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SAFETY FACTOR OF MATERIAL OF BOLTED JOINT PARTS DURING SHEAR DEFORMATION

Abstract: *The results of computer simulation of deformation of a steel bolt, nut and washer in a bolted joint were presented in the article. Color contours characterizing the value of the safety factor of material of bolted joint parts in terms of ultimate and yield strength under shear deformation conditions were obtained.*

Key words: *safety factor, bolt, nut, washer, plate, load, deformation, ultimate strength, yield strength.*

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Introduction

Bolted joints are the most common fastening joints. The joint includes connected parts, bolts, nuts and washers of various configurations [1-3]. Depending on the direction of the acting loads relative to the centerline of the fasteners in the joint, various combinations of deformations occur in the materials of these parts. In some works, studies have been carried out to find the dimensions of steel bolts, nuts and washers, depending on the resulting shear, tensile and compression deformations [4-8].

With the classical bolted joint scheme, external loads act on the upper and lower plates in opposite directions. This leads to deformations of the shear layers and crumpling of the surface layers of the bolt, bending of the washer. A qualitative assessment of the degree of deformation of the material of standard parts can be performed after mechanical tests in the laboratory. Each material has an ultimate strength at which the material breaks. To determine the operability of a loaded part, a safety factor is used, which is represented by the ratio of the ultimate strength of the material to the maximum load [9-10]. Calculating the values of the safety factor of joint fasteners will allow you to determine the critical contact areas and make a forecast of partial destruction of the material during loading.

Materials and methods

The calculation of the safety factor of the material of standard parts of the bolted joint was carried out in the APM FEM module of the KOMPAS software. For this purpose, models of two connected plates, a bolt, a nut and a washer were created. All models were given the properties of structural steel: yield strength – 235 MPa, Young's modulus – 200000 MPa, Poisson's ratio – 0.3, density – 7800 kg/m^3, thermal coefficient of linear expansion – 0.000012 1/°C, thermal conductivity – 55 W/(m×°C), compressive strength – 410 MPa, endurance strength (tensile) – 209 MPa, endurance strength (torsion) – 139 MPa. The created models of the parts included in the bolted joint are presented in the Fig. 1.

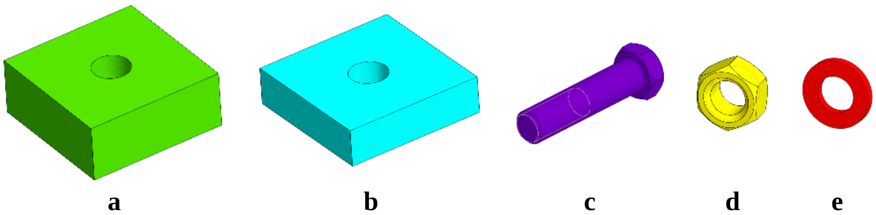


Figure 1. Models of parts included in the bolted joint: a – upper plate; b – lower plate; c – M12 bolt; d – M12 nut; e – washer.

All models were given different colors in order to identify them in the joint. Two square plates measuring 45×45 mm had a through central hole with a diameter of 12 mm to accommodate the bolt rod. The thickness of the upper plate is 18 mm, the thickness of the lower plate is 12 mm. The M12 bolt had a total length of 57 mm, a rod length of 50 mm. Three 1.5×45° chamfers are made on the hexagon head and the rod of the bolt. A 0.6 mm fillet was made between the head and the rod of the bolt to reduce stress concentrations. The length of the threaded section on the bolt rod is assumed to be 25 mm. The washer with an inner diameter of 13 mm, an outer diameter of 24 mm and a thickness of 3 mm was installed under the lower plate. The 10 mm thick M12 nut pressed the washer. Four identical 1.5×45° chamfers were made on the nut. The Figure 2 shows a cross-sectional model of the bolted joint.

