TECHNIQUE OF DESIGNING OF RELEASABLE THREADED CONNECTIONS OF AUTOTRACTOR TECHNICS

Anatoliy Kuzmin, Vladimir Shevchuk

Volgograd State Technical University
Auto Tractor Faculty
Lenin avenue 28, Volgograd, Russia
tel.: +7 (8442) 418159, fax: +7 (8442) 900981
e-mail: snab.79@mail.ru, svp05@bk.ru

Abstract

The analysis of work of joints of tractors of models DT-VT allows to make the conclusion about presence of breakages because of low constructive strength and not correct definition of parameters of details. Probes of breakages of joints shows that today at designing of joints there is no system of the account of a mode of behavior and joint life cycle. Designing of threaded connections of automobile and tractor technics should be carried out taking into account modes and duration of operation of the car on these modes. Designing of threaded connections is carried out taking into account operation and life cycle modes. It is offered to carry out calculation taking into account accumulation of fatigue damages to a current of set time of operation. For definition of parameters of fatigue strength the technique of the accelerated tests is offered. The technique allows to define parameters of fatigue strength which it is necessary to use in calculations threaded connections. In work probes of a tension of joint of a driving wheel of a caterpillar, are resulted by a method of the is finitely-element analysis. For probes settlement models are offered and tested. Settlement models allow to simplify construction of geometrical model for use in computer programs and calculations. Using the described technique of designing it is developed construction a retainer screw with a special thread.

Keywords: *thread joints of tractors; designing; fatigue damages; accelerated tests; special thread*

Threaded connections of the tractor unit (TU) work in various conditions of environment, and influence of constants or variable loadings. The problem of designing of any joint consists in correctly to pick up this or that type and a kind of joint and to define the basic geometrical sizes of its elements depending on character and size of the external loading, used materials, requirements of reliability, durability and service conditions.

The analysis of the data on tests of tractors of models DT-VT on test station (TS) and to supervision in actual practice operation, release since 1972г. It is defined that the quantity of refusals on threaded connections is made about 8 % from total number, by half from which design [7, 8]. Principal causes of refusals are: Collapse of a bolt owing to weariness, infringements of modes of the tightening, insufficient constructive strength, infringement of impermeability of joint.

Probes tensity fixing details of a driving wheel of tractors of models DT-VT in actual practice operation and at bench tests, show recurrence of loadings and non-uniformity of distribution of efforts. The maximum stretching efforts are equal 82 000 H on each carrier, and a bending moment – 47 600 N×м. Total pressure in a body of a fixing detail reach values 462 MPa, with amplitude of change 112 MPa that testifies to fatigue damage accumulation. In Fig 1 schedules of change of efforts and pressure in process of change of position of an investigated carrier at driving wheel rotation are presented.

Presence of variable pressure is while in service connected with change tensity at performance of various works TU. It affects working capacity of a threaded connection and frequently leads to failure. In this connection it is important at designing and calculation of parameter of a fixing detail to consider these changes, for maintenance of the set resource of a threaded connection.

Feature of an offered technique is, definition of characteristics of fixing details proceeding from the set number of cycles tensity variable pressure, in various service conditions, thus values of pressure, should be more or are equal to an endurance limit. And in calculation the condition is used: allocating operation modes, for everyone define quantity of cycles of influence $\mathbf{n}_{ij}$ and accept that values of average pressure of a cycle satisfy to a condition:

$$[(\sigma_{m11})_{min}; (\sigma_{mij})_{max}] \geq \sigma_{-1}\,, \tag{1}$$

where:
σ_{mij} – average pressure of a cycle of ij th mode of operation,
$[(\sigma_{m11})_{min}; (\sigma_{mij})_{max}]$ – a file of variable pressure,
σ_{-1} – an endurance limit.
Thus the sum n_{ij} is the set general resource (n_z) a fixing detail:

$$\Sigma\, n_{ij} = n_z\,, \tag{2}$$

where:
n_{ij} – quantity of cycles of influence of an constant, at ij-th mode of operation,
n_z – the set resource of a threaded connection.
Using a hypothesis of linear accumulation of damages [3],

$$\sum \frac{n_{ij}}{N_{ij}} = 1\,, \tag{3}$$

where:
$N_{i,j}$ – durability at level of pressure corresponding i, j – modes of behavior.

