EQUAL-STRESSED MACHINE PARTS DESIGN

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The main configurations characteristic of many machine parts is their symmetry. Accounting for the symmetric properties of the design new opportunities to simplify the work with the standard programs using the finite element method (FEM) where creates [1].

The only limit to these possibilities is the need to preserve the symmetry under transformations of the structure related to its optimization. If such optimization concerns the geometric properties of a part, then this step is very difficult, as the optimal design under asymmetric loading, as a rule, are not symmetrical.

Cross-section elements of the supporting structures traditionally chosen depending on the available range of rolled products or are made, usually close to symmetric shapes: round, ring, square, rectangle, hexagon, etc.

Such section, despite its adaptability, often don’t provide uniform distribution of stress loads.

The problem is how to develop a design method that allows to find new non-symmetrical cross section, providing, however, equal stress in detail [2, 3].

The purpose of this study is the reduction of metal machinery parts while maintaining their operational reliability by further development of the method of the virtual models by increasing efficiency optimizing configuration and dimensions of the symmetrical components under acting loads.

To achieve this objective in the work were solved following tasks:

– improved method of virtual models of equal to the stress machine parts;

– showing the virtual model method application to the solve a one-dimensional design tasks of the equal to a busy rod configuration suspended by one end;

– solved the task of designing statically indeterminate rod, clamped on both ends;

– completed a practical test of the method in the calculation of the tank bottom with a positive technical effect.

Consider a simple example [4, 5]. When loading a round tube according to the scheme shown in Fig. 1 *a* stress distribution along the pipe axis have the form shown in Fig. 1 *b*. Modifications to the pipe equal cross-section fitting under the external loads with the purpose of mechanical stress uniform distribution in the tube equal resistance allows to reduce metal consumption of the structure without significant loss of its reliability.

A similar phenomenon is observed when considering the reconciliation of an equivalent stresses plot in the cross section of the circular pipe (Fig. 2).

And here the change in cross section of the pipe for the purpose of uniform stress distribution to optimize the design, turning it into a pipe of equal stress.

The problem of optimization in the above sense of design is reduced to the calculation of such design details, which, after load preset forces would ensure uniform distribution of mechanical stresses throughout the volume, in the case of the above example, as the length of the pipe and on any of its cross section.

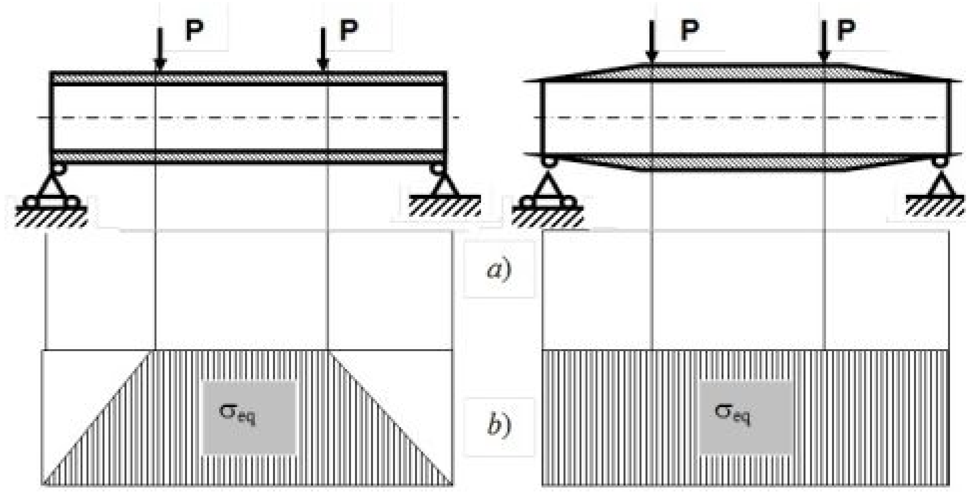

Figure 1 – Scheme of equal pipes loading longitudinal section (left) and equal stress (right)

