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Railway Track Degradation Modelling Using Finite Element Analysis: A Case Study in South Africa

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ABSTRACT

This study utilizes finite element analysis (FEA) to examine railway track degradation, emphasizing the performance and durability of rail components under varying loading conditions. Static, dynamic, and fatigue simulations are conducted to identify high-stress regions, particularly at rail joints and sleeper interfaces, which are most prone to accelerated wear and failure. A refined three-dimensional (3D) modelling approach enhances simulation accuracy, providing detailed insights into stress distribution and contact dynamics. NX Nastran is used for static and dynamic load analyses, while SolidWorks is used for fatigue evaluations to predict material resilience and failure points under cyclic loading. These findings support the development of effective maintenance and reinforcement strategies, contributing to enhanced track longevity and safety.

Keywords: dynamic load, finite element, railway track, numerical modelling

1. INTRODUCTION

Railway infrastructure serves as a fundamental pillar of economic development, facilitating the efficient transportation of goods and passengers across extensive distances. However, increasing demand on railway networks has intensified stress on track components, accelerating wear and degradation. Heavy-haul operations, compounded by aging infrastructure, exacerbate these challenges, particularly in freight-intensive contexts, raising critical concerns regarding safety, efficiency, and reliability. Track degradation results from complex interactions between train loads and material fatigue, with high-stress areas such as rail joints and sleeper interfaces being particularly susceptible to damage. The necessity of reinforcing these zones to mitigate risks associated with dynamic loads was emphasized [1], while the limitations of conventional maintenance strategies in predicting optimal repair intervals were highlighted [2]. These limitations often lead to either premature maintenance interventions, incurring excessive costs, or delayed responses, heightening the risk of track failures. Finite element analysis (FEA) has emerged as a powerful tool in railway engineering, enabling precise simulations of static and dynamic forces acting on track components. This computational approach provides critical insights into stress distributions, fatigue life, and potential failure points. Despite its potential, gaps remain in the application of FEA to address the unique challenges of railway systems, particularly under heavy-haul and high-speed operations. International studies, such as those conducted by [3] and [4], have demonstrated the effectiveness of FEA in analyzing track degradation. However, localized factors, including material properties and operational loads, necessitate tailored models for improved accuracy. Research by [5] underscores the influence of dynamic loads at rail joints, emphasizing the need for advanced simulations to predict structural damage and optimize maintenance strategies.

This study employs FEA to model and analyze railway track degradation using NX Nastran and SolidWorks. Detailed simulations of key components, including rails, sleepers, clamps, and pads, are conducted to evaluate their performance under static, dynamic, and fatigue conditions. The objective is to enhance the accuracy of simulations through refined 3D modelling, contributing to more effective predictive maintenance strategies. The following research questions guide this investigation:

- How can FEA be used to simulate the linear static and dynamic behaviour of railway track components?
- What critical stresses indicate fatigue and degradation in track components?
- What improvements in 3D modelling are necessary to enhance the predictive accuracy of track degradation simulations?

It should be noted that all figures are given in the Appendix, at the end of this paper.

2. SIMULATION SCHEME AND GEOMETRY

Mathematical development

The development of finite element analysis (FEA) models, in both South African and international contexts, begins with mesh generation. This step involves discretizing the geometry of railway track components into finite elements, each representing a complex shape as smaller, interconnected parts. This division enables the application of numerical methods to effectively analyze the mechanical responses of the system.

During mesh generation, material properties such as young's modulus, Poisson's ratio, and density are assigned to each element. These properties simulate the mechanical behaviour of track components under various loading conditions. Boundary conditions are subsequently defined to replicate operational constraints, such as fixing certain points on the track or applying loads and displacements that mimic the dynamic interactions between trains and tracks. As noted by [6], the fineness of the mesh significantly affects the accuracy of the model, particularly in areas subject to high stress. In contrast, [7] emphasize the trade-off between computational efficiency and accuracy, suggesting that finer meshes improve accuracy but increase computational costs.

Each finite element is mathematically represented by an element stiffness matrix K^e, which is computed based on the material properties and shape functions of the element. These elements form discrete domains where the governing partial differential equations are simplified into algebraic equations. The software generates the element stiffness matrices and load vectors, assembles them into system equations, and applies the specified boundary conditions. It then solves the system of equations to determine the nodal displacements (field variables), which in turn allow the computation of resulting stresses and strains for each element, as demonstrated in Equations (1) to (13).

Element equations (Geometry creation)

The stiffness matrix of the element is denoted as $K^{(e)}$ and the force vector as $\vec{P}$. The elemental equations are formulated as:

$$\vec{P} = (K^e)\vec{u} \quad (1)$$

Where, $\vec{u}$ represents the nodal displacement vector at the nodes of the element. This formulation describes the behaviour of individual elements within the larger structure [8].

System equations (Geometry creation)

Once all elements are formulated, they are integrated into a unified global system of equations that describes the entire structure. This integration process combines the contributions from each element to construct a global stiffness matrix K and a global force vector $\vec{P}$.

The global equations can be written as:

$$\vec{P} = [K]\vec{\Phi} \quad (2)$$

Where $\vec{\Phi}$ is the global displacement vector representing displacements at all nodes of the structure [8]. Advanced techniques were introduced for matrix assembly, crucial in complex geometries like railway tracks, where elements connect at multiple nodes [9]. This stage ensures that the entire structural response can be evaluated from individual contributions.

Element properties (Material properties)

Material properties are embedded within the elasticity matrix E, as discussed by [10], particularly in structural applications subjected to various loading scenarios.

The elasticity matrix $[E]$ is expressed as:

$$\lambda = \frac{vE}{(1+v)(1-2v)} \quad (3)$$

$$\mu = \frac{E}{2(1+v)} \quad (4)$$

where λ and μ are elastic lame constants which can be expressed through the elasticity modulus E and Poisson's ratio ν:

- Boundary conditions:

Boundary conditions are enforced on the global system, modifying the global stiffness matrix and force vector to accurately represent the constraints imposed on the structure. These conditions are essential for ensuring realistic simulation outcomes. The geometric boundary condition is given by

$$u_i = \overline{u_i} \text{ ; on } S_u \quad (5)$$

Where u_i: Displacement component, $\overline{u_i}$: Specified displacement and S_u: The boundary where the displacement boundary condition is applied.

The challenges of enforcing these conditions were addressed in large interconnected systems [11], which are highly applicable in railway track simulations.

- Strain equations:

If u and v represent the x and y components of displacement, respectively, then the stress-displacement relationships are described by:

$$\sigma_x = \frac{E}{(1+v)(1-2v)}\{(1-v)\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\} \quad (6)$$

$$\sigma_x = \frac{E}{(1+v)(1-2v)}\{(1-v)\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\} \quad (7)$$

$$\tau_{xy} = \frac{E}{2(1+v)}(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}) \quad (8)$$

Detailed derivations of these equations were provided, which are essential for simulating both static and dynamic loads encountered in railway operations [9]. These equations are central to accurately modelling stress distributions within railway tracks. The stress components must also satisfy the differential equations of equilibrium:

$$\tau_{xy} = \left\{\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y}\right\} + x = 0 \quad (9)$$

$$\tau_{xy} = \left\{\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \sigma_y}{\partial y}\right\} + y = 0 \quad (10)$$

These equilibrium equations, discussed in [11], are crucial for ensuring the accuracy of the stress distributions in the railway track model.

Stress equations (Principal stresses):
In a three-dimensional solid body, the three principal stresses (σ1, σ2, σ3) can be determined as the roots of the following cubic equation:

$$\sigma^3 - I_1\sigma^2 + I_2\sigma - I_3 = 0 \quad (11)$$

Where:

$$I_1 = \sigma_{xx} + \sigma_{yy} + \sigma_{zz}$$

$$I_2 = \sigma_{xy} + \sigma_{xz} + \sigma_{yz} - \tau_{xy}^2 - \tau_{xz}^2 - \tau_{yz}^2$$

$$I_3 = \sigma_x\sigma_y\sigma_z + 2\tau_{xy}\tau_{xz}\tau_{yz} - \sigma_x\tau_{yz}^2 - \sigma_y\tau_{xz}^2 - \sigma_z\tau_{xy}^2$$

For a two-dimensional body, the two in plane principal stresses (σ1, σ2) are given by:

$$\sigma 1{,}2 = \left\{\frac{\sigma_{xx} + \sigma_{yy}}{2}\right\} \pm \sqrt{\left(\frac{\sigma_{xx} - \sigma_{yy}}{2}\right)^2 + {\sigma_{xy}}^2} \quad (12)$$

Model development
The process of model development for FEA involves the following steps:

- Geometry definition: The first step is to define the geometry of railway track components, including rails, rail pads, guide plates, and sleepers, using computer-aided design (CAD) tools. Standardized dimensions based on railway track configurations are used to ensure the model accurately reflects real-world conditions. Previous studies, such as [12], highlight the importance of precise geometry definition for achieving accurate simulations in railway applications.
- Mesh generation: The model is divided into a series of finite elements to prepare it for analysis [8]. As explained by [6], optimal mesh density is important for capturing areas of stress concentration without overly increasing computational demands.
- Assignment of material properties: Collected material data, including mechanical properties such as yield strength and density, are assigned to each component to ensure realistic simulation behaviour [8]. Accurate material properties are crucial for obtaining reliable FEA results, especially when evaluating fatigue and failure modes [9].

