ANALYSIS OF RAIL FASTENING SYSTEM DELTA LAGER I FAILURE

ANALÝZA PŘÍČINY PORUŠENÍ UPEVŇOVACÍHO SYSTÉMU KOLEJNIC TYPU DELTA LAGER I

Autoři:

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Anotace:

V rámci příspěvku je prezentována analýza možných příčin opakovaného porušování upevňovacího systému patkových kolejnic typu Delta Lager I. Tento systém upevnění je běžně používán při budování podzemních drah metra. Běžné bezpečnostní prohlídky na trati metra odhalily větší množství odtržených vysokopevnostních šroubů, které zajišťují spojení kolejnice a betonového pražce. Výpočty vedoucí k objasnění příčiny porušování byly provedeny s podporou programu ANSYS 11.0. Prostorový výpočtový model zohledňující kontakty mezi jednotlivými konstrukčními částmi byl vytvořený dle výkresové dokumentace. Na sestaveném výpočtovém modelu byla provedena řada nelineárních výpočtů pro různé varianty imperfekcí systému upevnění - pražec. Na základě provedených výpočtů byly odhaleny konstrukční nedostatky uvedeného systému upevnění.

Annotation:

Within the presented paper an analysis of possible causes for failure of rail fastening system Delta Lager I is presented. The type of fastening attributed as Delta Lager I is commonly used in underground railway system. Routine safety inspections revealed higher amount of broken high-strength steel bolts that secures interconnection between the rail and a concrete sleeper. Performed computations were carried out using ANSYS 11.0 to help to found out cause of the problem. Spatial computational model of fastening construction including different contact regions was modeled in conformity with drawing documentation. Further were performed non-linear computations in several alternatives of imperfections configuration. On accounts of FEM computations were determined inadequacies in construction of rail fastening system.

Foreword

The aim was to analyze construction detail which provides flexible interconnection between the concrete sleeper and rail. The type of fastening attributed as Delta Lager I is commonly used in underground railway system. Interconnection is assembled from several parts. Steel cantilever which is supposed to stabilize rail in requested position is directly connected to the sleeper with prestressed bolts. Soft foam layer is put under the base of rail to reduce vibration and noise.

The reason for proceeding structural analysis is fact that during railway operation occurred unexpected problems. Prestressed bolts securing the coherence of steel cantilever and sleeper are loaded over the bearing resistance and often break which causes unacceptable damage of whole fastening.

Structural analysis of rail fastening is carried out to determine stress distribution over the construction especially over the prestressed bolts. Computations were performed using Finite Element Method applied on compiled numerical models. Mathematical models were modeled with the aid of internationally certified software ANSYS 11.0 based on FEM. Computational models are worked out considering project documentation and further documentation. Results and findings are presented in text and figures.

Description of rail fastening

Interconnection is assembled from several parts. Steel cantilevers which are supposed to stabilize rail in requested position are directly connected to the sleeper with prestressed bolts. Bolts M24 class 8.8 are prestressed as requested. Force is transmitted from the bolts to steel cantilevers by steel excenter. Steel cantilevers are provided by rubber lining which is inlayed between the cantilevers and the rail. Cantilevers are at both sides of the rail and stabilize it in requested position. Cantilevers are underlaid with the PE plates. Soft rubber layer is put under the base of rail to reduce vibration and noise.

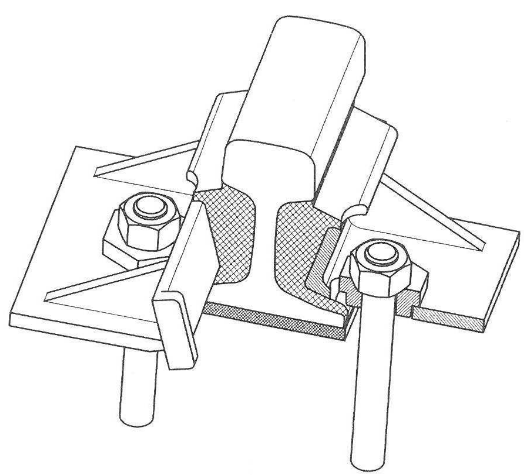



Figure 1, 2: Detail of fastening

Computational model

Computational model was compiled using software ANSYS 11.0. 3D mathematical model was made in conformity with obtained project documentation. Detailed solid model of whole fastening was made concerning the sufficient length of rail. 2D computational model would not be able to involve all necessary effects.

