Stress Load Analysis and Optimization of Suspension Clamp Assemblies in Railway Modular Cantilever Systems: An FEA Approach

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Abstract

This research explores the stress load analysis of suspension clamp assemblies within the Modular Cantilever System (MCS) used in railway Overhead Equipment (OHE). These assemblies support catenary wires of varying sizes and endure diverse vertical and horizontal loads due to different MCS configurations. The design allows installation in both top and inverted positions, leading to compressive and tensile forces. Finite Element Analysis (FEA) was employed to assess these variable loads. The study revealed stresses and casting errors within the parts, providing valuable insights for improvement.

Keywords: Railway, Suspension Clamp, Modular Cantilever System (MCS), OHE, Catenary Wire, COMSOL

Introduction

Railway Overhead Equipment (OHE) includes a Cantilever Assembly to hold catenary & contact wires. In this arrangement catenary wire secures contact wire with intermittent copper dropper wire. The catenary wire is held in place, a component of conventional clamp assembly which is part of conventional Cantilever Assembly.

A suspension clamp is a crucial component in railway overhead systems, specifically in the Cantilever Assembly of the Railway Overhead Equipment (OHE). Its primary function is to secure the catenary wire, which, in turn, holds the contact wire along with intermittent copper dropper wires. The suspension clamp assembly ensures the catenary wire is sturdily anchored, maintaining the integrity and stability of the entire overhead system.

In conventional designs, the suspension clamp assembly is an integral part of the Cantilever Assembly, providing essential support. However, advancements in technology have led to the development of specialized suspension clamps, such as those used in current MCS. Unlike traditional designs, these innovative suspension clamps offer unique features and improved functionalities.

MCS suspension clamp assembly, for instance, boasts adaptability and versatility. It can be mounted on pipe structures, offering flexibility during installation. This means it can be easily adjusted, slid over, or flipped as per specific requirements, enhancing the overall efficiency and ease of installation of the railway overhead system.

In summary, suspension clamps play a pivotal role in ensuring the stability and reliability of railway overhead systems, and innovative designs like those found in MCS bring added flexibility and efficiency to the installation process.

This study explores the rationale behind employing Finite Element Analysis (FEA) in the evaluation of these suspension clamp assemblies. FEA, a sophisticated simulation technique, has become instrumental in engineering practices, allowing for an in-depth analysis of stress distribution, performance under varied loads, and structural optimization. By employing FEA, engineers gain invaluable insights, enabling them to not only assess the structural integrity but also innovate and enhance the design.

Fig 1a. – Conventional Suspension Clamp

Fig 1b. – Raychem Make MCS Suspension Clamp

The suspension clamp assembly, a cornerstone of railway overhead systems, encounters diverse challenges in the MCS environment. With the catenary wire threading through various MCS setups—overlap, crossover, anti-creep, and enduring constant loads—the clamp faces intricate directional forces. Moreover, the design complexity escalates, considering the catenary wire's adaptability to both standard aluminum pipe (as depicted in Fig 1b) and the inverted position, crucial for installations in tunnels and specific site requirements.

In this context, stress analysis of the suspension clamp structure becomes paramount. Evaluating the clamp's performance under such multifaceted MCS configurations is essential. This study delves into the intricate stress patterns and structural responses, shedding light on the clamp's robustness and adaptability in real-world scenarios. By dissecting these complexities, this research endeavors to pave the way for enhanced suspension clamp designs, ensuring durability, flexibility, and safety within diverse railway environments.

Theory / Experimental Set Up

The mounting of the suspension clamp on MCS is as shown in fig 2a & 2b below.

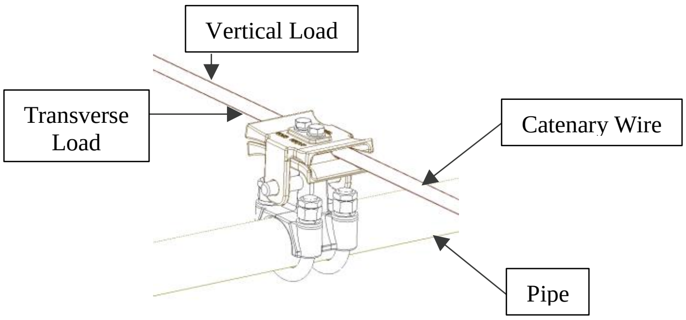


Fig 2a. – Top mounting of the suspension clamp.

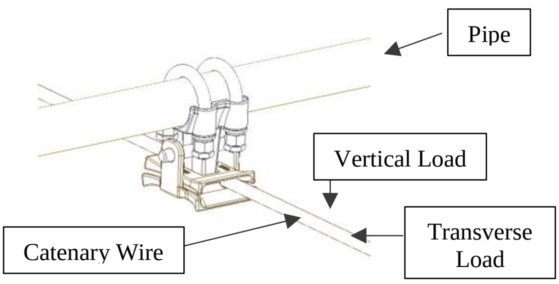


Fig 2b. – Flipped mounting of the suspension clamp.

