Jamming of hand-operated riveter – the problem and solving it in process of modelling

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Abstract. During the exploitation of hand rivet tools, abnormal situations arise due to the jamming of the used mandrel (core) in the actuating mechanism, leading to an increase in process time. The main purpose of the article is establish of hand rivet tools teeth parameters to eliminate self-braking of the used mandrel (core) in the actuating mechanism. Parameters of the rivet tools teeth are determined by force analysis. The limit equilibrium conditions by the modeling process of rivet tool exploitation were obtained. The strength conditions are determined by force dependencies. The condition of self-braking of the used mandrel (core) in the hand rivet tool jaws is determined. As a result of numerical simulation, the recommended values of the angles of inclination of the teeth front surface of the rivet tool jaw, which are eliminate jamming of used mandrel (core) in the actuating mechanism, are obtained. The recommended values of the angles of inclination of the teeth front surface of the rivet tool jaw should not be less than 32 degrees.

1. Introduction

In building, engineering and other spheres, there is a need in anchorage and joining loaded details made of different materials. For their joining different types of rivet are used.

In engineering specialists, focus on the advanced methods of joining details. So, the work [1] address issues of setting friction rivets. Researchers pay attention to joints of plates made of thermoplastic material with a short armature made of glass fibre or without it. Production of component assemblies, consisting of a substrate made of aluminium alloy, which are connected with double one-sided doublers made of aluminium or carbon fibre with the amplified epoxy tar, is under consideration in the article [2].

The article [3] examines the influence of feed force on the vibration of riveter core. A percussive rivet is the basic process of joining outer sheet metal shells of an aircraft to its frame. Workers, who use hand-operated instruments for rivets (grabbing hammers and rivet cores), undergo sizeable levels of vibration that received manually, and run risks to get the hand-arm vibration syndrome. Researchers have worked up the laboratory scale apparatus and methodology for estimation the vibration of rivet beams. It increases the safety of work and productivity during the assembling.

The work [4] considers the process of controlling riveted joints. The author suggests the ultrasonic control system for checking dotty corrosive splits in rivets of multilayer structures. Changes of hardness in rivets for
estimating the bridge in different technological methods of processing materials are presented in the work [5].

The article [6] shows the results of modelling for increasing the reliability of constructions of mechanical joints by means of semi-tubular rivets. Such modelling allows improving the stability of constructions. Three different types of configuration of joining were modelled in the work [7]. The optical measuring system was used for estimating the factual shapes of a die and a rivet. Then the results were entered into the simulated model. Inflexibility of riveting tongs was modelled as the numeral spring. The combined model of the Coulomb friction and the friction was applied. Frictional coefficients were defined by means of the inverse modeling.

Nowadays for fixing and joining of sheet materials are widely used rivet joints with using open type extractor rivets. A quite easy and cheap, concerning the construction and exploitation, hand-operated mechanism that does not require special skills in work and high qualification of a worker, is used to carry out joints of details by means of extractor rivets. That is why hand-operated riveter (mechanical, pneumatic, pneumatic-hydraulic) have been widespread [3].

Great attention is paid to the reliable grip of the rivet mandrel by the rivet tool teeth, while designing rivet tool. Conditions for the capture and compression of the rivet mandrel are set while designing rivet tool jaws. The internal angle of the rivet tool jaws teeth determines the reliability of the mandrel grip. The teeth are made with equal angles to simplify the production of the jaws.

However, during the working with a hand-operated extractor riveter some difficulties can occur:
- presence of a sharp edge of a rivet on one side of it;
- a broken part of rivet body can stick in a working mechanism of the riveter.

Thus, this article considers the ways of solving the last of two issues stated above.

The purpose of this work is the theoretical support for the modelling of work of a riveter mechanism and establishment of requirements, which prevent the jamming of a rivet core in the mechanism of the riveter.

2. Experimental Part

For establishment the causes of jamming of the core in the working mechanism of the hand-operated riveter we consider a device of the extractor rivet and a working mechanism of the riveter.

Diameters of extractor rivets (d1) are most often correspond to the diapason of sizes from 2.4 mm to 6.4 mm, diameters of rivet cores (d) from 1.85 mm to 3.71 mm. In practice, the most widespread variant is that one, in which a rivet body is made of aluminium alloy, and a core is made of steel. In terms of construction, an extractor rivet is presented on the Figure 1.