Particular parts of fastening are modeled with structural finite elements SOLID45. These are used for the 3-D modeling of solid structures. Separated parts of the computational model are covered by contact and target surface finite elements TARGET170 and CONTACT173. The former used to represent various 3-D “target” surfaces for the associated contact elements (CONTACT173). The contact elements themselves overlay the solid elements describing the boundary of a deformable body and are potentially in contact with the target surface, defined by TARGET170.

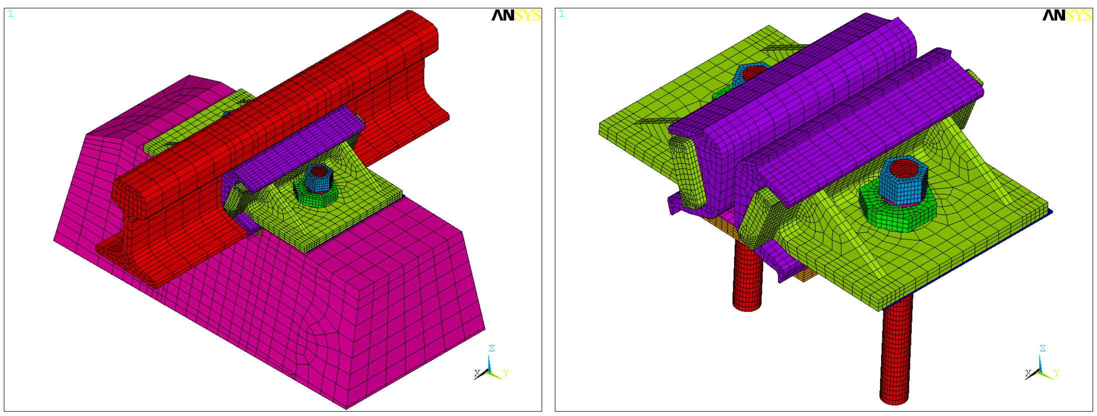


Figure 3, 4: Computational model

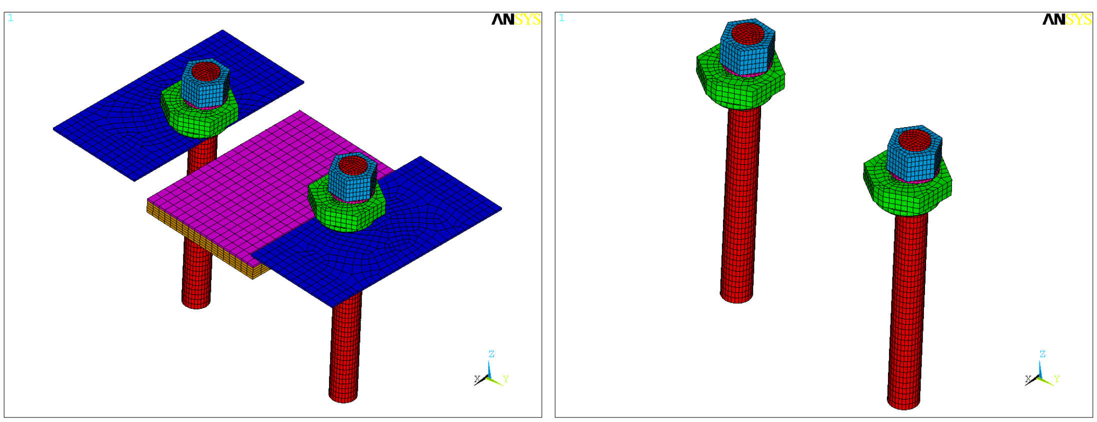


Figure 5, 6: Parts of computational model

Carried out computations

Nonlinear analysis of construction detail was carried out in two alternatives:

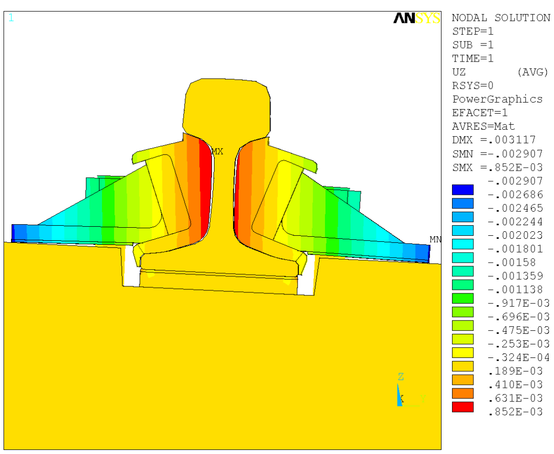
Gap between the PE plate, which is laid under the steel cantilever and a solid sleeper, is included in computation model. In conformity with documentation the gap is 3 mm (0 mm alternatively). Solution is divided into two load steps. Within the first load step the prestressed effects are computed. Finalization of bolts in direction towards the sleeper about 3 mm (prestressed effect calculation alternatively) was carried out. Achieved normal force in bolt is 26 kN (126 kN alternatively). In the second load step nodal forces appropriate to weight of locomotive are applied.

Results and findings

Within the proposed paper an analysis of rail fastening construction Delta Lager I is described. The aim was to find out the cause of steel bolts M24 class 8.8 rupture.

The load cases were defined by ordering party. Bolts are tightened by torque wrench to achieve the required 200 Nm of torque (normal force in bolt is 126 kN). The second load case is vertical load caused by the locomotive (appropriate wheel force is 65 kN).

Stress analysis of fastening was carried out for two possible conditions of initial geometry. In the first case the geometry of fastening is modeled strictly according to project documentation. Gap between the PE plate, which is laid under the steel cantilever, and solid sleeper is included in computation model. In conformity with documentation the gap is 3 mm. Finalizations of bolts in direction towards the sleeper about 3 mm was carried out. Achieved normal force in bolt is 26 kN. Abnormal rise of bending stress was noticed (fig. 7, 8).



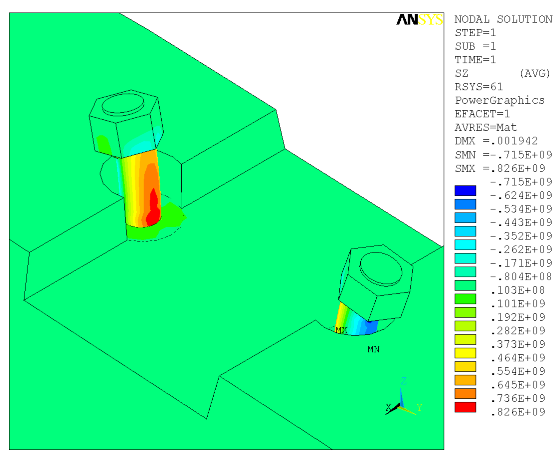


Figure 7, 8

Figure 9, 10

In the second case the gap between the PE plate, which is laid under the steel cantilever and solid sleeper is considered to be zero. It is provided by offsetting the contact surfaces. Achieved normal force in bolts corresponds to required value 126 kN. Subsequently vertical load was applied. On the basis of computations bending stresses are noticed again. Stress concentration appeared at excenter and steel cantilever (fig. 13, 14). Straining other construction parts of fastening from vertical load is not significant.