Suspension clamp assembly faces different loads as below.

1. Vertical Load of OHE Wires

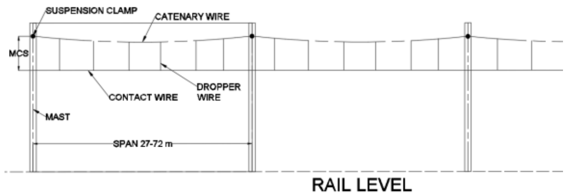


Fig 3 – MCS OHE Arrangement

As shown in fig. 3 catenary wire held contact wire with the help of intermittent dropper wires. So, the combined dead load of both wires acts on suspension clamp. For maximum 72-meter span total weight of both wires are as below table

Catenary Wire C/s	**Contact Wire C/s**	**Total Weight for 72 m span**
65 mm^2 – 0.6 kg/m [1]	107 mm^2 – 0.95 kg/m [1]	111.6 kg [1]
125 mm^2 – 1.19 kg/m [1]	150 mm^2 – 1.34 kg/m [1]	182.16 kg [1]

Other weights considered as per below table.

Item	**Weight**
Weight of maintainer with tools	100 kg [1]
Extra of unforeseen	25 kg [1]

2. Transverse Loads of OHE wires in 72 m span

Item	**Weight**
Radial load due to stagger of 200 mm on 65 / 107 sq mm wires	27 kg [1]
Wind load of 216 kg/m^2 for 65 / 107 sq mm wires	279 kg [1]
Radial load due to stagger of 200 mm on 125 / 150 sq mm wires	34 kg [1]
Wind load of 216 kg/m^2 for 125 / 150 sq mm wires	349 kg [1]

Methods / Cases

Suspension Clamp assembly 3D model developed and simplified by suppressing curves and complexity to reduce meshing errors and computational time.

Total four cases defined for different orientations of clamp and catenary and contact wire sizes.

1. Case 1 - Top mounted suspension clamp for 72 m span and 65 / 107 sq mm wire.

Vertical Load – 241 kg / 2410 N
Max Transverse Load – 306 kg / 3060 N

2. Case 2 - Flipped mounted suspension clamp for 72 m span and 65 / 107 sq mm wire.

Vertical Load – 241 kg / 2410 N
Max Transverse Load – 306 kg / 3060 N

3. Case 3 - Top mounted suspension clamp for 72 m span and 125 / 150 sq mm wire.

Vertical Load – 307 kg / 3070 N
Max Transverse Load – 383 kg / 3830 N

4. Case 4 - Flipped mounted suspension clamp for 72 m span and 125 / 150 sq mm wire.

Vertical Load – 307 kg / 3070 N
Max Transverse Load – 383 kg / 3830 N

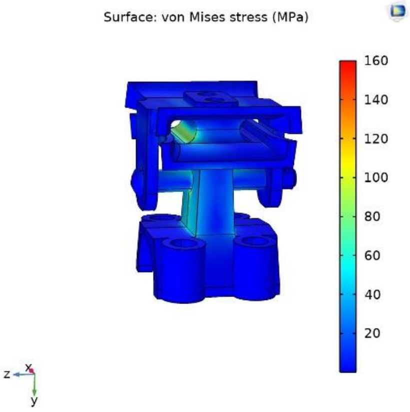
Above load cases are applied in COMSOL Multiphysics with solid mechanics module to calculate stresses and deformation.

Simulation Results

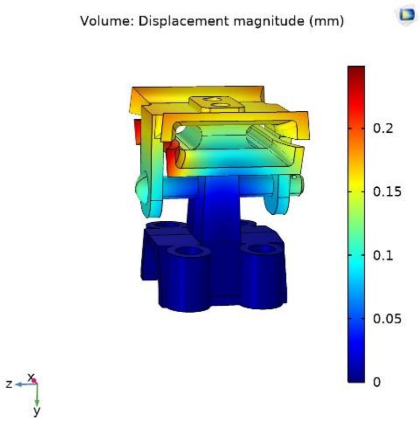
Simulation performed as per above defined cases and von mises stresses and volumetric deformation plotted as below.