![Figure 1. The construction of the extractor riveter: 1 – rivet core; 2 – rivet body; 3 – dangerous section of the rivet core; 4 – rivet head.](image)

Despite the variety of constructions of hand-operated riveters (FIT DIY 32003; MATRIX 40515; STAYER RX600; STANLEY MR33), the working mechanism of instruments can be constructively presented as the scheme in the Figure 2.

A tapered lead-in part 2 service for ensuring the oblong empty and working process of jaws 3, moving in loading process and work of riveter. The tapered part allows jaws go separate ways and close up during their oblong movement along the lead-in part. A wedge-like locking mechanism 4 by means of a spring and the tapered lead-in part provides the jam of jaws 3 during the seizure of the core.
The working mechanism of hand-operated riveter for extractor rivets:
1 – a rivet; 2 – a lead-in part; 3 – a jaw; 4 – a wedge-like locking mechanism; 5 – a frame; 6 – a tapered lead-in part; 7 – a spring; 8 – an adjusting part.

A frame 5 services for placement of the working mechanism, fixing the leverage mechanism of riveter and provides necessary inflexibility and durability of the construction. The tapered lead-in part 6 services for unification of the riveter and enables to work with rivets of different diameters (go in a set with the riveter). In case of necessity of changing the rivet of one diameter to another, it is necessary to replace one tapered part with another of a suitable diameter of the using rivet. A spring 7 and an adjusting part 8 service for ensuring the required gripping force of rivet (it can be regulated during the rivet assembling or in process of servicing the instrument).

The principle of operation of the working mechanism of hand-operated riveter (Figure 2).

In process of loading of the rivet 1 jaws 3 go partially right and move apart to allow the core to move in. The rivet is being set until tight by an outer flange of the rivet body in to the tapered lead-in part 6, as it has been shown in the Figure 2. Meanwhile, the wedge-like locking mechanism moves right, compressing the spring 7. It ensures the radial stress of a primary seizure of the core by jaws. The mechanism is ready to work. Jaws seize the rivet core practically along the whole segment of a circle of the core. It provides the largest crumpling area of the core. This feature is determined by the construction of jaws. There is a special inner thread (teeth) on the surface of jaws. On the one hand, in provides the manufacturability of jaws 3, and on the other hand, it limits the angle by the top of jaw thread.

During the movement of the lead-in part 2 to the right, jaws 3 grab the core 1 and pull it. In result, a rivet head goes into the frame of a rivet, but with the significant effort the core tears in the dangerous section of the rivet core.

By the ending of force impact of a person, under the elastic force of a compressed spring 7 the wedge-like locking mechanism of the tapered lead-in part 6 replaces the jaws 3 to the left and partially separates them. The core of the rivet should disengage and fall out the riveter. Then the process of riveting repeats.

Sometimes it happens, that after finishing of riveting, the broken part of the rivet core jams in the working mechanism, preventing the process of loading of a new rivet (Figure 3).
In this case, jaws’ inner thread 3 squeeze themselves in a worked core very deeply. It prevents the opening of jaws. The effort to extract the worked core be means of a new rivet 1 leads to an additional penetration of the inner thread of jaws in the worked core. That is why the desired result cannot be reached. It leads to the additional wasting of time and useless efforts.

With the goal of working up a practical decision of the given task, it is necessary to determine efforts, arising during the work of the mechanism.

Let us examine the limit equilibrium of the rivet core in the working mechanism of riveter (Figures 3, 4).

In a state of the limit equilibrium different powers have an effect on the core: limit breaking strength $N_{br}$, normal reactions $N$ a prop of upper and lower inner thread of jaws, force of friction between sidelong surfaces of upper and lower jaws and surfaces of compression mark on the rivet core $F_{fr}$. In its turn, forces of friction of inner thread of upper and lower jaws are equivalent

$$F_{fr} = N \cdot \nu,$$

where $\nu$ – coefficient of force of friction between the material inner thread of jaws and the material of the core.

Thus, the condition of the limit equilibrium of a rivet core in the working mechanism can be described as

$$N_{br} - 2 \cdot \left( N \cdot \cos \left( \frac{\alpha}{2} \right) - F_{fr} \cdot \sin \left( \frac{\alpha}{2} \right) \right) = 0,$$

where $\alpha$ – the angle between sidelong surfaces of the inner thread of jaws (by the top of jaw).