Simulation setup
In the simulation setup, the following aspects are carefully defined:

- Boundary conditions: These simulate the support provided by the ballast and subgrade beneath the track. Constraints are applied to limit movement in critical directions, thereby preventing unrealistic displacements [8]. This step is essential for accurately replicating the physical constraints encountered by railway tracks during operation. According to [13], correctly implementing boundary conditions is vital for achieving realistic simulation outcomes.
- Load application: Static and dynamic loads, representing train operations, are applied to the track based on the axle load of typical train configurations. These forces mimic the stresses caused by train passage and other external factors [8]. Research by [14] indicates that simulating varying load conditions can significantly affect the accuracy of degradation assessments in railway tracks.
- Contact interactions: Contact interactions between track components including wheel-rail, rail pad-sleepers, and guide plates-tension clamps, are carefully modelled. These interactions are crucial for simulating load transfer and understanding how stresses occur at component interfaces [8]. Accurate modelling of contact mechanics is essential for predicting how components interact under load and influence degradation mechanisms over time. The importance of capturing detailed component interactions in railway systems through FEA was demonstrated [15].

3. MODEL PRE-PROCESSING

Analysis selected and performed
The study focused on critical components of the railway system, including rails, angle plates, tension clamps, rail pads, and sleepers, with an emphasis on evaluating the structural safety of the track. An illustration of these components is shown in Figure 1. The analysis is divided into three simulations:

- Static load analysis – Evaluated the track's structural response to stationary loads.
- Dynamic load analysis – Assessed the track's structural response under dynamic or moving loads.
- Fatigue analysis – Examined the long-term performance of the track under repeated cyclic loading to simulate continuous stress from passing trains.

Load analysis
The structural integrity of the railway track was assessed under static and dynamic load conditions using NX Nastran software. The process involved pre-processing steps, including meshing and applying constraints, followed by post-processing to evaluate stresses.

Meshing and fixed constraints: The track model was discretized using 10-node tetrahedral elements (CTETRA), as these elements are suitable for accurately representing the track's complex geometries, such as curved surfaces and joints. Their quadratic shape functions provide high precision in regions of high stress concentration, which is essential for identifying potential failure points [11].

Component interactions, particularly between the rails and sleepers, were modelled using a surface-to-surface contact approach. This method effectively accounted for variations in contact pressure and slippage, ensuring realistic simulation results [7]. Fixed constraints were applied at specific points on the model to replicate real-world boundary conditions, such as supports and physical restraints. These constraints are critical to accurately capturing the structural behaviour under operational loads [6].

Forces applied: In South Africa, the railway infrastructure supports a maximum axle load of 30 tons, according to Transnet freight rail [16]. Two load cases were defined for the analysis:

- Static load case: The axle load was amplified by a safety factor of 1.75, as recommended [17], resulting in a total static load of 52.5 tons per axle or 26.25 tons per rail.
- Dynamic load case: An additional 26% was added to the static load to account for dynamic effects, such as speed and track irregularities [18]. This resulted in a total dynamic load of 66.15 tons per axle or 33.08 tons per rail.

Table 1 summarizes these load parameters, while Figure 2 visually depicts the applied load distribution.

Table 1. Load parameters

Load case	Parameter	Value (per axle)	Value (per rail)
Static load	Static	52.50 tons	26.25 tons
Dynamic load	Dynamic	66.15 tons	33.08 tons

Fatigue analysis

The fatigue analysis was conducted to evaluate the long-term durability of the railway track under repeated loading. This analysis estimates how many load cycles the track can handle before fatigue-related damage affects its structural integrity. A detailed 3D model of the railway track (see Figure 3) was created to capture how loads are distributed across its components during actual operation.

SolidWorks simulation was used for both pre-processing and post-processing:

- Pre-processing: This phase involved defining the mesh structure of the model, assigning material properties specific to railway components, and applying boundary conditions that mimic the actual constraints on the track.
- Post-processing: This phase included reviewing simulation results to evaluate fatigue life by examining areas of maximum stress, load cycle counts, and damage buildup from repeated loading.

Meshing and fixed constraints: A fine mesh was created using tetrahedral elements to represent the track's geometry accurately. These elements are particularly effective for capturing stress concentrations in complex areas, such as junctions, ensuring reliable results [6] and [7].

The interaction between components, such as rails, sleepers, and underlying structures, was modelled using a gluing method. This technique ensures realistic load transfer across the components and prevents separation during repeated loading. It closely replicates actual operational conditions, enabling accurate fatigue life predictions [11] and [9]. Boundary conditions were applied to critical points like edges and support to replicate real-world constraints and avoid unrealistic deformations. The dynamic load of 66.15 tons per axle (33.08 tons per rail) was applied cyclically to evaluate the fatigue life of the track. This detailed process ensured the simulation accurately represented real-world operational stresses.

4. RESULTS AND DISCUSSION

The results of this study are divided into three sections, each corresponding to a different load case in the finite element analysis (FEA) model. These load cases were load case 1 (static load), load case 2 (Dynamic load), and load case 3 (Fatigue analysis).

Load case 1 – FEA results (Static load)

Overall structure analysis: Under static loading conditions, the FEA model reveals a peak stress of 349.93 MPa, with the guide plate exhibiting the highest concentration of stress. This finding emphasizes the critical role of the guide plate in absorbing static forces during operation. The stress distribution across the structure is presented in Figure 4, with a detailed focus on the left and right regions of the model to capture localized stress variations.

Rails and Sleepers analysis: The rails and sleepers were separately evaluated for induced stress under static load. The maximum stresses observed were 28.39 MPa for the rails and 23.11 MPa for the sleepers. With yield strengths of 450 MPa and 60 MPa, respectively, safety factors of 15.85 for the rail and 2.60 for the sleeper were calculated, demonstrating the ability of both components to safely withstand static loads. Stress distributions for these components are depicted in Figures 5 and 6.

Rail pads and Guide plates analysis: The analysis shows a peak stress of 3.79 MPa for rail pads and 349.93 MPa for guide plates. Comparing these values to their respective yield strengths (8.3 MPa for rail pads and 700 MPa for guide plates), safety factors of 2.19 and 2.00 were obtained. These results confirm the adequacy of the design under static conditions, see Figures 7 and 8.

Tension clamps analysis: The tension clamps experienced a maximum stress of 280.44 MPa, well below their yield strength of 950 MPa. This gives a safety factor of 3.39, indicating they are reliable under static loads (see Figure 9).

Load case 2 – FEA results (Dynamic load)

Overall structure analysis: Dynamic loading resulted in a peak stress of 348.97 MPa, with the guide plate again showing the highest stress concentration. The stress distribution patterns across the full structure and selected areas under dynamic loading conditions are illustrated in Figure 10.

Rails and Sleepers analysis: Under dynamic conditions, the rails and sleepers experienced stresses of 35.69 MPa and 29.04 MPa, respectively. Safety factors were determined as 12.61 for the rail and 2.07 for the sleeper, confirming their resilience to dynamic loading. The stress distributions are shown in Figures 11 and 12.

Rail pads and Guide plates analysis: Dynamic loads induced peak stresses of 4.78 MPa in the rail pads and 348.97 MPa in the guide plates, corresponding to safety factors of 2.74 and 2.01, respectively. These results affirm the capability of these components to operate safely under dynamic conditions. Stress profiles are provided in Figures 13 and 14.

Tension clamps analysis: The stress observed in the tension clamps under dynamic loading was 280.42 MPa, yielding a safety factor of 3.39, consistent with the static analysis. The dynamic stress distribution is shown in Figure 15.

Load case 3 – FEA results (Fatigue)

Fatigue analysis assessed the long-term durability of the railway track under repeated loading. The model predicted a lifespan of approximately 109,800 load cycles, which translates to a service life of approximately 50 years when subjected to typical operational conditions (Equation 15). High-stress areas, such as rail joints, were identified as critical zones for fatigue cracking, as illustrated in Figure 16.

