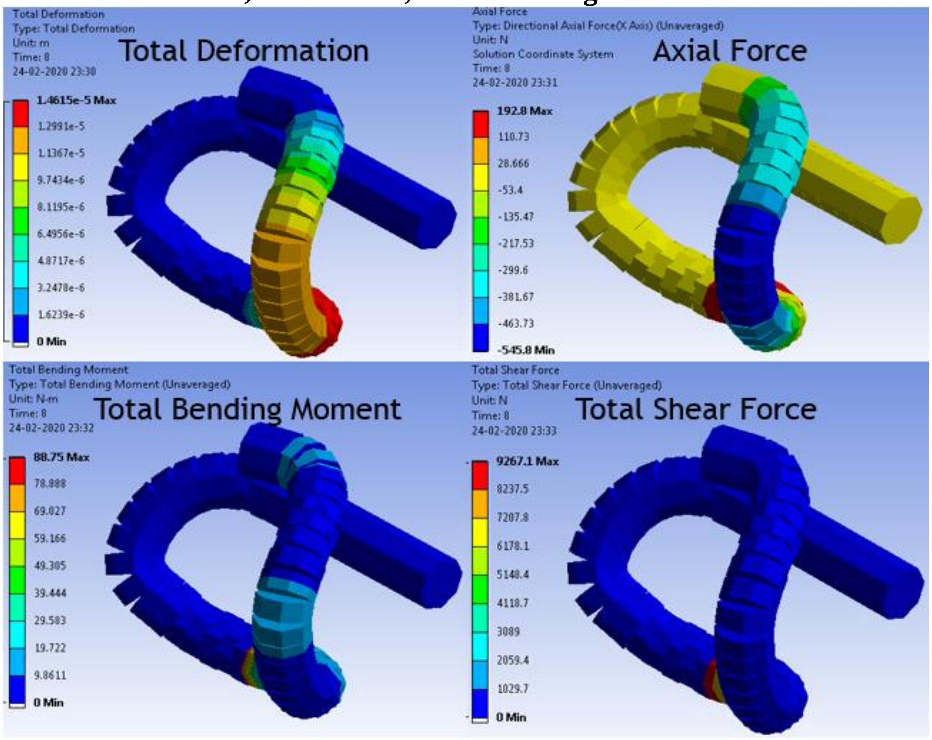


Fig.6. 2nd Case
Total Deformation, Axial Force, Total Bending Moment and Total Shear

For the 1st Case, the **Fig. 7** Load vs. Deflection Curve follows the equation (nonlinear – 2nd order) $\mathbf{y = -1156.4x^2 + 3081.7x + 39.265.}$ The Stiffness is calculated from the Load vs. Deflection Curve, **Fig.8**. After the loading at 34th step, the Stiffness of 3000 N/mm gradually decreases to 500 N/mm at 64th step, which is describes the nonlinear behaviour at the Toe.

