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FEM ANALYSIS OF TRUSS HOLLOW SECTION JOINT

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ABSTRACT
Truss structures are widely used in construction of large-scale buildings. Design of steel structures is standardised in detail through set of European standards called EUROCODE. One of these standards, ENV 1993-1-8 deals with design of joints, but it does not cover the design of conical element for reduction of circular hollow section to the joint.
Finite element method was used in this paper to analyse this conical element with complex shape. The chosen design parameters were varied in order to obtain smooth stress distribution. Results showed that existing design can be modified, reducing the mass while keeping stress levels within acceptable limits.
Keywords: FEM, Truss Joint, Design, Circular Hollow Section Joint

1. INTRODUCTION
A wast majority of roof, bridge and other large structures are realised as trusses. Trusses proved themselves as reliable lightweight structures which are capable to carry excessive loads while keeping the construction mass low. The design of trusses is usually divided into two phases: calculation of forces in truss elements, and design of truss elements, such as sections, joints and supports. Both phases can engage finite element method as very reliable and already proven method, supported by lot of software vendors.
There are also standard procedures for design and calculation of trusses. These standards, which are in use in Europe, include: EN 1991 Eurocode 1 (Basic of design and actions on structures), ENV 1991-1 (Action on structures), ENV 1991-2-1 (Densities, self-weight, imposed loads for buildings), ENV 1991-2-2 (Actions on structures exposed to fire), ENV 1991-2-3 (Snow loads), ENV 1991-2-4 (Wind actions), ENV 1991-2-6 (Actions during execution), EN 1993 Eurocode 3 (Design of steel structures), ENV 1993-1-1 (General rules - Supplementary rules), ENV 1993-1-2 (Structural fire design), ENV 1993-1-3 (Supplementary rules for cold formed thin gauge members and sheeting), ENV 1993-1-4 (Supplementary rules for stainless steels), ENV 1993-1-6 (Supplementary rules for the strength and stability of shell structures) and ENV 1993-1-8 (Design of joints).
These standards are mainly used to estimate common loads and to provide guides and suggestions for design of truss components. Individual elements should be analysed separately, since these calculations are not covered by standard procedures.
The element analysed in this paper is conical joint which reduces the radius of cylindrical hollow truss section. This joint is used to connect the tubular truss element with spherical truss node. It is loaded with tension or compression, depending on its location in truss structure.

2. 3D TRUSS ANALYSIS

To estimate loads acting on the joint, 3D FEM analysis of truss structure was performed. The software used is NX I-deas v.11. 3D truss structure wears a roof section with area A=22932700 mm². The load caused by wind and snow, according to "EN 1991 Eurocode 1" is 1.5 kN/m². Therefore, the structure is loaded by total force Q=34399050 N. When this force is distributed to 18 nodes in upper truss zone, each node is loaded with vertical force F=1911 N.

Figure 1. Truss analysed is a roof structure

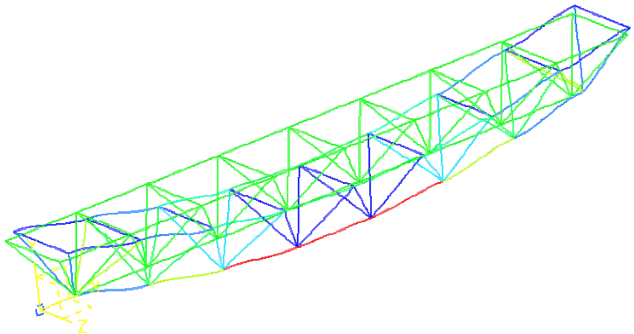

Figure 2. Due to symmetry, only one segment was analysed by means of FEM software

Fig.1 shows the actual structure, and fig. 2 shows truss section analysed with FEM software.- The analysis showed that individual elements are loaded with maximum force 31100 N.