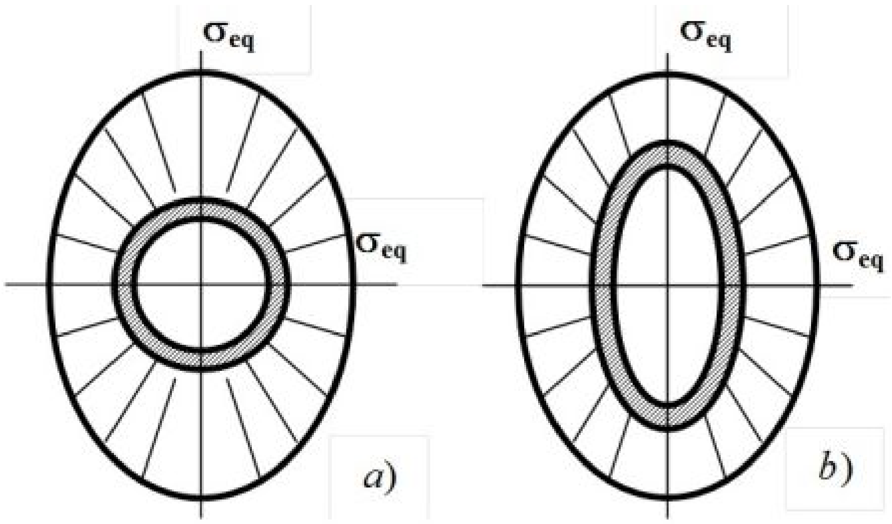

Figure 2 – The transition from a pipe of equal cross-section (left) to the tube equal to the voltage (right)

This calculation by analytical methods is challenging, even when using modern computers. The solution to the problem by the finite element method is complicated by the fact that the cross section is equal to the resistance opposed to the round can't be beat for a large number of symmetric elements.

If you are breaking some design into finite elements and the scheme and parameters of external loading, the stress-strain state (SSS) of each finite element is determined by the settings of the stiffness of the material from which it is made, its shape and dimensions, as well as external (concentrated or distributed) load.

If these specific parameters are equal for the two finite elements, and their SSS is also equivalent (Fig. 3).

When the inequality parameters of at least one the factors is natural to assume the equivalence of the SSS (Fig. 4 *a*). This equivalence can be theoretically eliminated by the violation of the other factor equality (Fig. 4 *b*), which acts on SSS in the «opposite» direction [6].