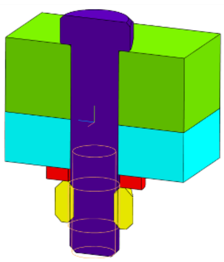
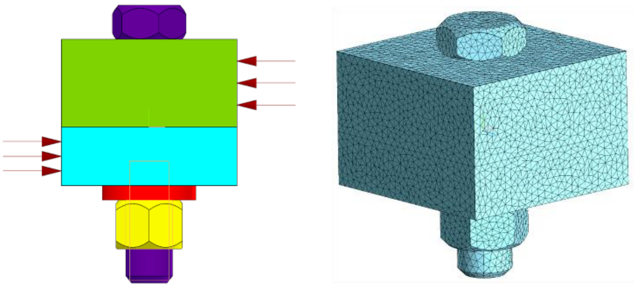


Figure 2. The model of the bolted joint in the section.

Two identical loads of 8 kN in different directions were applied to the side surfaces of the plates. These loads lead to shear deformation of the material of standard parts. The accuracy and duration of the computer calculation were set by dividing all models of joint parts into finite elements. The following mesh conditions were accepted: type of elements – 10-node tetrahedra, maximum side length of the element – 2 mm, the maximum thickening factor on the surface – 1, the dilution factor in the volume – 1.5, number of finite elements – 36163, number of nodes – 63736. The conditions of the computer calculation are shown in the Fig. 3.



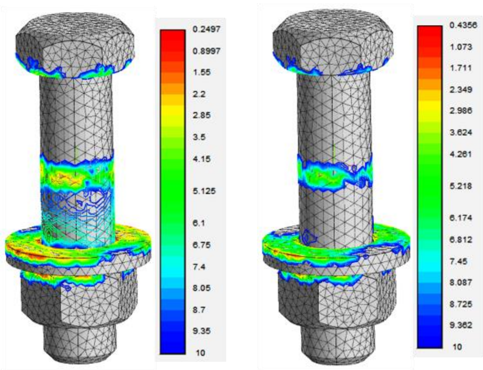
a b

Figure 3. Calculation conditions: a – constant load application; b – dividing the bolted joint model into finite elements.

Results and discussion

The core of the system calculated some inertial characteristics of the bolted joint model: model weight – 0.524206 kg, the absolute value of the reaction – 0.000002 N, the absolute value of the moment – 103.483379 N×m.

The calculation results, in the form of generated color contours of the values of the safety factor of material for yield and ultimate strength, were shown in the Fig. 4.



a b

Figure 4. Calculation results: a – safety factor of material (yield strength); b – safety factor of material (ultimate strength).

Two connecting plates were hidden from the bolted joint model to consider the deformed state of standard parts after loading. The yield and ultimate strength of the structural steel under study were taken as permissible stresses. To the right of the deformed models of standard parts, a color scale is presented, the values of which determine the value of the safety factor of material. The calculated color contours of the calculated coefficient are displayed on the models. The smaller the safety factor, the higher the probability of material failure.

It is noted that the minimum value of the yield strength safety factor is approximately 0.19 less than the minimum value of the ultimate strength safety factor. At the same time, the intensity of the distribution of the values of the yield strength safety factor is greater. The most deformed areas are identified on the bolt rod at the junction of the two plates, on the end surface of the bolt head, nut and washer. At the same time, the washer is subjected to the greatest deformation. A small value of the safety factor of material of the washer can be eliminated by selecting a washer of greater thickness.

Conclusion

Thus, taking into account the displacement of the two connected plates under the action of constant load, all standard bolted joint parts are subjected to characteristic deformation. The washer is subjected to the greatest deformation due to its small thickness. Deformations of lower intensity of the end surface of the washer, head and rod of the bolt at the boundary of separation of the two plates are noted. The safety factor of material in terms of ultimate strength, taking into account maximum deformation, is about twice as large as the safety factor of material in terms of yield strength. For the washer, the safety factor of material in terms of yield strength in the most loaded zones is reduced to 0.25, which is a critical value.

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