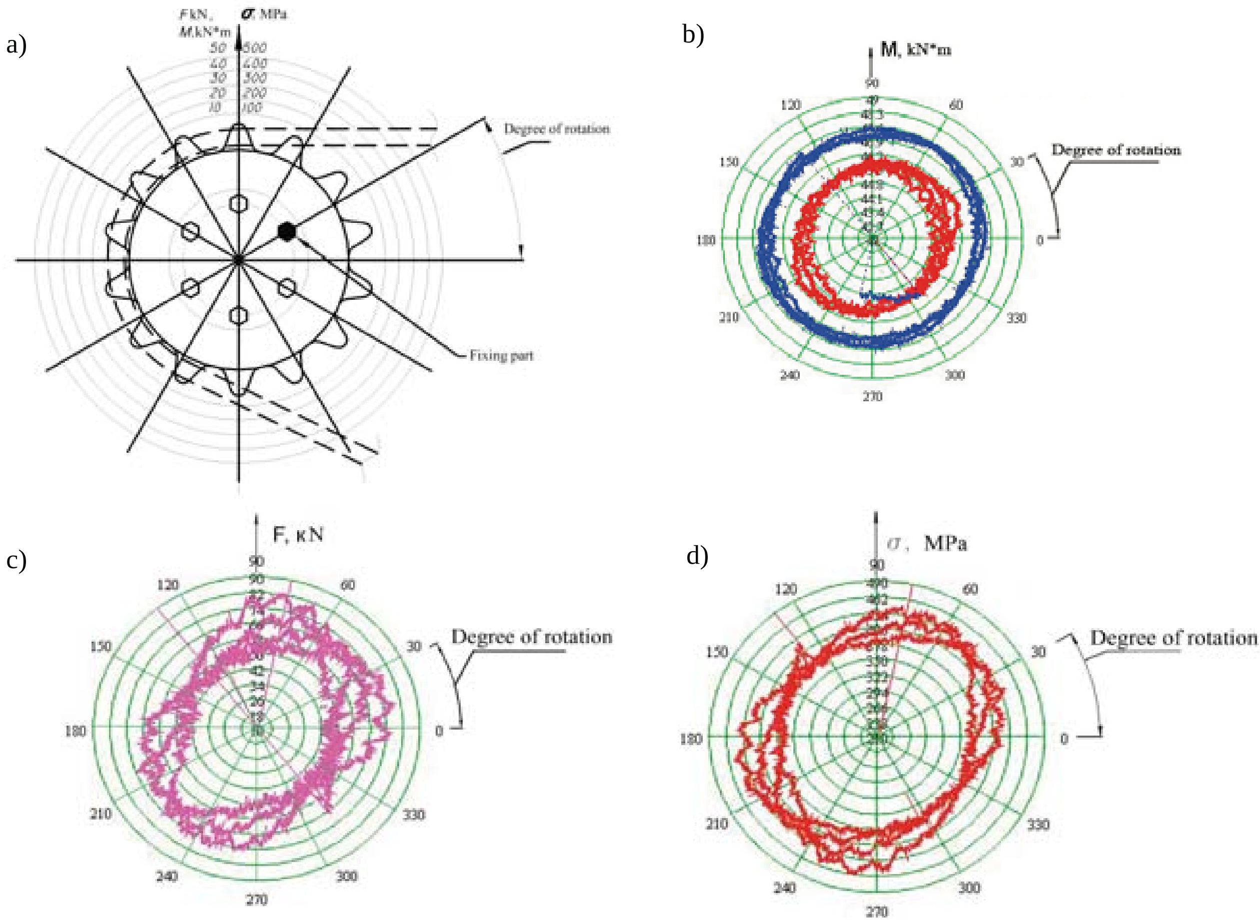

Fig. 1. Change loading a bolt of fastening of a driving wheel: a) system of coordinates; b) the bending moments in mutually perpendicular planes; c) stretching effort along an axis of a bolt; d) total pressure in section of a fixing detail

Define such characteristics of a fixing detail at which joint works in storage site of fatigue damages at various levels σ_{mij} in a current of the set resource n then in a detail material damages which will collect will lead to fatigue failure. As a result joint parameters pay off with the account of modes of operation TU and the guaranteed maintenance of the set resource of operation.

Dependence of durability and average pressure of a cycle is described by the equation [10]:

$$\sigma_{mij}^{m} \cdot N_{ij} = \sigma_{-1} \cdot N_{-1} = 10^{C} \ , \tag{4}$$

where:
σ_{mij}, N_{ij} – pressure and durability corresponding i, j – to method of working,
σ_{-1} – an endurance limit,
N_{-1} – durability at level of pressure equal to an endurance limit,
m, c – parameters of curve fatigue strength.