ISSN: 2233-7857 IJFGCN

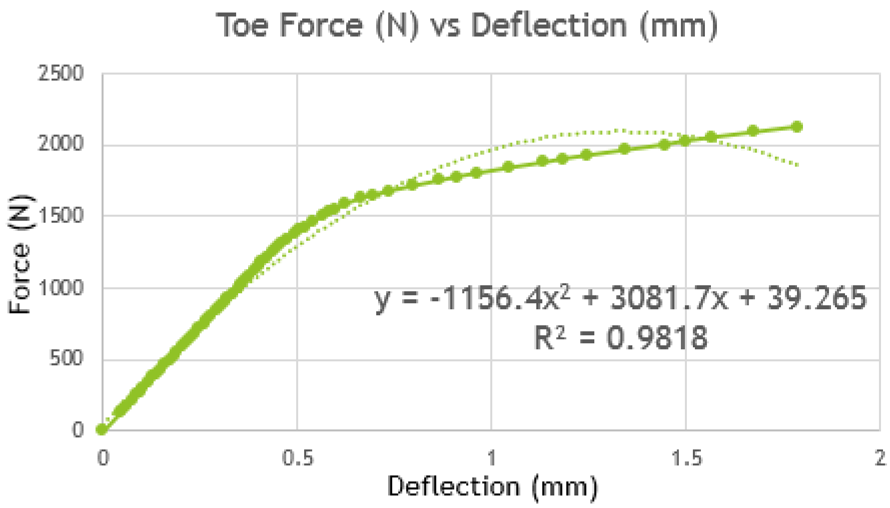


Fig.7. Force vs. Deflection Curve – 1st Case

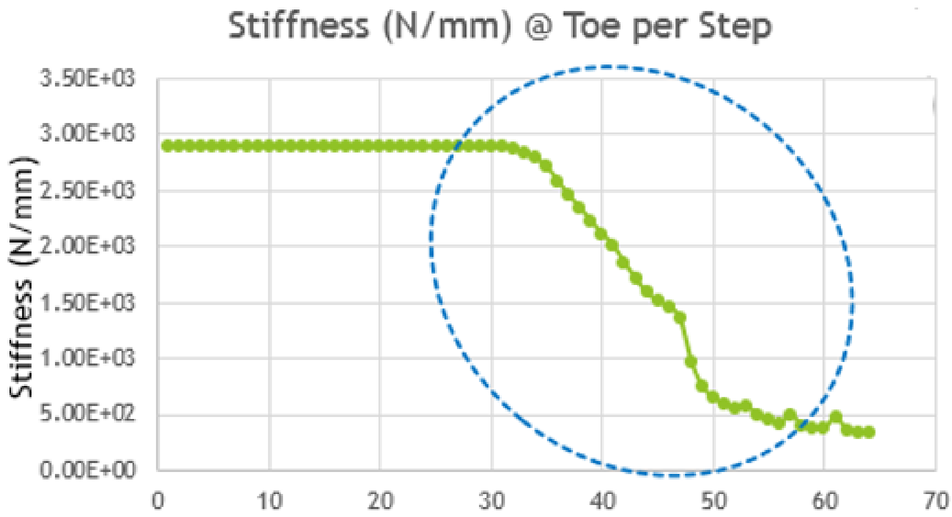
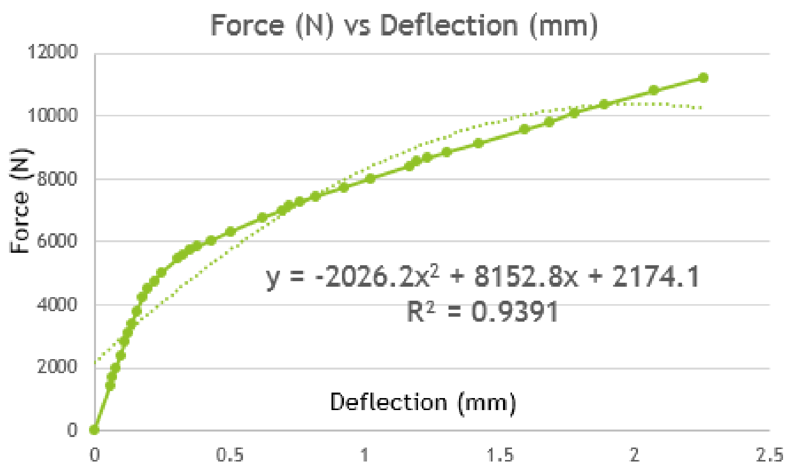


Fig.8. Stiffness (N/mm) Curve represented as a Polynomial 2nd Order – 1st Case

For the 2nd Case, the **Fig.9,** Load vs. Deflection Curve follows the equation (nonlinear – 2nd order) **y = -2026.2x² + 8152.8x + 2174.1.** The Stiffness is calculated from the Load vs. Deflection Curve, **Fig.10**. After the loading at 2nd step, the Stiffness of 25000 N/mm gradually decreases to 380 N/mm at 4th step, which is describes the nonlinear behaviour at the Heel.