The key findings for both static and dynamic load cases are summarized in Tables 2– 4, which include stress-induced values, yield strengths, and calculated safety factors for each component.

Table 2. Strength criteria

Description of Yield strength	**Symbol**	**Unit**	**Value**
Rail	R_y	MPa	450
concrete sleeper	R_y	MPa	60
Rail pad	R_y	MPa	8.3
Guide plate	R_y	MPa	700
Tension clamp	R_y	MPa	950

Table 3. Safety factor (static load)

Load case 1 Yield strength	**Yield strength of material, σ_s [MPa]**	**Stress Induced, σ_i [MPa]**	**Safety factor**
Rail	450	28.39	15.85
B70 Sleeper	60	23.11	2.60
Rail pad	8.3	3.79	2.19
Guide plate	700	349.93	2.00
Tension clamp	950	280.44	3.39

Table 4 Safety factor (dynamic load)

Load case 2 Yield strength	**Yield strength of material, σ_s [MPa]**	**Stress Induced, σ_i [MPa]**	**Safety factor**
Rail	450	35.69	12.61
B70 Sleeper	60	29.04	2.07
Rail pad	8.3	4.78	2.74
Guide plate	700	348.97	2.01
Tension clamp	950	280.42	3.39

In addition to static and dynamic stress analysis, a fatigue analysis was conducted to assess the railway track's long-term durability under repeated cyclic loading. The simulation results indicate that the railway track structure can endure a minimum of 109,800 load cycles. Here, one load cycle represents a complete train passage across the track. To estimate the operational lifespan of the railway track, the following formula was applied:

$$Number\ of\ years = \frac{Total\ load\ cycles}{Daily\ cycles} \quad (13)$$

$$Number\ of\ years = \frac{109800}{365\ x\ 6} = 50.14$$

This calculation demonstrates that the railway track has an expected service life of approximately 50 years under typical operational conditions. This substantial lifespan highlights the design and the favourable fatigue performance of the track materials. Specifically, the high yield strength of key components such as the guide plates and rails contribute to this longevity.

Discussion of results

The discussion integrates the findings from three primary simulations: static load analysis, dynamic load analysis, and fatigue analysis. Each simulation provides a distinct perspective on the structural behaviour, stress distribution, and durability of the railway track under operational conditions.

Static and dynamic load analysis: The static and dynamic analyses revealed key stress patterns and safety margins for critical components, including rails, sleepers, rail pads, guide plates, and tension clamps. While both

analyses indicated that the components remain within safe operating limits, dynamic loads resulted in higher stress concentrations, consistent with prior studies. For instance, dynamic forces exacerbate stress concentrations, particularly at rail joints, thereby accelerating track degradation [19]. Similarly, dynamic loading leads to significantly higher localized stress than static loading, which aligns with this study's findings [20].
However, contrasting perspectives in the literature shed light on additional influential factors. The ballast quality, including its compaction, moisture levels, and fouling, plays a more critical role in load distribution and track stability than dynamic loading alone [21]. Supporting this view, [22] highlighted the effectiveness of geogrid reinforcement in ballast layers, which redistributes loads and reduces settlement, thereby enhancing overall track stability. Similarly, the ballast degradation due to repeated load cycles directly impacts track geometry and alignment, significantly influencing long-term performance [23].
While this study focuses primarily on the track components, these insights underscore the complexity of railway track degradation. Incorporating ballast quality and interactions between track components and substructures into future analyses could yield a more holistic understanding of the system's behaviour under loading.

Fatigue analysis: The fatigue analysis confirmed that cyclic loading significantly influences the track's long-term durability, with high-stress zones such as rail joints being particularly prone to fatigue cracking. These results align with [24], who identified cyclic loading as a primary driver of fatigue failure in railway tracks. Their research highlighted the importance of monitoring cyclic stresses to predict failure and improve maintenance strategies, findings that are supported by this study.
However, other factors beyond cyclic loading also merit consideration. Environmental conditions, such as temperature variations and material composition, may have a more pronounced impact on fatigue life than cyclic loading alone [25]. For example, thermal expansion and contraction can exacerbate stress concentrations and accelerate crack propagation, a phenomenon not fully explored in this study. Incorporating environmental factors such as temperature fluctuations, humidity, and corrosion effects into future simulations could provide a more comprehensive understanding of fatigue behaviour.

5. CONCLUSION

This paper presented a thorough study into the degradation mechanisms of railway tracks in the South African railway system using finite element analysis (FEA). The primary objectives were to analyze the effects of static and dynamic loading on track components and evaluate their implications on stress distribution and fatigue life. By leveraging advanced simulation techniques within the SolidWorks platform, the research provided detailed insights into critical areas of track degradation and proposed strategies to improve maintenance practices and enhance track longevity.
The FEA simulations accurately modelled the geometry of the railway track, encompassing essential components such as rails, sleepers, rail pads, and fastening systems. Static and dynamic load cases, representing typical operational conditions, were applied to evaluate stress distribution and identify critical regions prone to degradation. Dynamic load cases incorporated train axle forces and replicated cyclic stresses experienced by railway tracks, offering a realistic representation of long-term operational effects. Key findings include the identification of critical stress points at rail joints and fastening systems, where maximum von mises stresses occurred under dynamic loading. Despite these elevated stresses, the track components maintained sufficient safety margins, affirming their structural integrity. The analysis also highlighted the significant role of rail pads in mitigating stress transfer, underscoring the importance of using materials with damping properties. The fatigue analysis revealed the potential for degradation at high-stress regions, particularly rail joints, due to cyclic loading. This emphasizes the necessity for improved joint designs or targeted maintenance interventions to mitigate crack initiation and propagation. Furthermore, the track's estimated service life of approximately 50 years reflects the current design under typical operational conditions. However, the study also revealed opportunities for further optimization to address factors influencing long-term durability. To enhance the predictive accuracy and practical application of the findings, the study highlights the following areas for future research and improvement: incorporating ballast quality, exploring environmental effects and enhancing monitoring strategies.