From the equation (2) taking into account (1) we evaluate the limit breaking strength of rivet core $N_{br}$

$$N_{br} = 2 \cdot N \cdot \cos \left( \frac{\alpha}{2} \right) - \nu \cdot \sin \left( \frac{\alpha}{2} \right).$$

On the other hand, the limit breaking strength of the rivet core can be found from the condition of durability, under which

$$\sigma_t = \frac{N_{br}}{A_c} \leq [\sigma_t].$$

where $\sigma_t$ – calculated normal intension within the stretching of the core, MPa, $[\sigma_t]$ – allowable normal stress within the stretching, MPa; $N_{br}$ – limit breaking strength, $N$; $A_c = \frac{\pi \cdot d^2}{4}$ – area of cross-section of the rivet core, mm$^2$; $d$ – a diameter of the rivet core, mm.
From (4)
\[ N_{byr} = [\sigma_f] \cdot A_c = [\sigma_f] \cdot \frac{\pi \cdot d^2}{4}. \]  
(5)

To get the dependency of limit breaking strength from the depth of the rivet core deformation, let us consider the condition, according what
\[ \sigma_{cr} = \frac{F_{cr}}{A_{cr}} \leq [\sigma_{cr}], \]  
(6)
where \( \sigma_{cr} \) – calculated normal intension of deformation of the core, MPa; \( [\sigma_{cr}] \) – allowable normal intension of deformation, MPa; \( F_{cr} \) – limit force of deformation, N; \( A_{cr} \) – the area of deformation of the rivet core, mm.

To determinate the area of deformation, we picture the magnified print of the inner thread, that was left in the rivet core after riveting the details (Figure 5).

\[ A_{cr} = a \cdot l \cdot z, \]  
(7)

where \( a \) – the length of sidelong surface of deformation, mm; \( l \) – the length of the segment of a circle of deformation, mm; \( z \) – the number of teeth of jaws, left after deformation.

The length of sidelong surface of deformation \( a \) is defined from the Figure 4 trough depth \( h \) of penetration of a tooth of jaws in the rivet core
\[ a = h \cdot \tan \left( \frac{\alpha}{2} \right). \]  
(8)

In result, the formula (7) looks like
\[ A_{cr} = h \cdot \tan \left( \frac{\alpha}{2} \right) \cdot l \cdot z. \]  
(9)

From the figure 3 the limit breaking strength of deformation is defined as
\[ F_{cr} = 2 \cdot N \cdot \left( \sin \left( \frac{\alpha}{2} \right) + \nu \cdot \cos \left( \frac{\alpha}{2} \right) \right). \]  
(10)

From (6) and (9) the limit breaking strength of deformation equals
\[ F_{cr} = [\sigma_{cr}] \cdot A_{cr} = [\sigma_{cr}] \cdot h \cdot \tan \left( \frac{\alpha}{2} \right) \cdot l \cdot z. \]  
(11)

We can define the depth of penetration of jaws' teeth into the core
\[ h = \frac{F_{cr}}{[\sigma_{cr}] \cdot \tan \left( \frac{\alpha}{2} \right) \cdot l \cdot z}. \]  
(12)

Or taking into account (10) we have
\[
2 \cdot N \cdot \left( \sin \left( \frac{\alpha}{2} \right) + \nu \cdot \cos \left( \frac{\alpha}{2} \right) \right) - \left[ \sigma_{cr} \right] \cdot \tan \left( \frac{\alpha}{2} \right) \cdot l \cdot z.
\]

(13)

From (3) and (5) we have the normal force
\[
N = \left[ \sigma_{cr} \right] \cdot \frac{\pi \cdot d^2}{8 \cdot \left( \cos \left( \frac{\alpha}{2} \right) - \nu \cdot \sin \left( \frac{\alpha}{2} \right) \right)}.
\]

(14)

The formula (13) taking into account (14) looks like
\[
h = \frac{\left[ \sigma_{cr} \right] \cdot \pi \cdot d^2}{4 \cdot \left( \cos \left( \frac{\alpha}{2} \right) - \nu \cdot \sin \left( \frac{\alpha}{2} \right) \right) \cdot \tan \left( \frac{\alpha}{2} \right) \cdot l \cdot z} \cdot \left( \sin \left( \frac{\alpha}{2} \right) + \nu \cdot \cos \left( \frac{\alpha}{2} \right) \right).
\]

(15)

The formula (15) defines the depth of penetration of jaws' teeth into the rivet core within the moment of breaking.