ISSN: 2233-7857 IJFGCN

Fig.9. Force vs. Deflection Curve – 2^{nd} Case

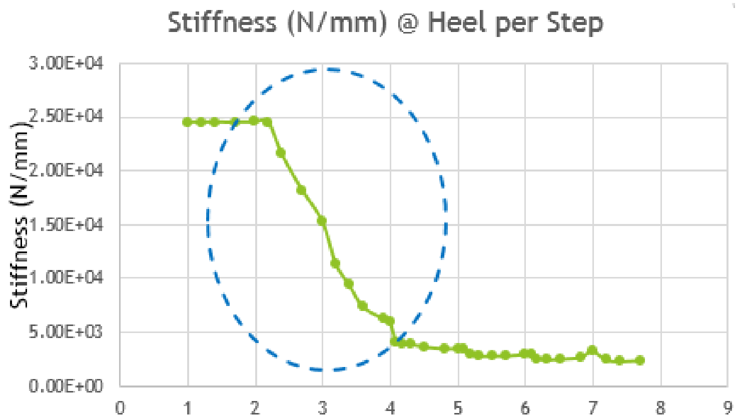


Fig.10. Stiffness (N/mm) Curve represented as a Polynomial 2^{nd} Order – 2^{nd} Case

The Elastic Rail Clip – ERC behaves non-linearly under its operating range of 850 Kg to 1100 Kg load. For the 1^{st} Case, the Stiffness curve starts behaving after 34^{th} step and stabilizes nearly after 64^{th} step. For the 2^{nd} Case, the Stiffness curve starts behaving after 2^{nd} step and stabilizes nearly after 4^{th} step. With different loading conditions, Elastic Rail Clip – ERC demonstrate the non-linear behaviour.

5. References

1. Deshimaru T, Tamagawa S and Kataoka H. Permissible lateral force and fatigue life for rail fastening system. Q Rep Rtri 2017; 58: 236–241
2. Mohammadzadeh S, Ahadi S and Nouri M. Stress-based fatigue reliability analysis of the rail fastening spring clip under traffic loads. Lat Am J Solids Stru 2014; 11: 993–1011.
3. Nagafuji, T., “Prediction on Service Life of Rail Fasten-ing Fluctuating Stress,” RTRI Report, Vol. 5, No. 8, pp. 65-74, 1991 (in Japanese).
4. Nagafuji, T., " Prediction on Service Life of Rail Fastening Fluctuating Stress, " RTRI Report, Vol. 5, No. 8, pp. 65-74, 1991 (in Japanese).
5. Hong Xiao, Jia-Bin Wang, Yan-Rong Zhang, The fractures of e-type fastening clips used in the subway: Theory and experiment, *Engineering Failure Analysis* (2017),
6. Zhao X, Li Z L, Dollevoet R. Influence of the fastening modeling on the vehicle-track interaction at singular rail surface defects [J]. J. Comput. Nonlinear Dyn, 2014, 9(3): 1-11
7. Jaroslav S. Measurement and analysis of dynamic and acoustic parameters of rail fastening [J]. NDT E Int. 2004, 37(2):119-129
8. Casado J A, Carrascal I, Polanco J A, et al. Fatigue failure of short glass fibre reinforced PA 6.6 structural pieces for railway track fasteners [J]. Eng. Fail. Anal., 2006, 13(2): 182-197
9. Ryue J, Thompson D J, White P R, et al. Investigations of propagating wave types in railway tracks at high frequencies [J]. J. Sound Vib, 2008, 315(1-2): 157-175
10. Thompson D J, Verheij J W. The dynamic behavior of rail fasteners at high frequencies [J]. Appl Acoust, 1997, 52(1): 1-17
11. Shang H X, Analysis of rail corrugations on rail fastening clip force [J]. Machinery, 2014,41(8):11-15
12. Luo X Y. Research and application of III type elastic clamping force [J]. Railway standard design, 2002 (6):15-16
13. Zhu S Y, Cai C B, Yin Q, *et al*. Dynamic analysis of rail fastening clip in high-speed railway [J]. J Eng Mech, 2013, 30(6): 254-258
14. Shang H X, Wen Z F, Wu L, Li W, *et al*. Finite element analysis of type Ⅲ rail fastening clip failure in metro lines [J]. Engineering Mechanics, 2015, 32(9): 210-215
15. Xiao Hong, Guo Xiao, Wang Haoyu, Ling Xing and Wu Sixing, Fatigue damage analysis and life prediction of e-clip in railway fasteners based on ABAQUS and FE-SAFE
16. Wang W, Wang Z, Zhao L, et al. Failure analysis of SKl15 spring fasteners for high-speed railway. Heat Treat Metal 2013; 38: 108–112.

ISSN: 2233-7857 IJFGCN