3. EXISTING TRUSS JOINT DESIGNS

Since trusses are in wide use, the truss joint are being manufactured in variety of designs. Fig. 3 shows some typical designs available on market today. The choice depends on manufacturability, strength, material used, manufacturing costs, shape of truss element cross-sections, etc.

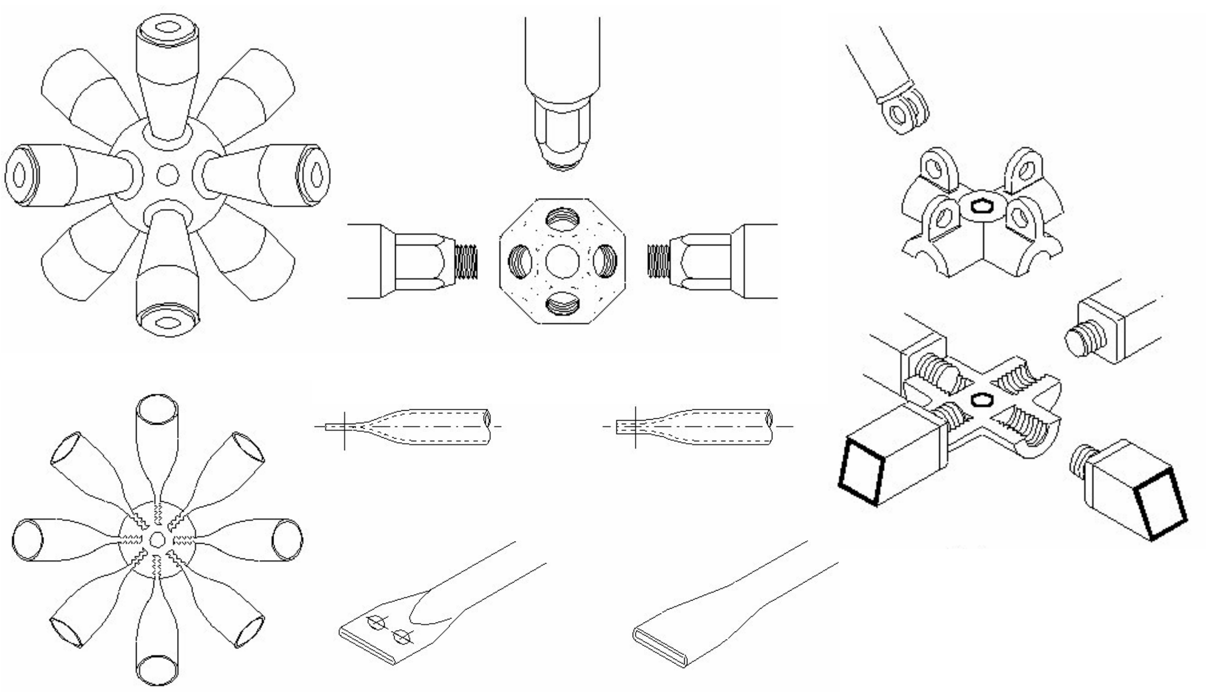

Figure 3. Examples of truss joint designs[8]

Since truss elements vary in cross-section shape, the design of joints can be realised differently. All these designs have the same function: to reduce the cross-section diameter, keeping minimum mass and maximum strength. To accomplish that, it is necessary to analyse stresses.

A number of researches were performed, in order to optimise design of truss joints. Gondos in [1], Jarmai in [2], and other authors [3...7] investigated mostly welded joints. Welded joints have good strength properties, but they lack an ability to be disassembled. Any malfunction of truss realised with welded joints increases costs of replacement or repair. On the contrary, joints realised with spherical elements with conical reductions offer a possibility to disassemble easily only one part of a structure.

4. STRESS ANALYSIS

The most common stress analysis method today is finite element method. We used commercial software "UGS I-deas v.11" to perform 3D static stress analysis. The joint being analysed was first modelled using built-in 3D modeller, revolving the starting cross-section, as shown in fig. 4. Fig. 4 also shows the tetrahedral finite element mesh, with boundary conditions applied.