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APPENDIX

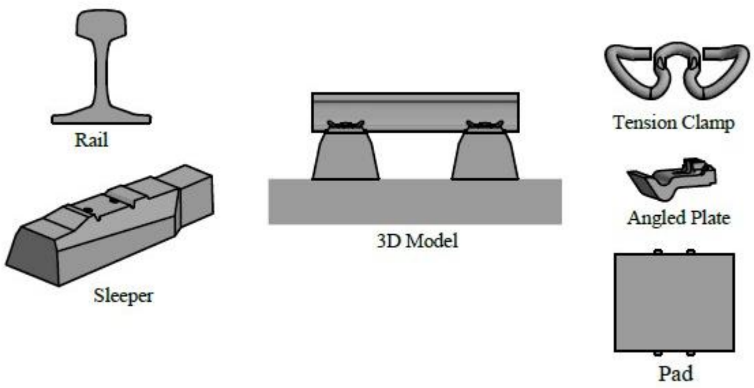

Figure 1. Layout of components

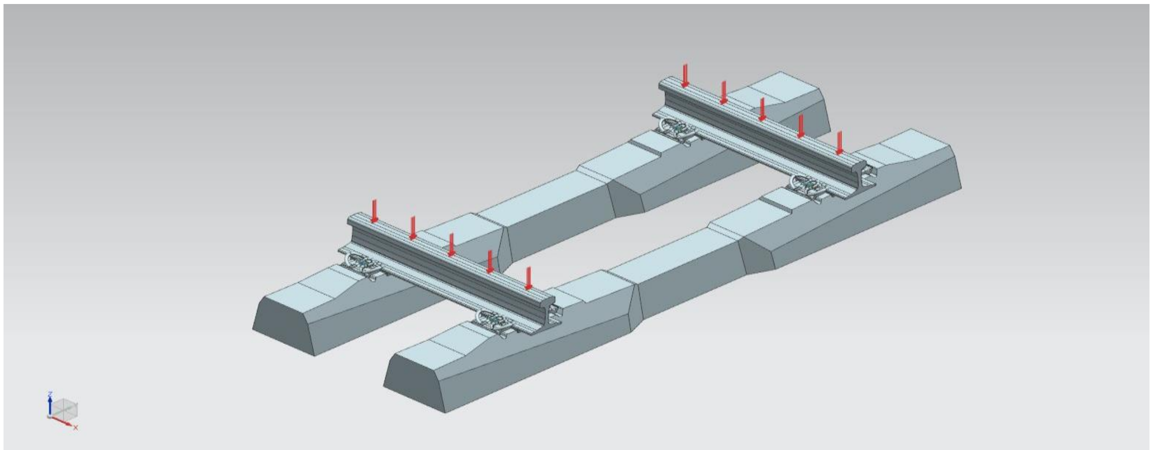

Figure 2: Distributed load applied

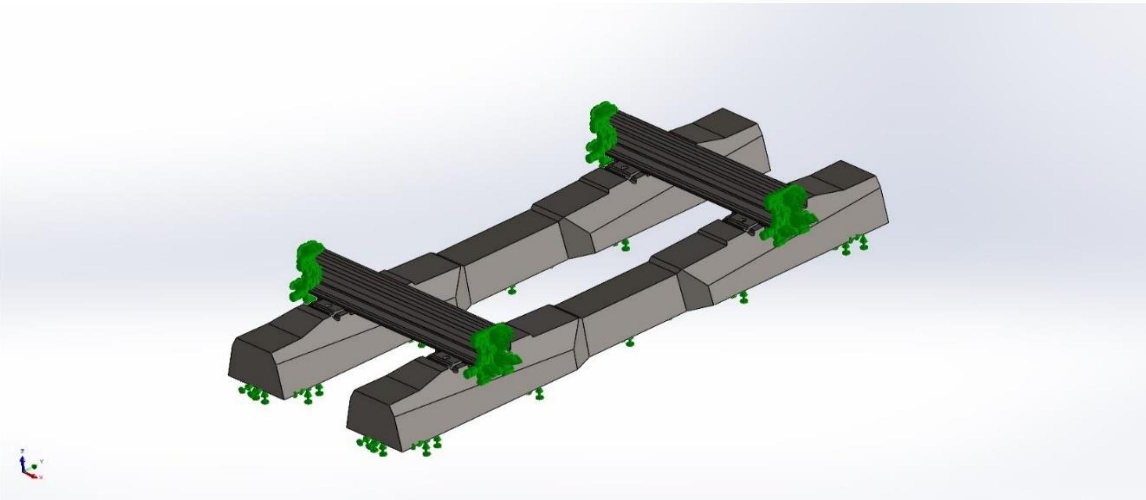

Figure 3. 3D Model – Railway track (fatigue analysis)

Load case 1 – FEA results (Static load)

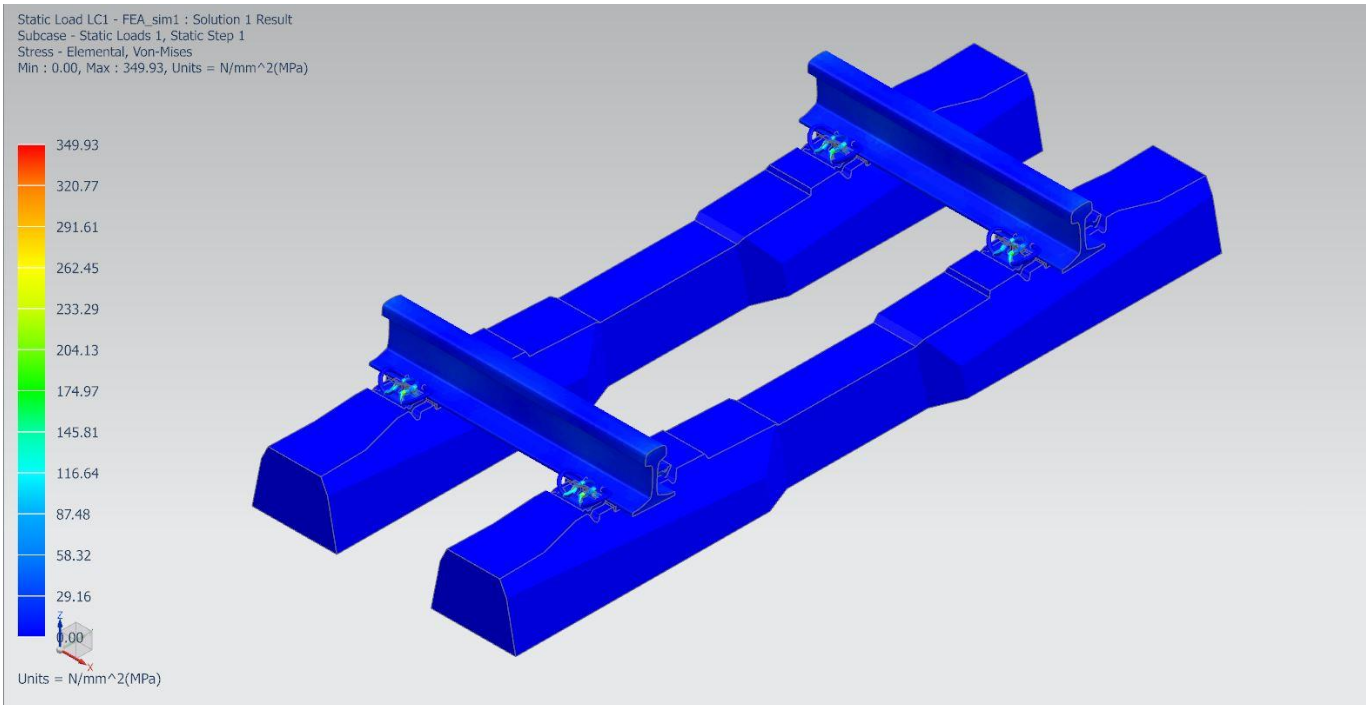

Figure 4. Induced stress (Von-mises)-Full structure

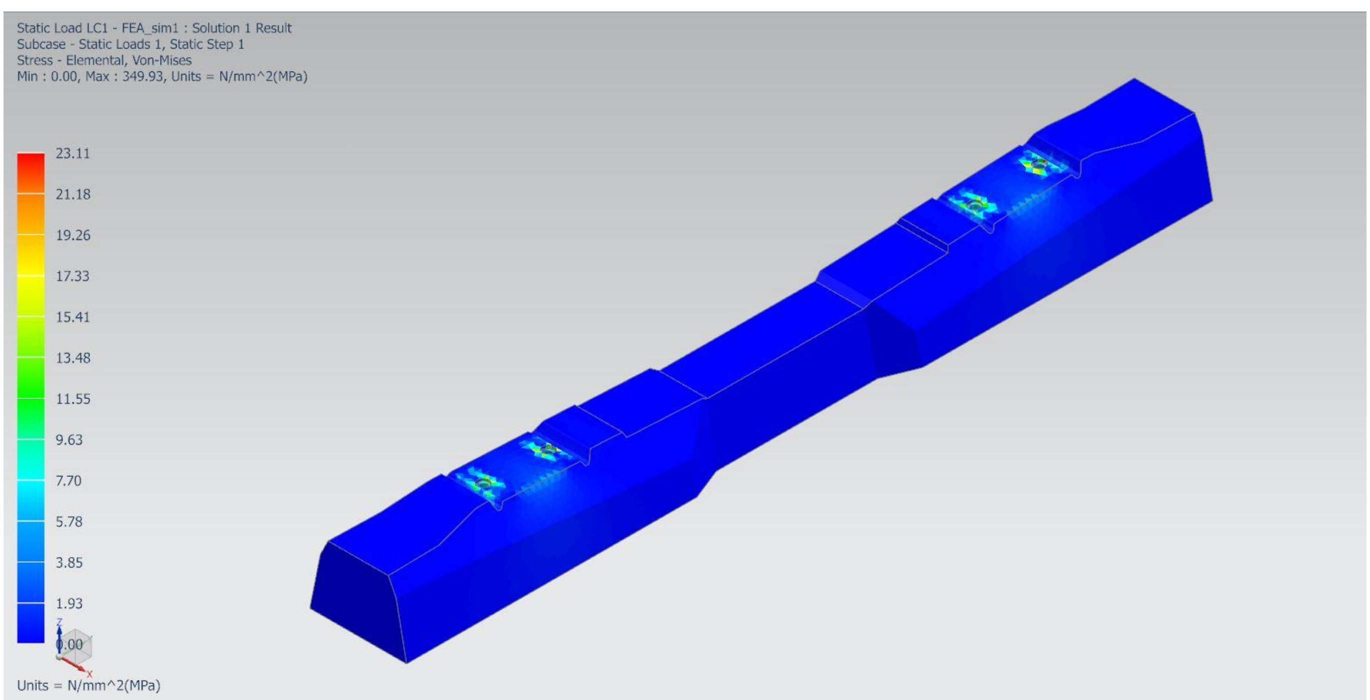

Figure 5. Induced stress (Von-mises) – sleepers (static load)