The defining parameter of standard details is average diameter of a thread. Therefore for definition of a design of a fixing detail it is necessary to write down and solve the equation expressing dependence of variable pressure and average diameter of a thread. Considering as an example the elementary case of the single threaded connection, the given equation looks like, [1]:

$$\sigma_{mij} = \left(F_{zat} + \frac{F_b}{2}\right) \cdot \frac{1}{A_b} \ ,$$

or (5)

$$\sigma_{mij} = \left(F_{zat} + \frac{F_b}{2}\right) \cdot \frac{4}{\pi \cdot d^2} \ ,$$

where:
F_{zat} - force of a tightening of a threaded connection,
$F_{zat} = 2{,}5 \cdot F$, where F – effort transferred to a detail,
F_b - a loading increment on a bolt,
$F_b = 0{,}2 \cdot F$, where F – effort transferred to a detail,
A_b - the area of settlement section of a bolt,
d – average diameter of a thread.

Solving system of the equations (3) – (5) concerning parameter d, taking into account conditions (1), (2) we will receive expression for definition of average diameter of a thread

$$d = \sqrt[2m]{\frac{3.31^{m}}{10^{C}} \cdot \sum\left(n_{ij} \cdot F_{ij}^{m}\right)} \ , \tag{6}$$

thus apparently from expression (6) calculation of an average it is made taking into account the set resource of work of joint and change tensity according to service conditions. But it is necessary to notice that expression (6) is not multiple-purpose for all types of joints as the equation (5) describing dependence of variable pressure from defining parameters of fixing details, registers proceeding from the concrete scheme нагружения and working conditions of projected joint. For definition of durability of fixing details, and also for the purpose of the specified choice of parameters of a design it is necessary to conduct the accelerated fatigue tests. The technique of carrying out of tests is based on a linear hypothesis of accumulation of damages [10] at loading samples by smoothly increasing loading and cutting-down of the longest series of tests. Tests consist at least of three series, and the longest their bottom is the third at which loading samples carry out from initial level below an expected limit of endurance. By results of carrying out of first two series of tests as it is specified in probes [3, 4], the parameter m, on the equation pays off:

$$\left(\sigma_{p1}\right)^{m+1}-\left(\sigma_{11}\right)^{m+1}-\alpha\cdot(m+1)\cdot\sigma_{p2}^{m}\cdot N_{p2}=0\,, \qquad (7)$$

where:
σ_{p1}, σ_{p2} – pressure of collapse of samples of the first and second series of tests,
σ_{11} – initial level of pressure of the first series of tests,
N_{p2} – quantity of cycles at which the sample of the second series of tests has collapsed.

Cutting-down of duration of tests is offered to be reached for the account нагружения samples from zero value of pressure with smoothly increasing loading [2]. Thus dependence of current pressure on cycle number is defined by expression:

$$\sigma = k\cdot n^{1/t}\,, \qquad (8)$$

where:
σ – operating pressure,
n – cycle number,
k, t – the factors defining the characteristic loading, which value steals up or pays off the decision of system of the equations [6].

On the basis of the analysis of the help data [3, 6] dependences of a limit of endurance of materials on time resistance to collapse, it is defined that values of factors to and t should satisfy to conditions (restrictions):

1. The Maximum pressure at which there should be a collapse of the sample should not exceed $0{,}6\sigma_{в}$,
2. Growth rate of pressure in a range (0,42-0,5 … 0,6-0,7) $\sigma_{в}$ should matter $\Delta\sigma \le 400$ Pa/cycle.
3. Growth rate of pressure in a range (0 … 0,42) $\sigma_{в}$ can matter $\Delta\sigma \ge 400$ Pa/cycle.

The offered program of tests is graphically shown in Fig 2. Speedup of tests is reached at the expense of fast overcoming of area of the pressure which are not influencing accumulation of damages. Thus factors to and t allow to receive the set kind of a curve нагружения taking into account imposed restrictions.

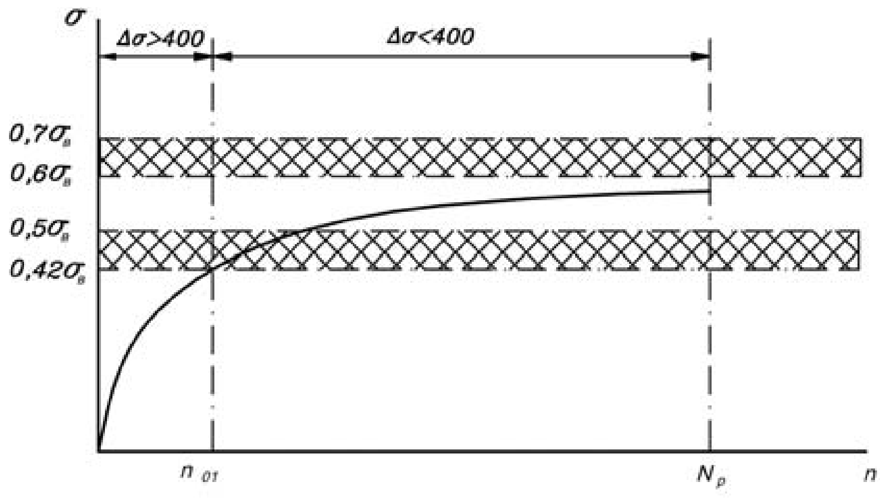

Fig. 2. The schedule of change of pressure from cycle number: σ – average pressure of a cycle; n – number of cycles нагружения; σв – time resistance to collapse at a tension; Δσ – growth rate of average pressure of a cycle