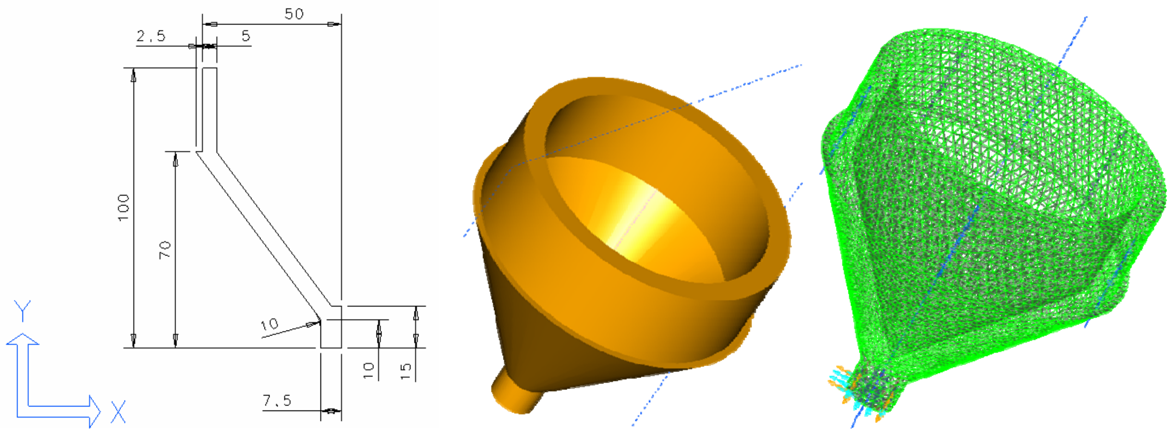

Figure 4. Starting cross-section was revolved to final 3D shape, and then meshed with FE

The parabolic tetrahedral elements were used for this analysis. The results of first analysis are shown in figure 5. The analysis showed that there is a large stress concentration at the narrow side of conical shape, and on the other side, there is a wasted of material which is not stressed at all. Therefore, a shape could be adjusted, to correct the stress distribution.

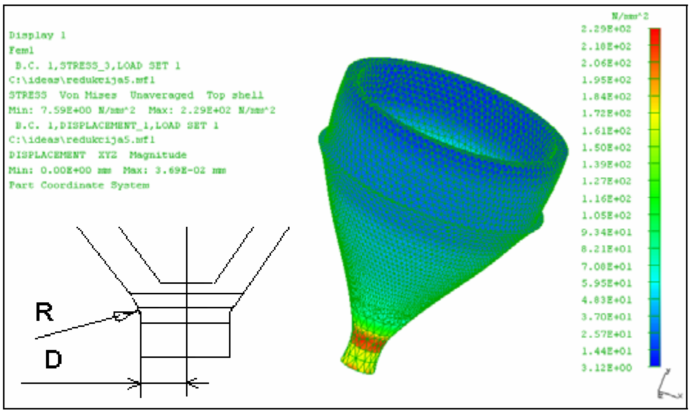

Figure 5. Results of the first stress analysis

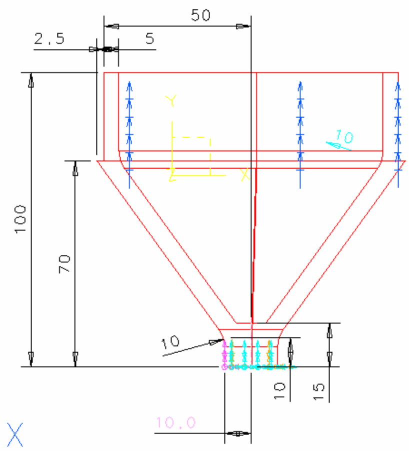

Figure 6. The new cross-section

Two dimensions were adjusted during this analysis, and the stress analysis was performed for each case. Fig. 6 shows the dimensions which were adjusted. The diameter D=7.5 mm (fig. 4) was changed gradually, between 7.5 and 10 mm. The fillet radius R between cylindrical and the conical part was also changed between 5 and 20 mm. The results showed that there is a limit for increase in radius R, because increase over 10 mm had no significant effect onto stress concentration.
Figures 7 and 8 show the stress distribution for different values of R and D. Figures 9 and 10 show the graphical relationship between these two values and the maximum stress.