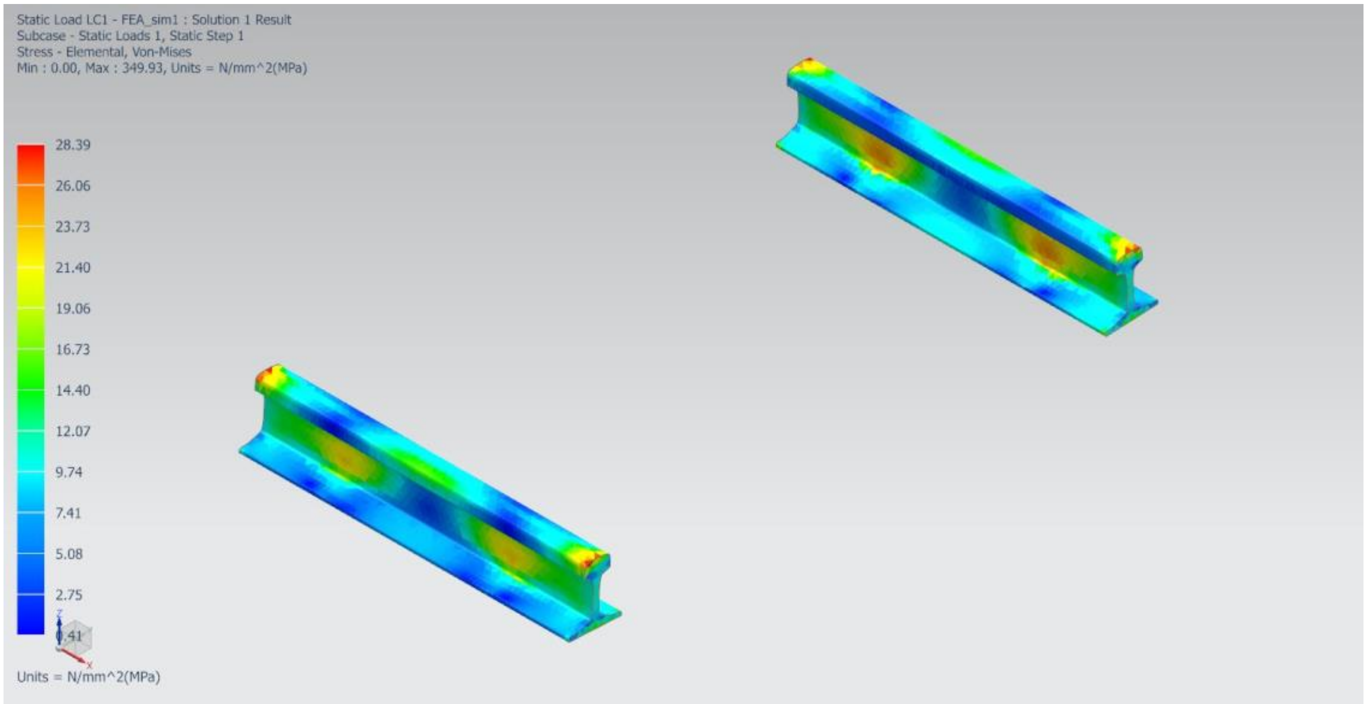

Figure 6. Induced stress (Von-mises) – Rails (static load)

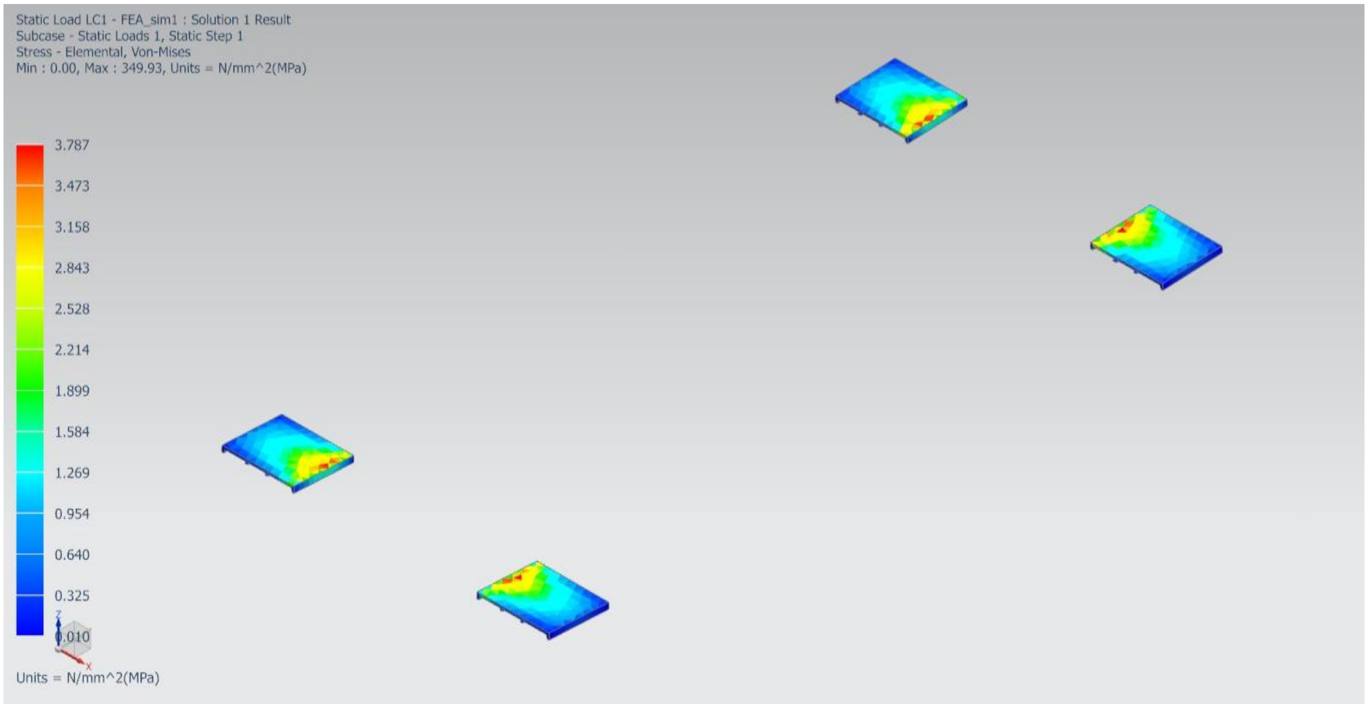

Figure 7. Induced stress (Von-mises) – Rail pads (static load)

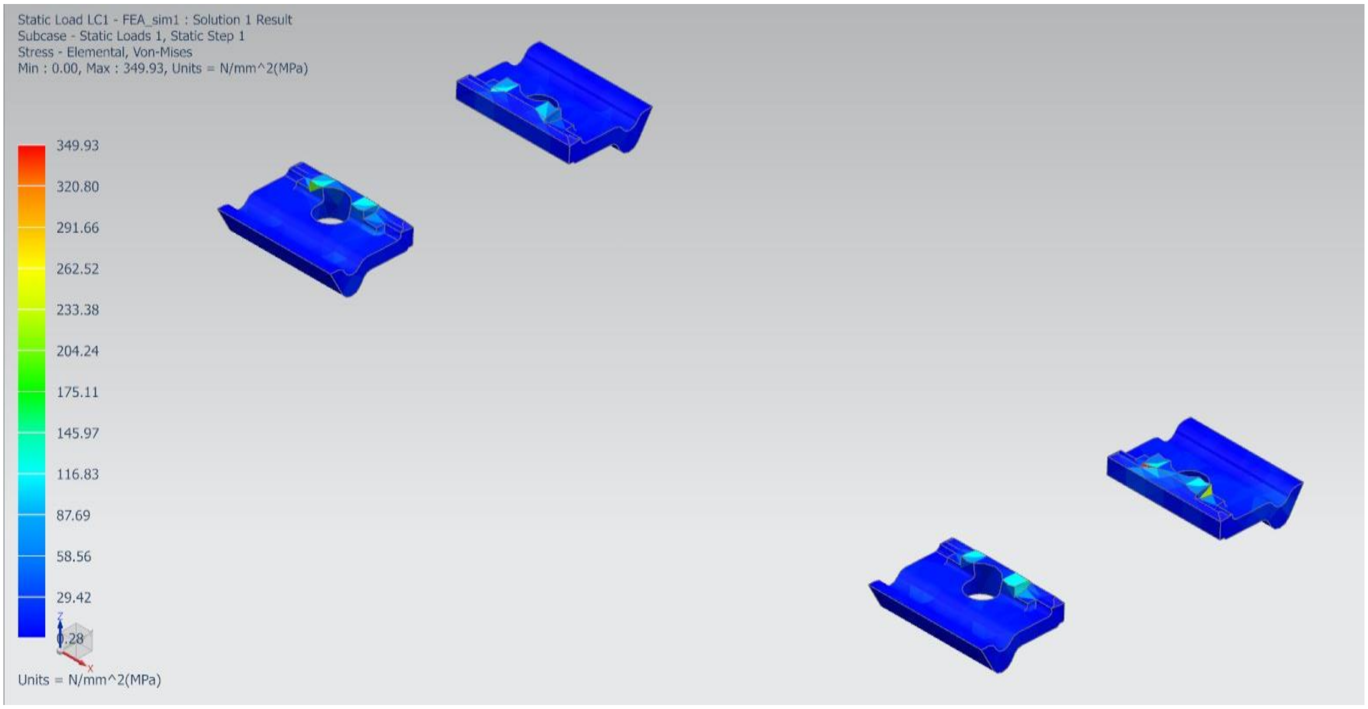

Figure 8. Induced stress (Von-mises) – Guided plates (static load)