Having transformed the equation (6) we receive dependence of total number of cycles Np on factors to and t, i.e.:

$$N_p = \left[n_{01}^{\frac{m}{t}+2} + 10^C \cdot \frac{\frac{m}{t}+2}{k} \right]^{1/(\frac{m}{t}+2)}, \tag{9}$$

Having set by values of parameters m, C, and also number of cycles n_{01} at which current pressure нагружения will reach an endurance limit, begins possible to estimate influence of coefficients k and t on duration of tests.

Value n_{01} is defined proceeding from a condition that growth rate of pressure below level of a limit of endurance should be more than 400 Pa/cycle. So having accepted (for constructional steels) expected value σ_{-1} equal 250 MPa, and growth rate of pressure α =1000 Pa/cycle, n_{01} accepts value – 250·103 cycles.

Using this data, by means of computer computing systems the surface in co-ordinates (Np, t, k) is constructed. In Fig 3 the surface expressed by the equation (9) is shown, at change of values to and t in a range [1…3·10^5] and [1...5], accordingly.

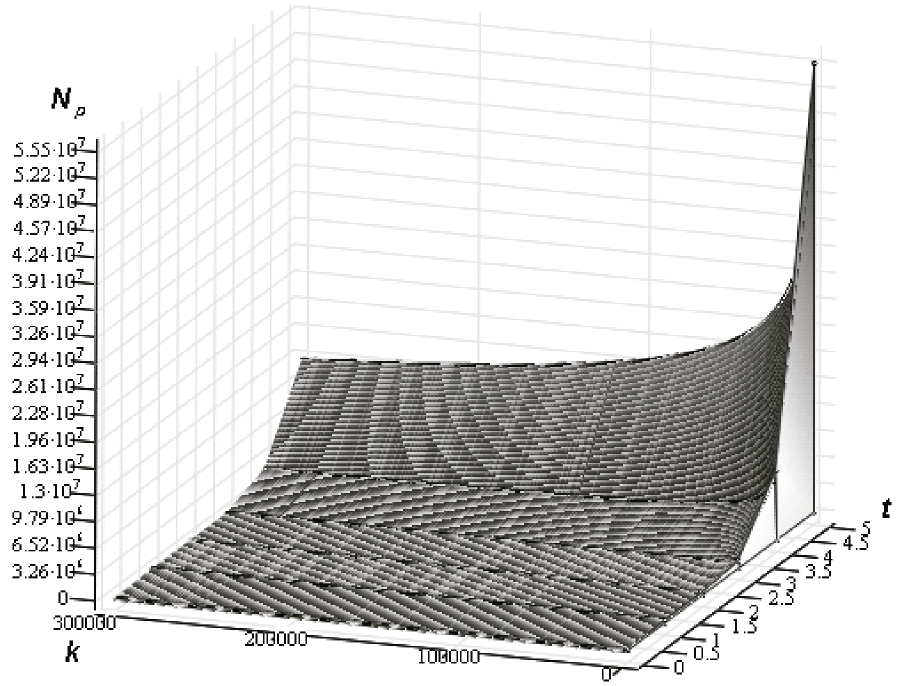

Fig. 3. The schedule of dependence of duration of tests Np from coefficients k and t

Having set by expected values of a limit of endurance and parameters of curve fatigue strength, it is possible to define numerical value of coefficients k, t the equations (8), and duration of tests. For definition of coefficients k and t solve the equations (10), (11), functions expressing an increment in the set point, considering thus resulted above a condition (restriction). The equation for a point n_{01} = 250·10^3 cycles, becomes:

$$\frac{d\sigma}{dN} = \frac{k}{t} \cdot n_{01}^{\frac{t}{1-t}} = 1000, \tag{10}$$

As the second point it is accepted n_2 = 400·10^3 cycles, from those reasons that on level of pressure it should is necessarily in area above an endurance limit. Expression a describing increment of function in this point becomes:

$$\frac{d\sigma}{dN} = \frac{k}{t} \cdot n_2^{\frac{t}{1-t}} = 400 \ , \tag{11}$$

Solving the equations (10) and (11) graphically (Fig 4 see), we receive values of coefficients κ=$2.23\cdot10^5$ and t=4.093.

