Comparative analysis of structural parameters of bolt-rivet rods

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Abstract. The article presents the general characteristics of bolt-rivet joints. The main structural parameters of bolt-rivet rods affecting premature shank tearing are given. Stages of rod installation process into hole are described and critical moments of shank tearing are determined. A graph showing the variation of the rod retraction force depending on the thickness of the package is obtained, and basic parameters are determined for comparing two types of rods with different design, but the same purpose. Methods of determining shank tear-off forces, as well as stresses arising in the neck during retraction, using Femap software product are considered. Maximum stress values are calculated on the example of two types of rods and analysis of possible shank tear is carried out at available parameters of neck. In conclusion, it is noted that with the help of IT-technology it is possible to improve not only the design of joints, but also the technology of their implementation, by changing the design of fasteners.

1. Introduction
The quality of the mechanical connections directly depends on the parameters of the fasteners in these connections. The main types of connections in mechanical engineering include riveting (Figure 1a), bolting (Figure 1b) and bolt-riveting (Figure 1c). Rivet bolts are installed in cases where there are no approaches for making rivet connections by the impact-free method, and if it is necessary to reduce the weight of the product design, which cannot be provided when using bolted connections (due to the weight of nuts). [1, 2, 3].

Figure 1. Construction of rivet (a), bolt (b) and bolt-rivet (c) connections.
In addition to the strength characteristics of the entire joint, it is necessary to take into account the strength of each of the elements in the process of making the joint [2, 3]. In particular, avoiding premature tearing of the process shank along the neck when pulling the rod into the hole. The structure of the rod is shown in Figure 2.

![Figure 2. Construction of bolt-rivet rod.](image)

Rod retraction process is performed in three main stages (Figure 3) [4-6]:

- installation of the rod in the hole and compression of the shank by the jaws of the tool along the surfaces of the ring rolling (Figure 3 stage I);
- retracting the rod into the hole by moving the cams in the tool (Figure 3 stage II);
- removal of the tool after full fit of the rod in the hole (Figure 3 stage III).

![Figure 3. Enlarged diagram of rod retraction process into hole.](image)

When the fastener is tensioned in the process of retracting the rod in step II, the shank may be prematurely torn off due to an increase in the force of placing the fastener in the hole completely by its mounting part over the entire thickness of the bag. The amount of this force depends not only on the total thickness of the assembled parts, but also on the shape of the lead-in part, the amount of tension and the type of lubricant [7, 8]. The purpose of the work is to determine the amount of stress in the neck of type A and type B rods using CAD/CAM/CAE systems with the same force of retraction into the hole and to conduct a comparative analysis of design parameters.

2. Methods and results
In this work the installation of bolt-rivet rods of Ø4 mm of two types A and B is considered. The design and main parameters affecting shank separation are presented in Figure 4.
Figure 4. Type A (a) and Type B (b) bars design.

The A-type rod has a secret head of 100°, a neck diameter of 2.2 mm. The material of the rod type A is a titanium alloy with a strength of 1080...1170 MPa. The shank tear-off force is 5000 N. The fasteners are installed in an aluminum alloy bag with an interference of 1.2%. The B-type rod has a 90° secret head, a neck diameter of 1.8 mm. The material of the rod type B is a titanium alloy, as well as the rod type A with a strength of 1080...1170 MPa. The shank tear-off force is 4119 N. The fastener is designed to be put into bags of aluminum alloys with an interference of 1.2% similar to a rod of type A.

Figure 5 is a graph showing the variation of the retraction force depending on the thickness of the package. It is taken into account that the rod is installed with a previously applied antifriction coating, which allows reducing the friction coefficient to 0.15. All calculations were performed during experiments in accordance with regulatory documentation [7, 9].

![Figure 5](image-url)

**Figure 5.** Plot of development of retraction force depending on package thickness: 1 - rod retraction force into hole, 2 - rod shank tear force A, 3 - rod shank tear force B.

The graph in Fig. 5 shows that the amount of retraction force at the maximum thickness of the package is as close as possible to the amount of tearing force of the shank of the type B rod, which obviously entails premature tearing during retraction.

A critical parameter contributing to premature shank separation is neck diameter. The larger the diameter of the neck, the greater the amount of shank tear-off force, which contributes to the unimpeded development of the retraction force when the rod is placed in packages with the greatest thickness [10].

The shank tear-off force with the specified structural parameters of the neck is regulated by the regulatory documentation of the Russian Federation and is determined experimentally by conducting tensile tests using universal rupture machines according to the scheme given in Figure 6.
Figure 6. Rupture Rod Test Diagram.

As shown in Figure 6, the rod is fixed on the conical surface of the head. Stretching is performed with gripping of mating part of bursting machine along surfaces of ring rolling of shank [8,9,10].

To obtain force values, it is not always possible to test full-scale samples, as in our case. This kind of test requires the production of an accurate shank-side gripping device due to the small size of the ring roll. In these cases, it is advisable to use CAD/CAM/CAE systems.

To compare the stresses that arise in the neck of the fasteners during retraction, processes were simulated in the Femap software product that simulate the tension of the rods with a maximum load that ensures the rod is fully seated in the hole of the aluminum alloy package with a maximum thickness.

Figure 7 shows the results of calculations of equivalent stress values in the neck of type A rods (Figure 7a) and type B rods (Figure 7b) when loaded with 3889,26 N force, which corresponds to the value of the retraction force into the packet with a thickness of 16 mm with a friction coefficient of 0,15 [7,9,10]. The load is applied along the end part of the shank, the fixation is made on the conical surface of the rod head, similar to the scheme for shank tear-off tests shown in Figure 6.

Figure 7. Calculation results for type A (a) and type B (b) rods.
Based on the results of calculations, it is determined that the maximum tension stresses occur at the narrowest point of the rod - the neck. It should be noted that in a rod of type A, the diameter of the neck is 2.2 mm, the value of maximum stresses reaches 1800 MPa. And in a rod of the type, the diameter of the neck is 1.8 mm, and the value of maximum stresses in this section is 1950 MPa. From the calculations, it can be seen that premature tearing of the shank along the neck can occur in both cases, because the stress values resulting from the application of the load necessary to ensure retraction of the rod into the hole exceed the value of the tensile strength for the titanium alloy, which does not exceed 1170 MPa.

3. Conclusion
Thus, by performing calculations and comparative analysis of some design parameters of two types of rods, it can be said that, with the existing IT technologies in the world and their capabilities, it is necessary to strive to improve the quality of production of machines and mechanisms by ensuring strength characteristics by changing the design of fasteners. In case of high stresses in the section of the rod neck, and the shank did not break off, there is a possibility of premature tearing of the shank when squeezing the ring to obtain a bolt-rivet connection. But this is a slightly different type of calculation in other software products.

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