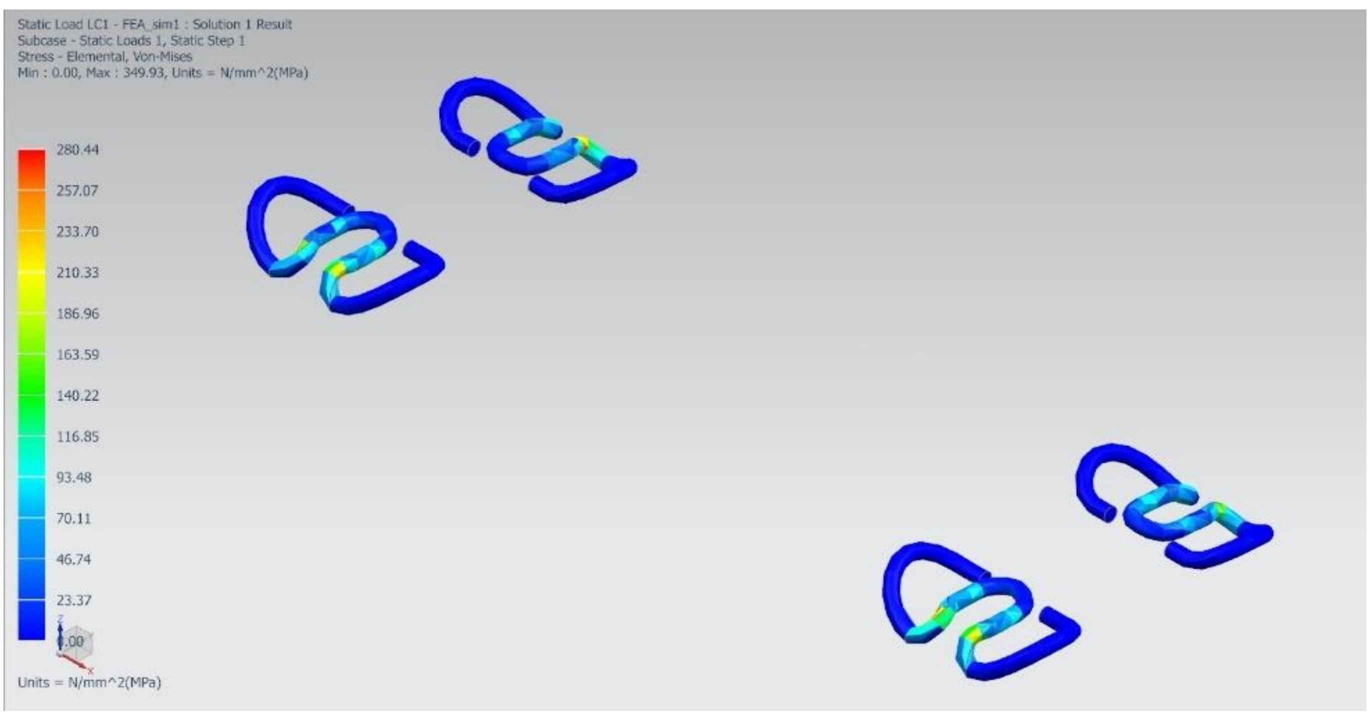

Figure 9. Induced stress (Von-mises) – Tension clamps (static load)

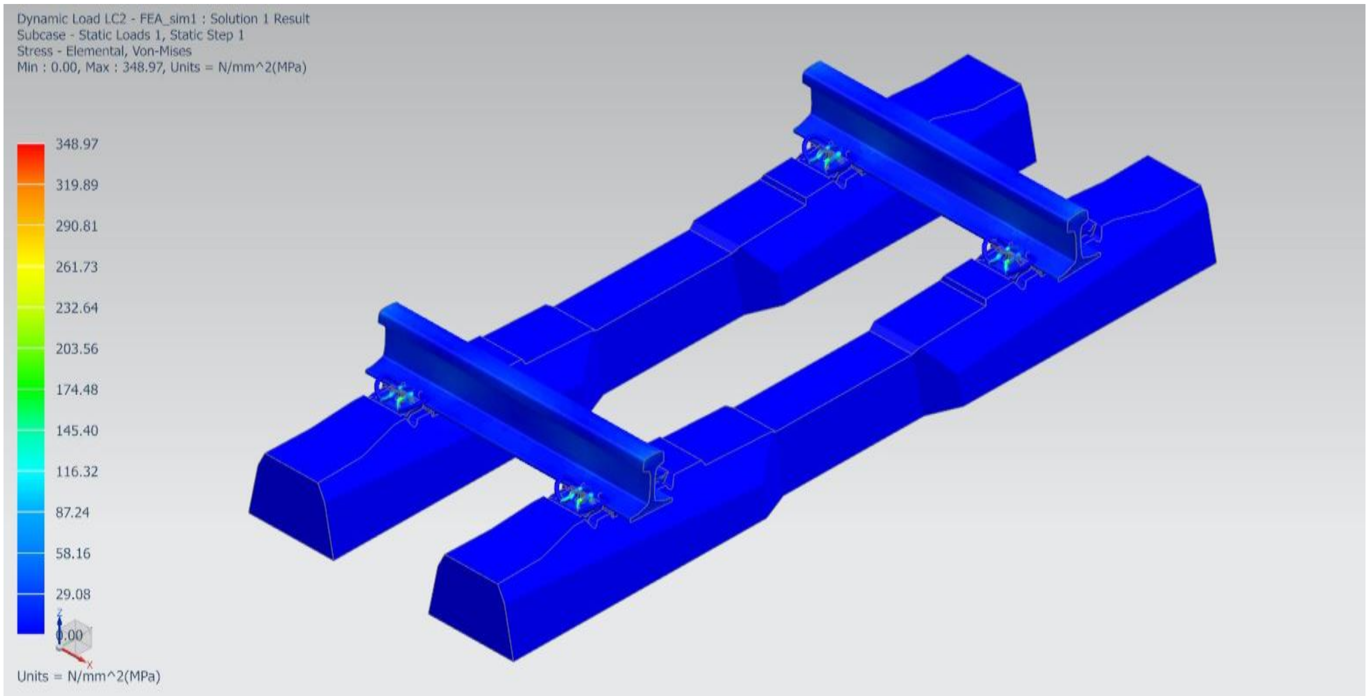

Figure 10. Induced stress (Von–mises) – Full structure (dynamic load)

