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MODELING OF PRESTRESSED BOLT CONNECTION IN LS-DYNA CRASH TEST ANALYSIS OF ROAD INFRACTRUCTURE

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Abstract: *Bolted connections are the most frequently used type of separable connections in the construction of machines and devices. In this study possibilities of modelling of this type of connections in the LS-Dyna environment with reference to designing a supporting construction of road infrastructure have been presented. Modelling a safety connector with the use of BEAM elements brings satisfactory results mainly when object of interest is a whole structure not a bolt only. In the case when mainly mechanisms of damage of a bolted connection are analysed it is justifiable to model a safety connector with the use of SOLID elements.*

Keywords: LS-Dyna, Road infrastructure, Bolt connection, Preload.

1. Introduction

With reference to a new safety standard PN-EN 12767 newly designed structures located in the road verge must meet the passive safety requirements. In the supporting construction of road infrastructure, proposed by the authors (Cichański, 2015), a safety connector has been used, which is subject to damage as a result of a crash of a moving vehicle into the construction. The main element determining the effectiveness of a safety connector is a bolted connection. However, it should also transfer loads resulting from the conditions of exploitation. Because of this it is very important to precisely specify, during a construction process, geometric and material properties of a connection, which would have an impact on the operation of a safety connector. Analytical calculations often occur to be insufficient. In such cases numerical simulations are successfully applied based on the finite element method. Then there is a series of issues to be solved and one of the basic ones is a manner of modelling a connection (Hadjioannou, 2016).

In the study the issue of modelling pre-load in safety connectors has been raised. Selected methods of modelling have been discussed. For consideration issue presented in the work the subarea of the road mast was chosen. Numerical analyses for a chosen subarea of a road infrastructure mast have been conducted. As a results of analysis normal and shear forces appearing in a bolt connector and reduced stresses were presented.

2. Object and conditions of tests

The foot of the mast being analysed has been presented in Fig. 1a. From the presented structure a subarea has been cut out, which is, namely, a safety connector being designed. It has been subject to further analysis in this study Fig. 1b. The lower plate of the thickness of 25 mm has been fixed by taking away degrees of freedom in all the directions. Constant translation has been applied to the bottom plate of the thickness of 10mm. Two analyses have been made. One with the pre-load of the 100 MPa introduced to the bolt shank and the other without pre-load.

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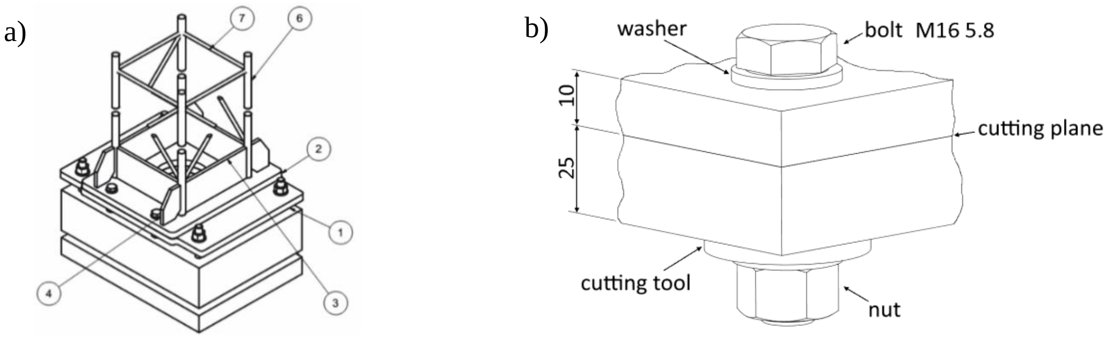

Fig. 1: a) Foot of the supporting construction equipped with a safety connector (1-foundation, 2-anchor bolt, 3-frame, 4-safety connector, 6, 7- rods of girder); b) safety connector.

3. Numerical modelling of a bolted connection

In order to verify the accepted assumptions and in order to analyse behaviour of the whole safety connector a numerical analysis has been conducted with the finite element method in the LS-Dyna environment. One of the basic issues during preparation of a numerical model has been the choice of a proper methodology of a bolted connection representation. Three manners of approach have been considered to model this type of connection in a wide range of possibilities available in the LS-Dyna environment. The main differences between them consisted in the application of SOLID and BEAM elements to model a coupler. The choice of a particular type of structural elements for a couplerh has determined the application of other types of contact elements between a coupler and a hole.