Under the formula (9) it is defined numerical value of duration of tests of the third series of samples Np=$5.65\cdot10^5$ of cycles.

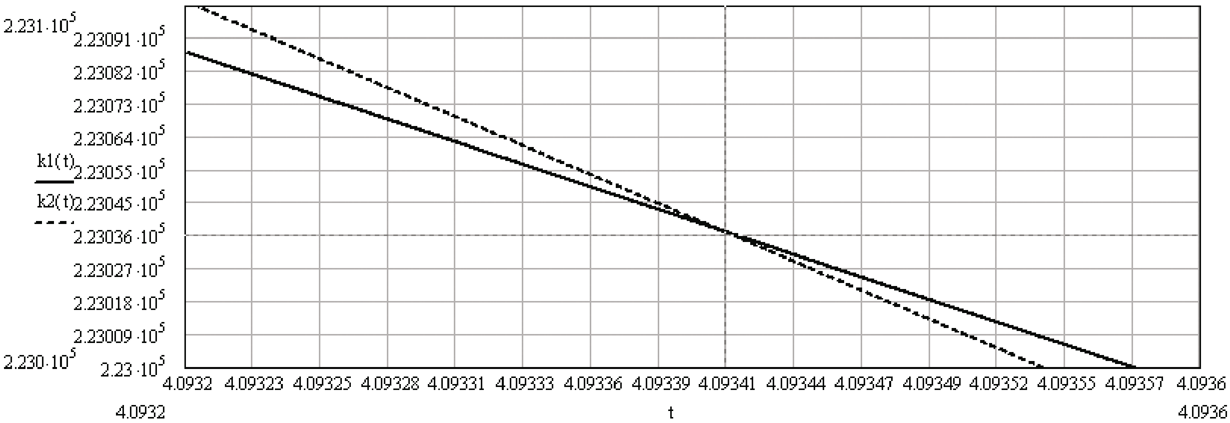

Fig 4. The schedule of dependence of coefficients k and t, in the set points

Accumulation of damages to a material occurs at pressure equal or more an endurance limit. Therefore at loading the sample on the third series of tests (when initial level of pressure below an expected limit of endurance) and the subsequent calculation it is necessary to consider pressure and number of the cycles which are not influencing a condition of the sample.

Having designated n_{01} – the number of cycles at which will reach current value of pressure of an endurance limit, N_p – number of cycles before collapse of the sample, it is possible to write down the equation expressing quantity of cycles in which current there is an accumulation of damages and fatigue failure of the sample at a series of tests from initial level of pressure below an expected limit of endurance:

$$\int_{\sigma_{-1}}^{\sigma_p} n d\sigma = N_p - n_{01}, \tag{12}$$

where:
σ_{-1} – an endurance limit,
σ_p – pressure at which has occurred collapse of the sample,
n - the current number of cycles defined by dependence (12).

Thus for the description of total quantity of damages it is possible to write down the equation:

$$\int_{n_{01}}^{N_p} n \cdot \sigma^m dn = 10^C, \tag{13}$$

where:
σ - the current pressure defined by dependence (8),
m, C – the parameters of curve fatigue strength received by results of first two series of tests.

Solving system of the equations (12), (13) we receive the formula for calculation of a limit of endurance:

$$\sigma_{-1} = \left[\sigma_P^{2t} - \frac{k^{2t} \cdot 2t}{(t-1)} \left(n_{01} - N_P \right) \right]^{1/2t} . \qquad (14)$$

By results of the spent tests characteristics of cyclic strength of fixing details are specified, and adequacy of the accepted constructive decisions is checked. In view of development of computer technologies and software products (ANSYS, APSYS, COSMOS WORKS, etc.) by calculation loading details of cars, and for the purpose of specification and drop of labour input of the analysis of parameters of the kinematic scheme of a threaded connection, an estimation of parameters cyclic loading, use of model of fixing details for calculation by a method of the is final-element analysis is offered.