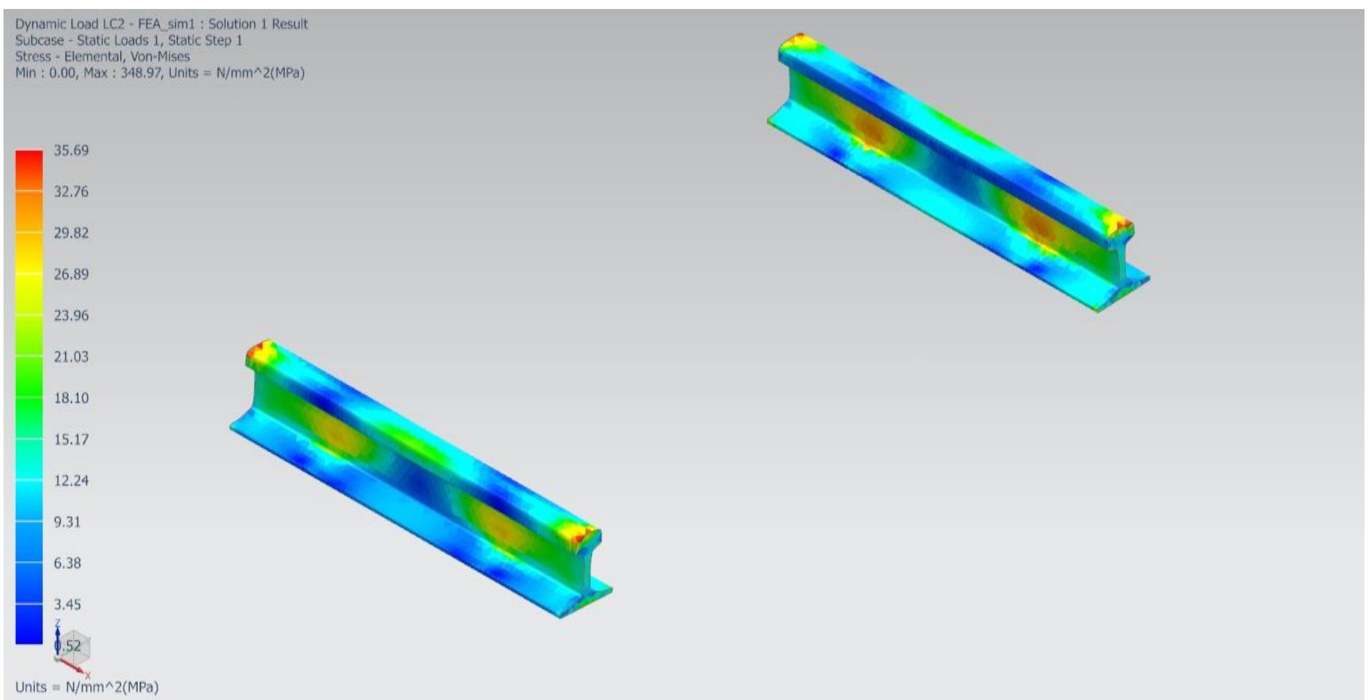

Figure 11. Induced stress (Von-mises) – Rails analysis (dynamic load)

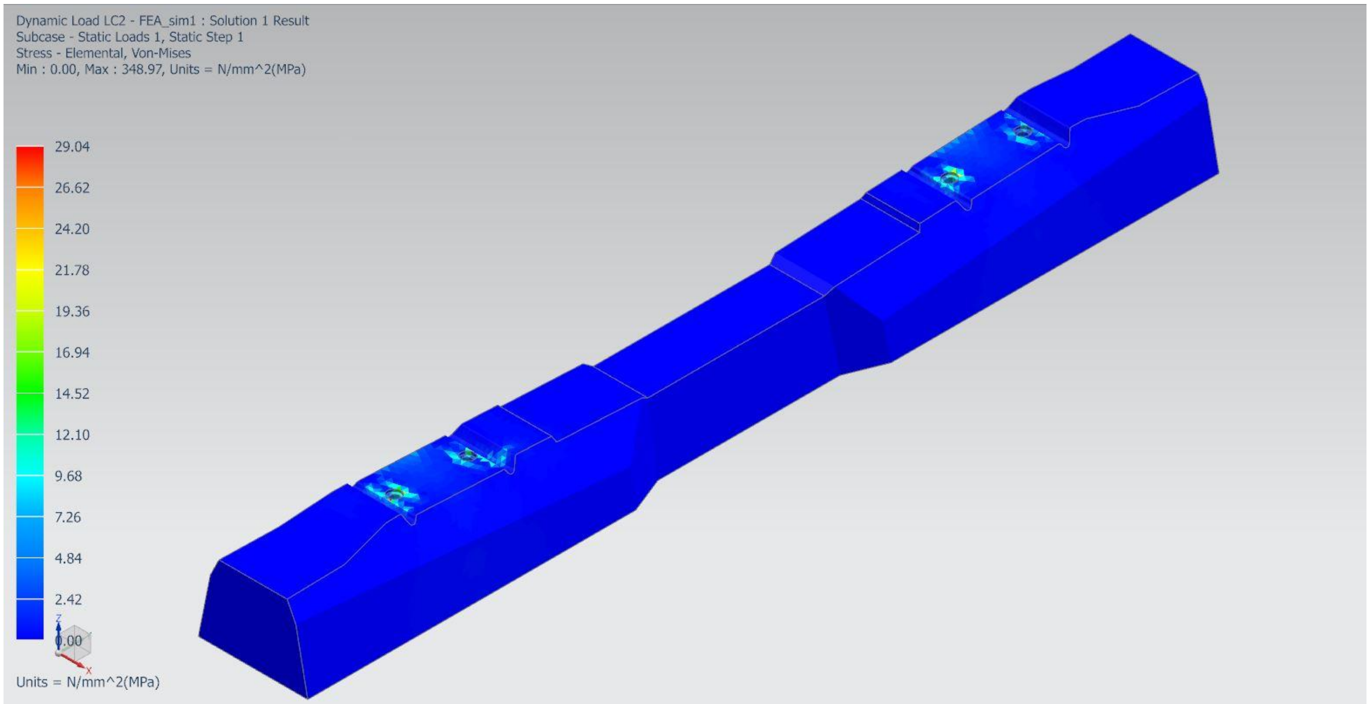

Figure 12. Induced stress (Von-mises) – sleepers (dynamic load)

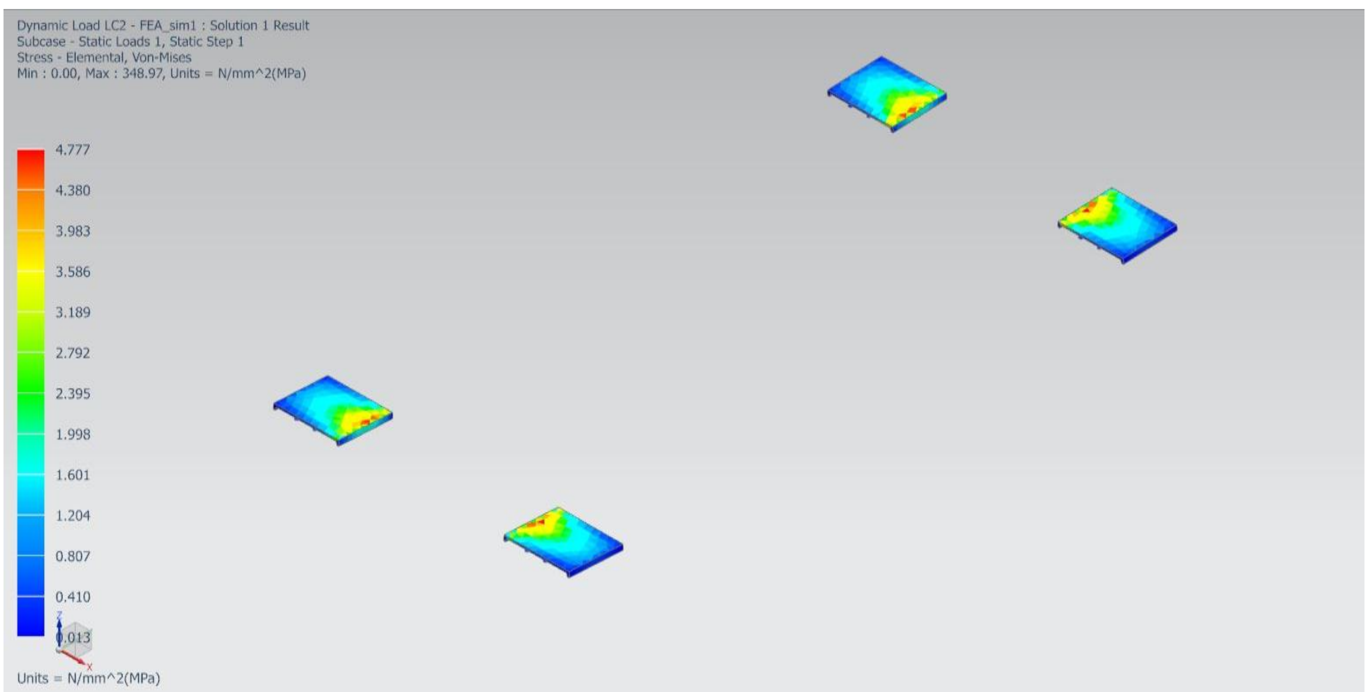

Figure 13. Induced stress (Von-mises) – Rail pads (dynamic load)