Beam model

The most frequently used technique of a bolted connection representation is the application of a beam element Fig. 2 (Shailesh, 2010). The bolt shank in this case is a beam with the defined cross-section, however, a connection of the shank with the holes in the plates can be made in two ways: with the application of SPOTWELD type contacts or with the use of NODAL_RIGID_BODY type constraints. These elements are strain resistant and if they are applied there is no need to define additional contacts between particular parts of a connector.

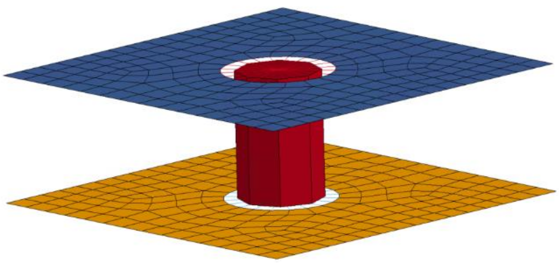

Fig. 2: BEAM type elements and NODAL_RIGID_BODY constraint.

In order to introduce pre-load into bold connection, the *INITIAL_AXIAL_FORCE_BEAM card should be used by providing the value of force resulting from a bolt tension. Values of normal and cutting forces in the bolt shank can be read directly from a BEAM element, however, there is no possibility of analysing shear stress in the contact point of the bolt and the hole.

Beam model with the application of contact beams

Another method used to model bolted connections is the application beam elements (Fig. 3), both to model a shank and to model the contact of a bolt with plates. For this purpose on the edge of the holes additional beam elements of a very small diameter (which allows for the use of *MAT_NULL) are created, and then between them and a beam, constituting the bolt shank, a separate contact is defined (Sonnenscheing, 2008). In this case the application of an AUTOMATIC_GENERAL contact is recommended. Between the bolt head, a cap and plates an *AUTOMATIC_SINGLE_SURFACE contact should be introduced.

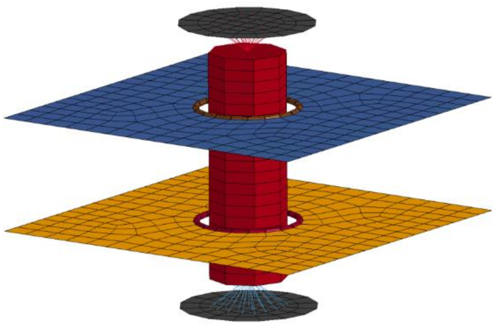

Fig. 3: BEAM type elements and CONTACT_BEAM elements.

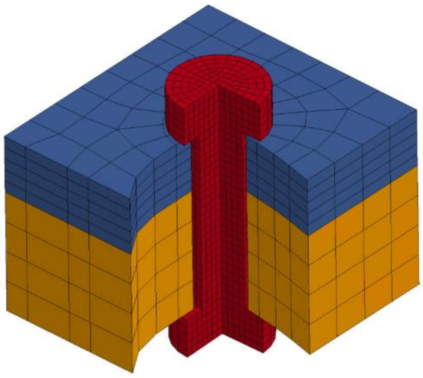

Fig. 4: SOLID type elements.

Similarly as in the previous approach, in order to introduce pre-load the *INITIAL_AXIAL_FORCE_BEAM card can be used. Apart from a possibility of reading the values of normal and cutting forces, this method allows for reading shear stresses. One needs to remember that if we use shell type elements they should have the second order shape function (Cichański, 2011).

Solid model

The fullest representation of a bolted connection is provided by modeling a connection with the application of solid elements (Fig. 4). A mutual interaction between bolt elements and plates is realized with the application of an AUTOMATIC_SURFACE_TO_SURFACE contact. In the case of applying this method pre-load of a bolt is possible through the introduction of stress in the initial phase of analysis. Then a STRESS_SECTION surface perpendicular to the bolt axis should be introduced. The introduced surface will also allow to read from the model of normal and cutting values and shear stresses for the elements. A connection between a bolt and a cap can be made in this case in two ways: through a connection of the shared nodes of the mesh or also through a TIED type contact. Thanks to the application of solid elements one can use advanced material models, and in this group also models providing for speed of strains and its impact on the character of strengthening and damage (Stopel, 2016).