1. Case 1 - Top mounted suspension clamp for 72 m span and 65 / 107 sq mm wire.

a. Von Mises Stresses (MPa)

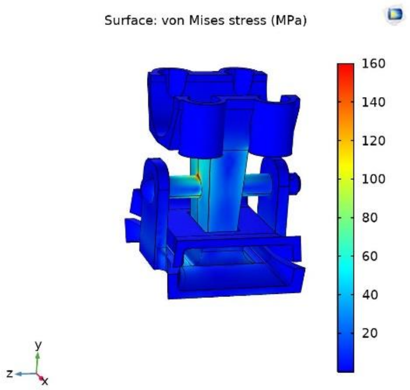


b. Volumetric Deformation (mm)

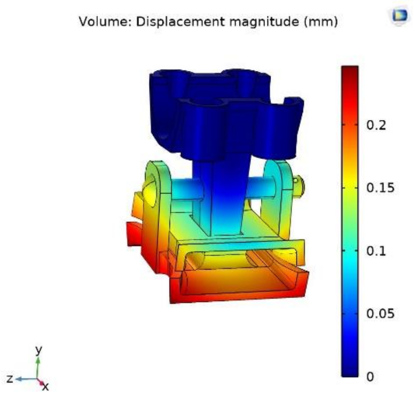


2. Case 2 - Flipped mounted suspension clamp for 72 m span and 65 / 107 sq mm wire.

a. Von Mises Stresses (MPa)

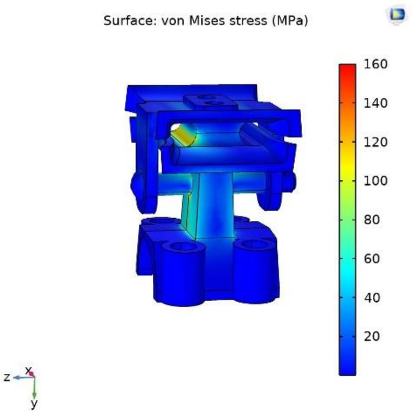


b. Volumetric Deformation (mm)

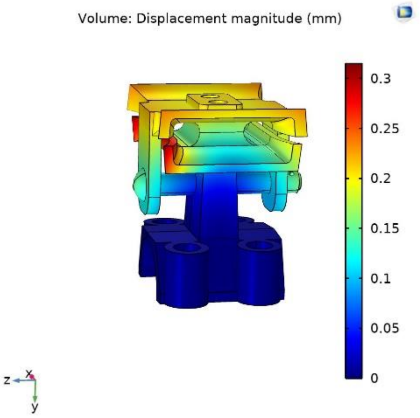


3. Case 3 - Top mounted suspension clamp for 72 m span and 125 / 150 sq mm wire.

a. Von Mises Stresses (MPa)

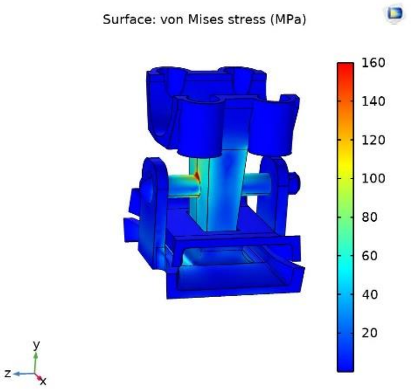


b. Volumetric Deformation (mm)

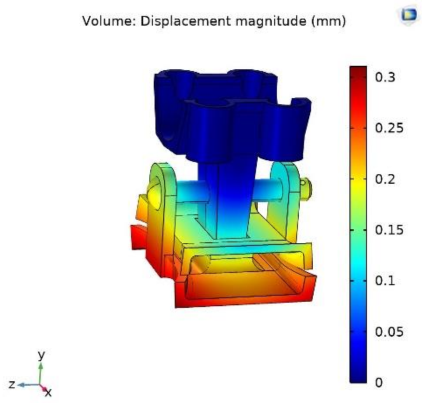


4. Case 4 - Flipped mounted suspension clamp for 72 m span and 125 / 150 sq mm wire.

a. Von Mises Stresses (MPa)



b. Volumetric Deformation (mm)



Conclusions

The analysis results indicate that the suspension clamp effectively handles different load conditions, demonstrating stresses and deformations within acceptable limits. However, the assessment identified specific areas experiencing higher stress concentrations. These concentrated stresses are often point stresses, indicating localized areas where the stress levels exceed the desired threshold.

To address these high-stress points, a recommended solution is to introduce fillets and smooth profiles. Fillets involve rounding off sharp edges or corners, distributing stress more evenly across the component. By incorporating fillets strategically in the design, stress concentrations at these points can be mitigated.

Additionally, employing smooth profiles, which involve creating gradual transitions and curves in critical areas, further helps in reducing stress concentrations. Smoothing out abrupt changes in geometry ensures that stress is distributed more uniformly across the surface, preventing localized areas from bearing excessive loads.

By implementing these design modifications, such as fillets and smooth profiles, engineers can enhance the suspension clamp's structural integrity. This proactive approach not only addresses the identified stress concentrations but also ensures the component's overall stability and reliability under varying load conditions.

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