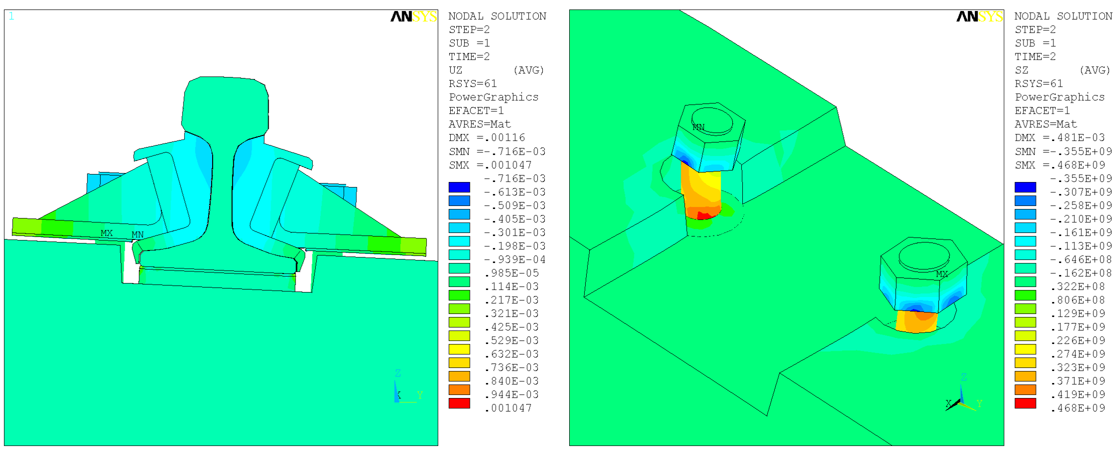


Figure 11, 12

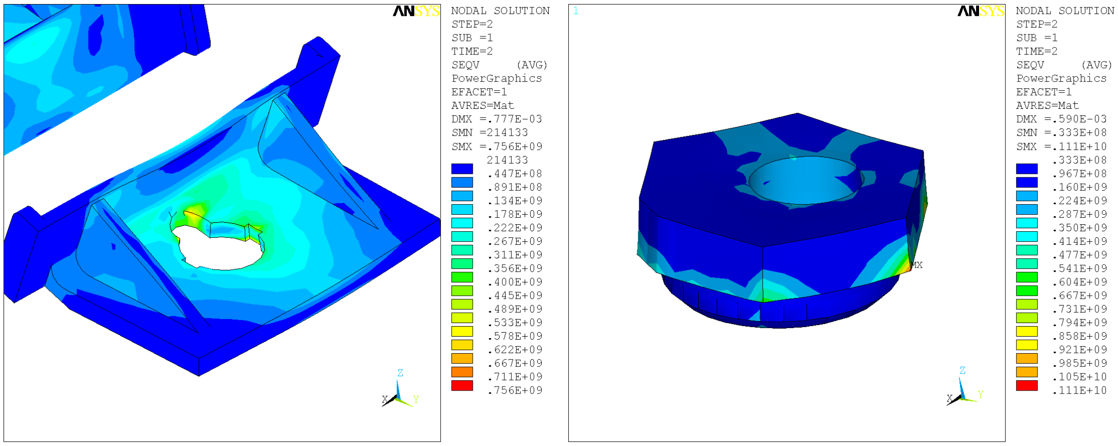


Figure 13, 14

Figure 15, 16

On the basis of stress analysis following attitude is assumed. The principle cause of bolts rupture is their significant bending even during installation. Such high-strength bolts are usually designed as prestressed when transmitting only normal and shear forces. Bending of the bolts which is caused by the analyzed construction system of fastening during tightening the bolts is not acceptable. Higher stresses at steel cantilever and excenter should be further analyzed. Possible way how to reduce them is construction adjustment.

Acknowledgements

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References and background papers:

[1] Specification of defects in the metro operation - fastening system Delta-Lager Ortec: Delta Lager table-eng

[2] ANSYS Release 11.0 Documentation, © 2007 SAS IP, Inc.