4. Results

Form the point of view of the operation of a safety connector, crucial information, for the analysis of which the simulations conducted have allowed, is the value of forces operating inside the bolt shank and strains and stresses resulting from them. In Fig. 5 normal and cutting forces for particular cases have been presented.

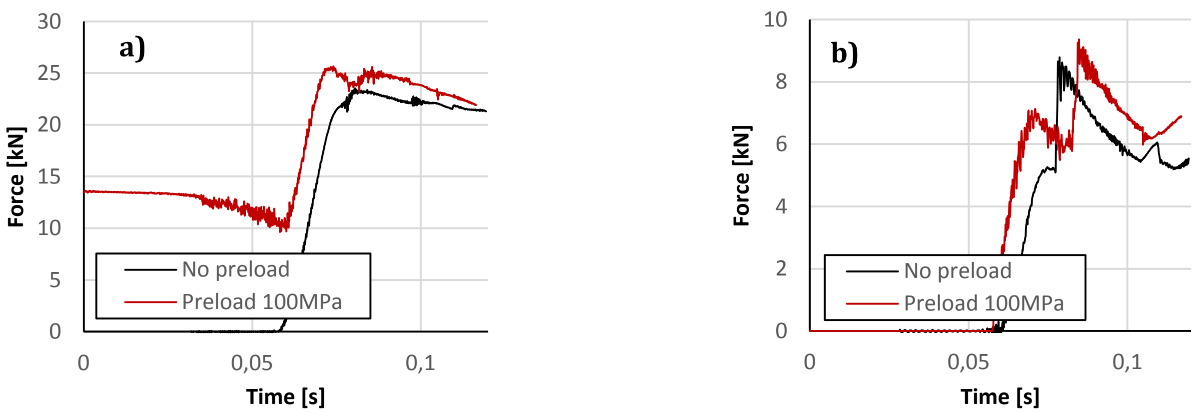

Fig. 5: Forces acting in a bolt connector a) normal forces; b) cutting forces.

Introduction of pre-load causes big differences f loading a shank in the initial phase of plate shift. At the moment of destruction differences between forces are small.

Modelling a safety connector with the use of SOLID elements has allowed for analysis of stress and strains in the bolt shanks. In Fig. 6 below a map of stresses and plastic strains in the shank for the analysed case of the node load along with the pre-load have been presented.

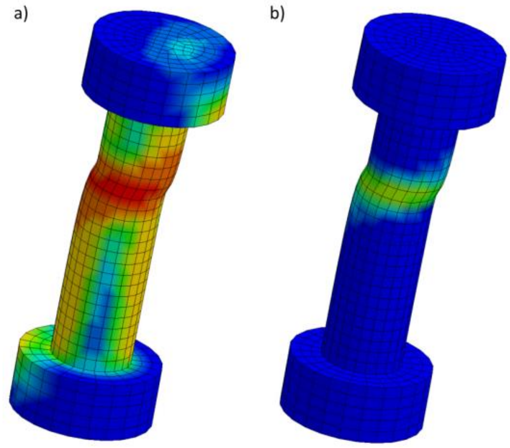

Fig. 6: Map of distribution of a) reduced stresses; b) plastic strains.

5. Conclusions

Designing a supporting construction that meets the requirements of the standard in the scope of passive safety the bolt used in the safety connector should be regarded as the most essential element of the construction. Because of the dynamics and complexity of the phenomena a proper tool to make calculations of such structures is the LS-Dyna software environment as there is a possibility of making explicit analyses.

Modelling a safety connector with the use of BEAM elements in the specified cases brings satisfactory results, mainly if a researcher is less interested in behaviour of a bolt only. In the case where mainly mechanisms of damage of a bolted connection are analysed, and the analysis of a safety connector is just such a case, in the authors' opinion it is justifiable to model a safety connector with the use of SOLID elements.

One needs to assume the application of the method based on solid elements where a bolted connection plays a vital role from the point of the operation of safety mechanisms. First of all from the point of view of assessment of the condition and behaviour of a bolted connection, a possibility to analyse the distribution of stresses and strains is extremely significant.

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