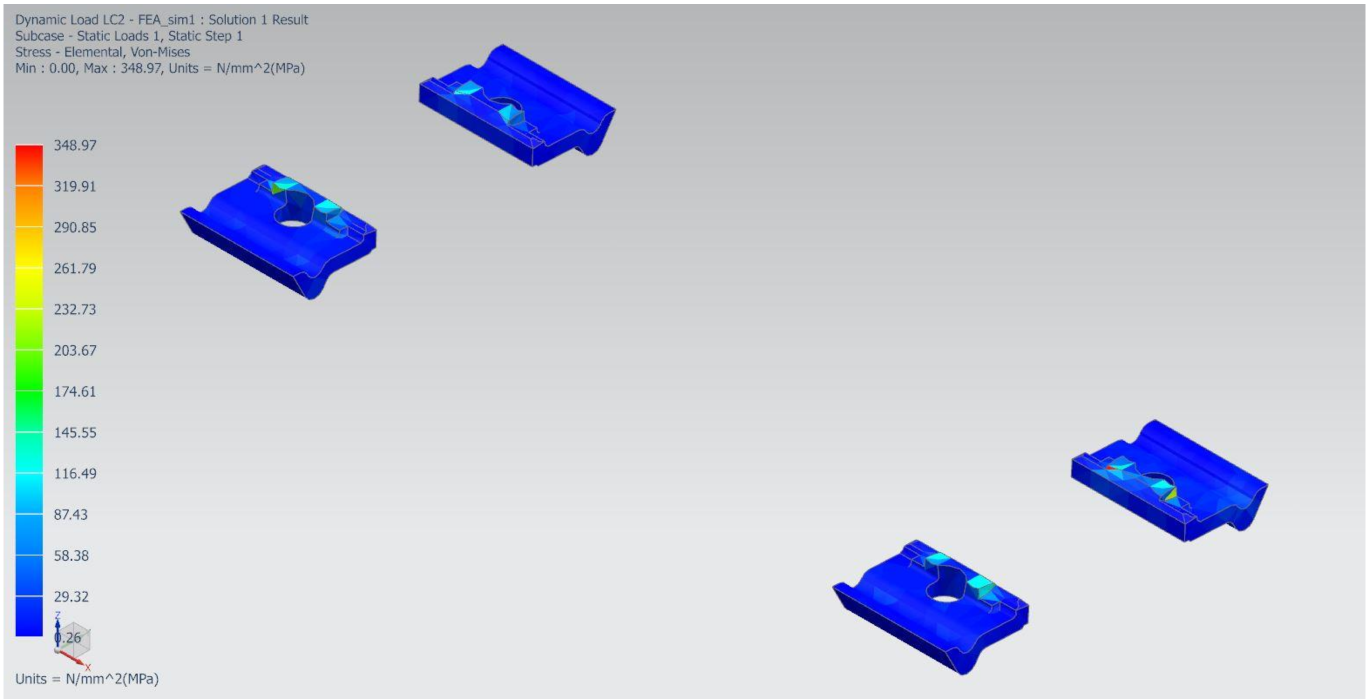

Figure 14. Induced stress (Von-mises) – Guide plates (dynamic load)

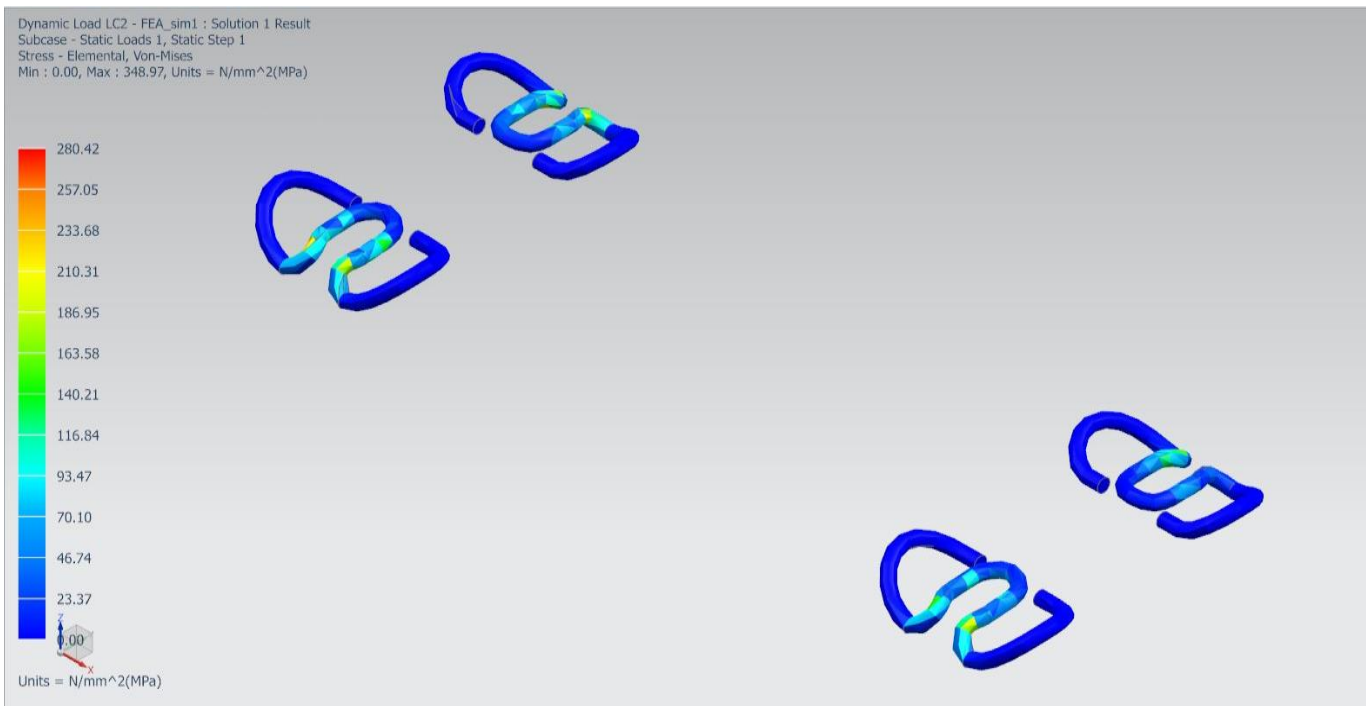

Figure 15. Induced stress (Von-mises) – Tension clamps (dynamic load)

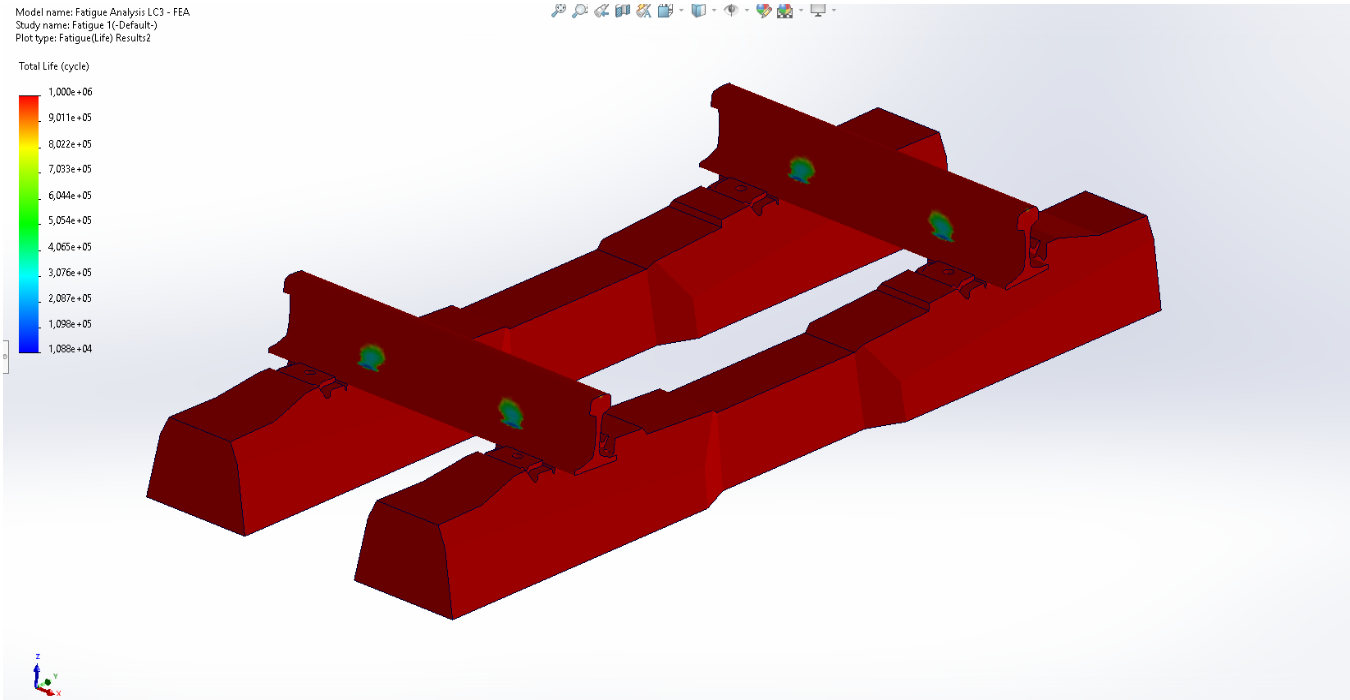

Figure 16. Fatigue total life (cycles) – Isometric view