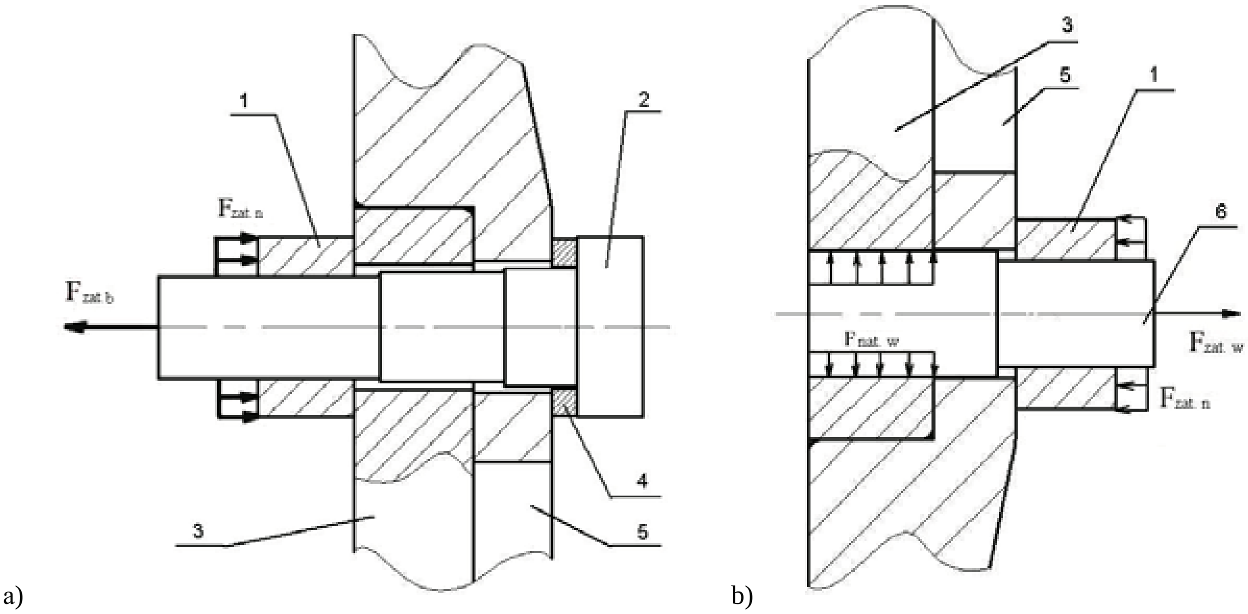

Fig. 5. Settlement models of a threaded connection: a) bolted joint; b) stud-bolt; 1 – a nut; 2 – a bolt; 3,5 – connected details; 4 – washer; 6 – stud-bolt;

Modeling is based on replacement of difficult forms of a carving part and acceptance as the cylinder with a diameter equal to average diameter of a thread. (Fig 5) Efforts from a preliminary tightening of details are applied to seatings in the form of equally effective forces ($F_{zat.\,b}$, $F_{zat.\,n}$, $F_{zat.\,w}$). The hairpin is established in one of connected details with tightness $F_{nat.\,w}$. Taking into account the resulted simplifications the model of a design of a threaded connection of a driving wheel caterpillar thrust system, with use of bolts and hairpins is realized. By results of calculation software allow to analyses values of total pressure of any detail, to visualize a tension of details. So with use of methods of the is final-element analysis the tension of details a shaft, a wheel, fixing details (Fig 6 see) is received, at influence of external which loadings of value correspond to real service conditions.

The greatest pressure arise on fixing details (a bolt - 654 MPa, a nut – 443 MPa), with concentration of pressure in radius under a bolt head and on the first conditional coil of a thread of a nut. Modeling of various conditions stress loading shows change of total pressure of fixing details in a range from 397 MPa to 654 MPa that testifies to presence cyclic loadings and accumulation of fatigue damages. Use of computer technologies represents the information on distribution of pressure in any section and allows to find the necessary constructive decision for drop of concentration of pressure that brings receptions of optimisation of parameters of details of knot in process of designing.