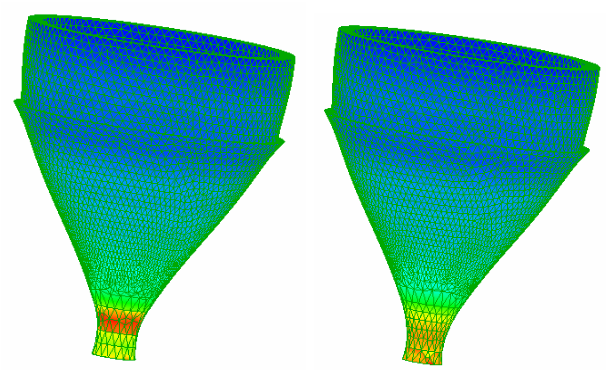

Figure 7. Results of stress analysis for different values of parameteres R and D, shown in 3D

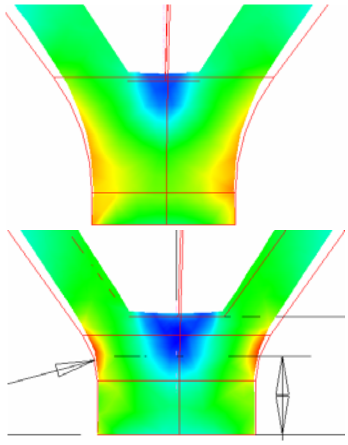

Figure 8. Cross-sectional stress distribution

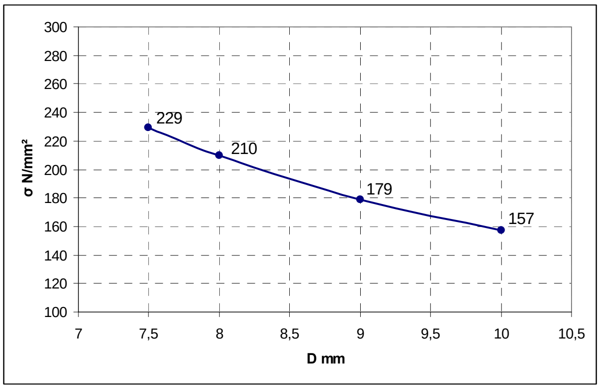

Figure 9. Maximum stress related to diameter D

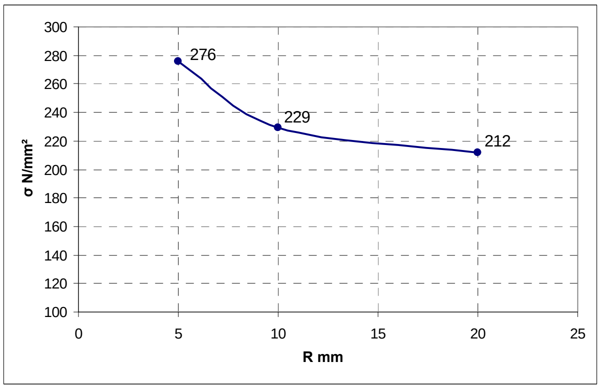

Figure 10. Maximum stress related to radius R

5. CONCLUSIONS

The analysis showed that there is a lot of space to optimise the geometry of this product. Further analysis should be performed, with special attention paid to manufacturability, depending on manufacturing technology applied: casting, forging, machining, etc.

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