3. Results and discussion

To determine the cause of jamming of a rivet core in the working mechanism, let us consider the rivet core at that moment, when teeth of jaws leaving the core. Under the elastic force of the spring 7 the wedge-like locking mechanism 4 presses on jaws 3, in order to press the left part of jaws by the tapered lead-in part (2) (Figures 2, 3). Meanwhile, the outer side of jaws abut on the tapered mechanism of the tapered lead-in part 6. The existence of a cone assists in the opening of jaws, setting the core free. However, sometimes it happens, that when only one of two jaws is removed, and the second stays in the core. By pressing on the worked core by the core of a new rivet, displacement of the worked core with jaws takes place. Meanwhile, removing of the worked core from teeth of jaws does not happen – we can see the jamming of jaws' teeth in the core without their additional opening. Analysis of forces shows: jaws undergo normal force 2\( N_2 \) and force of friction \( F_{fr2} \) from the wedge-like locking mechanism, normal force 1\( N_1 \) and force of friction \( F_{fr1} \) from the worked core, normal force 3\( N_3 \) and force of friction from \( F_{fr3} \) the tapered lead-in part. The scheme of acting forces during the opening of the working mechanism of riveter is in the Figure 6.

Trying to replace the worked core 1 to the right along the axis of symmetry of the working mechanism, the core with jaws moves right, so the outer surface of jaws 3 and the inner surface of the tapered lead-in part 2 won't adjoin (Figure 3). Thus, normal force 3\( N_3 \) and force of friction \( F_{fr3} \) equal zero. In this situation the rivet mechanism elements are pictured in the Figure 7.

![Figure 6. The process of opening of the working mechanism of riveter: 1 – a rivet core; 2 – riveter jaws.](image-url)
Figure 7. Elements of the rivet mechanism when the broken core is tried to be extracted:
1 – a rivet core; 2 – riveter jaws.

In the Figure 7 we can see that the process of opening of the rivet jaws can start only when the projection of resulting force of the wedge-like locking mechanism \( R \) on the horizontal is less than the sum of projections on the horizontal of resulting force of the core \( R_1 \). In this case jaws move left.

The condition of jamming of jaws in the worked core can be noted as

\[
\frac{N_1}{\cos(\phi_1)} \cdot \cos(\phi_1 - \alpha_1) > \frac{N}{\cos(\phi_2)} \cdot \cos(\chi - \phi_2),
\]

where \( \phi_1 = a \tan(v_1) \) – the angle of friction of a tooth of jaws; \( \phi_2 = a \tan(v_2) \) – the angle of friction of a tooth of the wedge-like locking mechanism; \( v_1 \) and \( v_2 \) – coefficients of force of friction between the jaws' tooth and the core and the wedge-like locking mechanism respectively.

If the inequation (16) is carried out, the effect of self-impeding appears. Thus, the jamming of the inner thread of jaws' mechanism in the worked core appears. Thus, in that way, it is necessary that the right part of the equation (16) to be higher than the left one for carrying out the process of extracting the broken part of the core. In other words, it is necessary that the condition (16) should be unexecuted.

Visualization of the graphical calculation of the inequality (16) for different possible variants of coefficients of friction force between the inner thread of jaws and the core is in the Figure 8.

Analysis of graphs, presented in the Figure 8, shows that the mutual replacement of jaws' teeth of the riveter and the worked core of a rivet can appear, when the amounts of projections on the horizontal of resulting force of the core \( R_1 \) [\( R(\alpha_1) = 2; 3; 4; 5; 6 \)] lie to the right side from the cross point with the Graph 1 [\( R(\chi) \)].

Figure 8. Graphical calculation of the inequality (16): 1 – the dependency of projection of the unlocking effort \( R \) on the horizontal; 2-6 – dependencies of projections on the horizontal of the resulting force of the core \( R_1 \) for different coefficients of friction force \( v_1 \) (a figure by \( R \) corresponds to \( v_1; 0.01 \)) and the angle of a tooth of a jaw (\( \alpha_1 \)).
4. Conclusion
Results of calculations show that for the most widespread amounts of coefficients of friction, the angle of inclination $\alpha_1$ must be more than 32°. In this case that jamming doesn't appear. In other words, the passing of a jaw tooth out of the rivet and its setting free are possible. In addition, taking into account wear-and-tear and production mistakes, it is necessary to foresee the additional increasing of an angle $\alpha_1$ for 10-15%. Thus, for providing a guaranteed removal of a broken part of rivet from jaws of the working mechanism the angle of inclination of an inner thread (on the side of entering the mandrel) must be more than 39°.

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