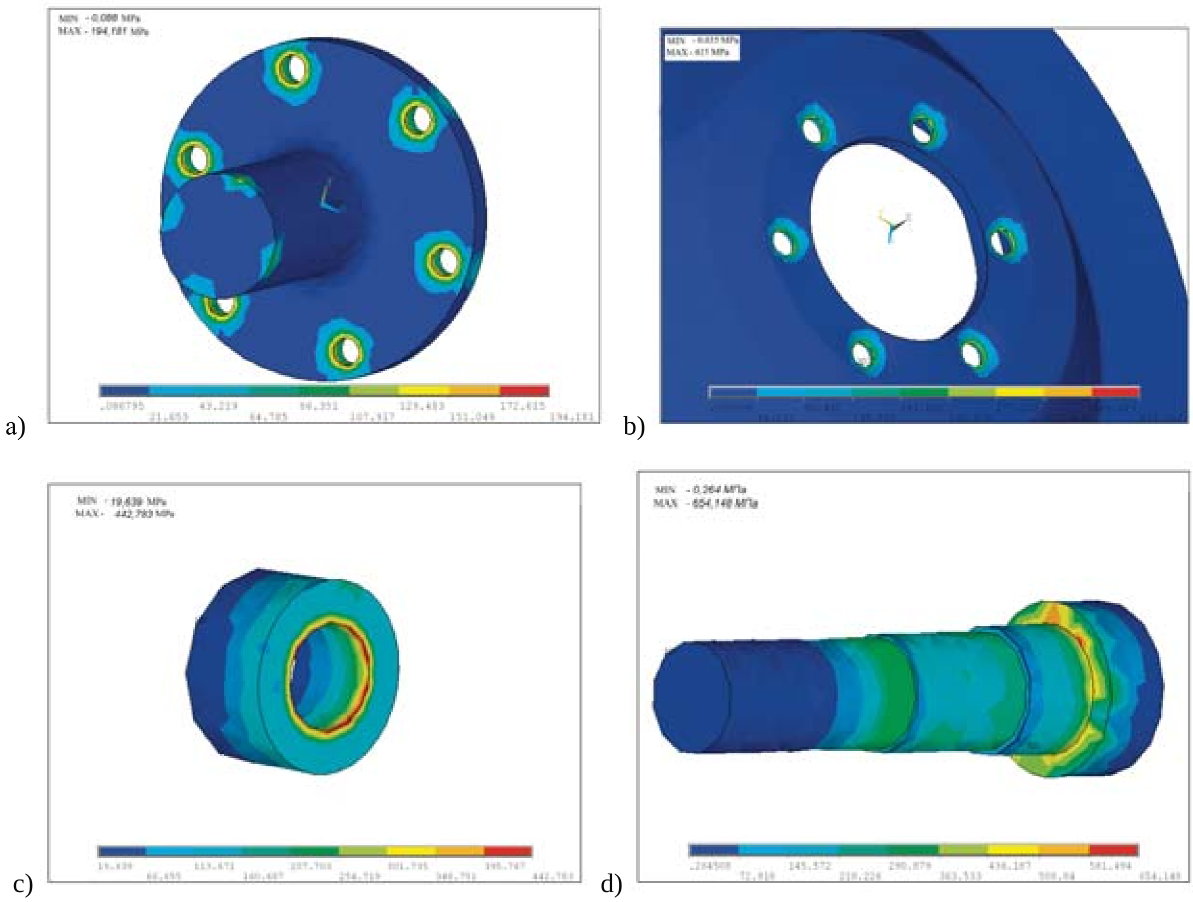

Fig. 6. Distribution of pressure of connected details: a) on a surface of a nave of a shaft; b) on a surface of a wheel; c) on a surface of a nut; d) on a surface of bolts

Amalgamation the offered methods of calculation and probe, and expressing them as consecutive actions, the technique of designing of fixing details which probably to present in the form of algorithm (see Fig 7) is formed.

Use of an offered technique in a complex with the accelerated fatigue tests and modeling stress loading with application of program complexes of the COMPUTER, stages of operational development of a design allow to reduce drawing considerably, and also to reduce quantity of refusals for the design reasons and to predict non-failure operation of work of a design.

Using the offered approach to designing of joints and the analysis of most often arising causes of a failure, has allowed to find the technical decision on elimination of self-unscrewing of fixing details. Modes of the decision of the given problem divide on mechanical and chemical. And highly effective for both modes the gear of fixing of a carving detail, the increase in contact pressure between coils of screwed together details is similar.

The author develops a design of a carving detail [5] which has a lock zone formed by lock elements on side faces of teeths of the thread, executed in the form of a ledge which height is defined on dependence:

$$a \geq \frac{\delta}{2 \cdot n} = \frac{1}{n} \cdot \frac{ES + ei}{4}, \qquad (15)$$

where:

a – height of a ledge concerning a cog side face,

δ – a spacing between side faces of teeths of a thread of the screw and a nut,

ei – the bottom deviation of a tolerance zone of average diameter of a thread of the screw,

ES – the top deviation of a tolerance zone of average diameter of a thread of a nut,

n – quantity of full coils of a thread of a nut.

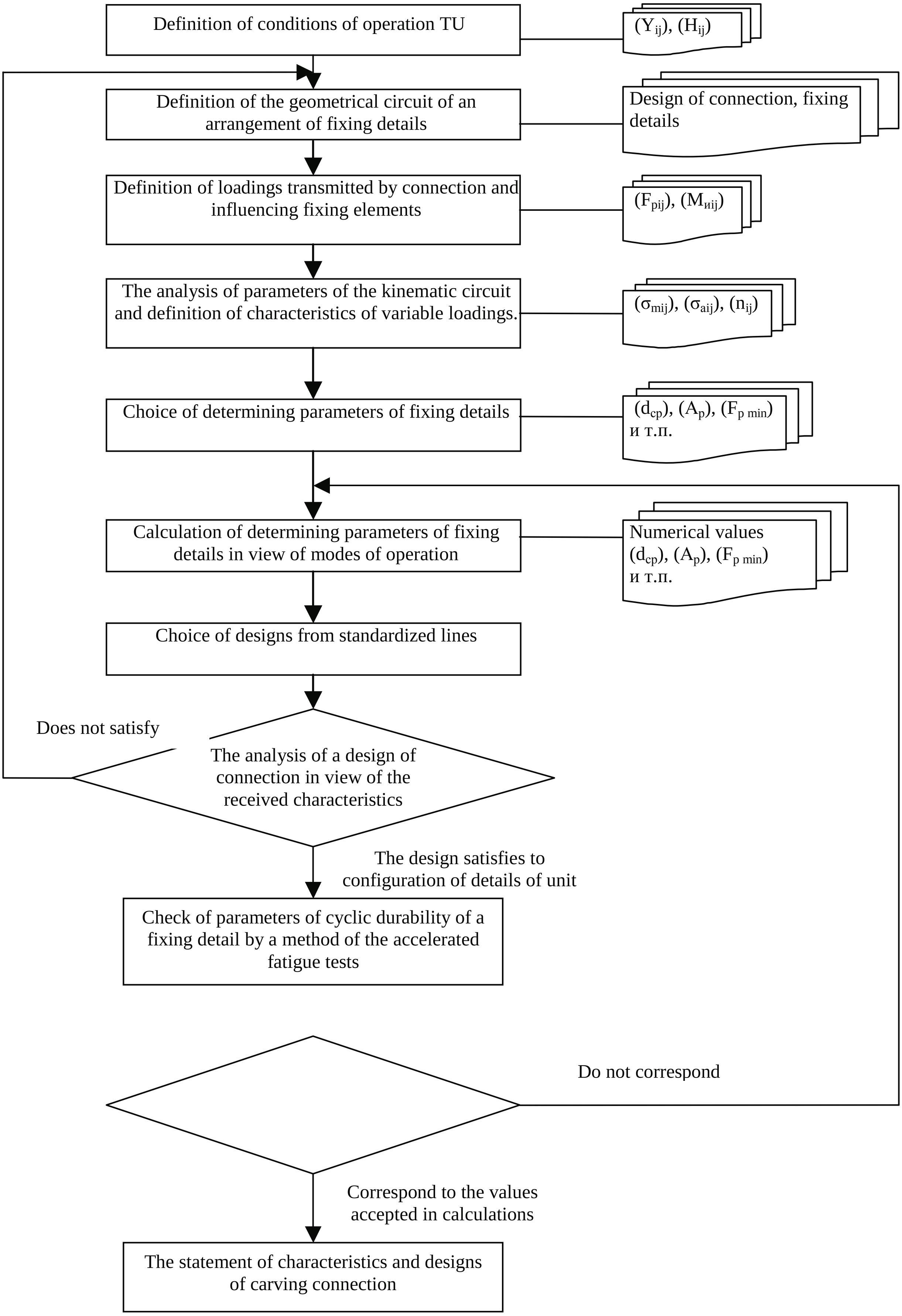

Fig. 7. Algorithm of designing of a threaded connection

Lock action grows out of pressure of lock elements 2 (Fig 8 see) executed in the form of ledges, on a side face 3 cogs of a thread of a nut 4. The joint tightening on the demanded length of a thread is carried out at the expense of deformation of lock elements 2 screws on last coils of a thread of the nut 4, creating additional pressure between thread coils.

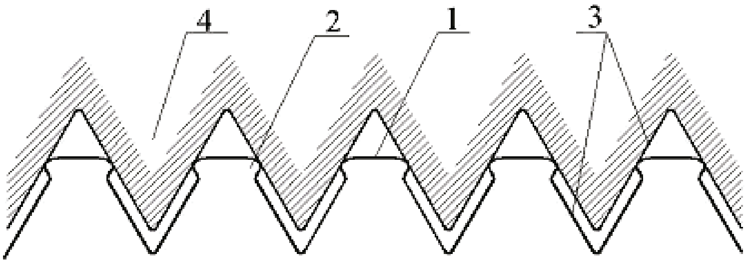

Fig. 8. Design of coils of a lock zone of a fixing detail: 1 – top of a coil of a thread; 2 – lock elements; 3 – a side face of coils of a thread; 4 – a nut body

Use of the offered approach at designing of fixing details allows to consider in calculations of parameters of details various working conditions TU with maintenance of the set resource. Allows the designer to analyse reliability of joint with increase of capacity of the car, the set resource, change of modes of behaviour of the car.

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