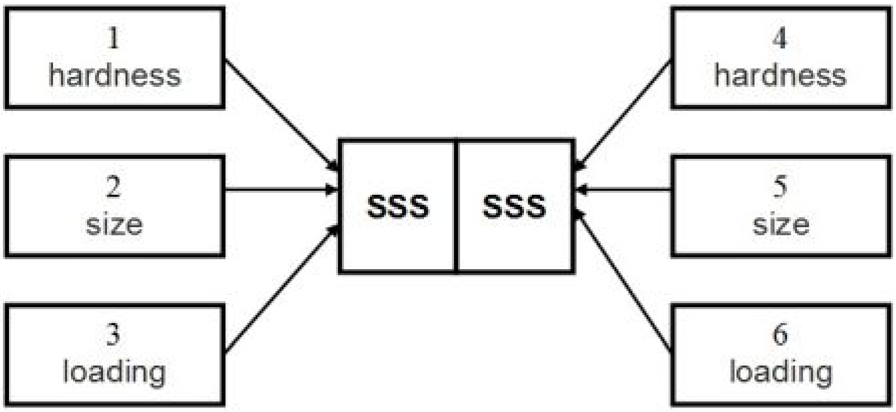

Figure 3 – The scheme of two piece design SSS formation

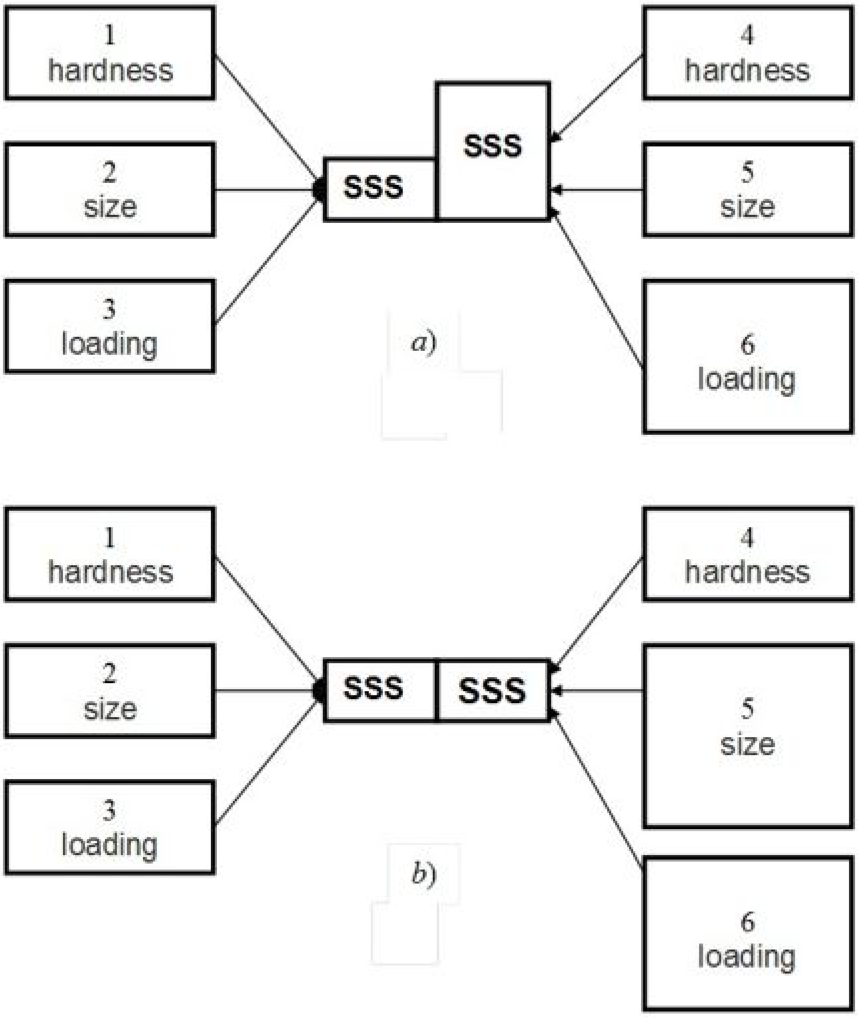

Figure 4 – The scheme to the role of factors influencing SSS assessment

Consider the example of solving such problem in one-dimensional statement. Let the round vertical rod, clamped the upper end of the loaded weight and the current along its axis the power *P*. If the length *L* and the material of the rod is given, the uneven distribution of stresses and deformations it can be compensated by the virtual uniformity of the cross-sectional area F, the hardness E or the external load P.

Accordingly, there are three types of virtual rods: size compensating stiffness compensating and external loading compensating (and possible combinations of these types).

The virtual object with an compensate for the size. Divide the rod into n sections of equal length l and «allow» these sections have the different (but constant within a phase) diameter D_i (i = 1, ..., n).

Will find the ratio of these diameters so that the stress plot in the rod was close to uniform. It will be closer to uniform than in more parts of the broken rod. Thus, the problem can be solved with any prescribed accuracy.

The virtual object with compensating rigidity. We introduce a methodological complication in the problem. Let, by analogy with the sensitivity to the asymmetry of finite elements CAD, the existing algorithm finite elements method (FEM) does not allow to simulate the rod elements of different diameter. As in statically determinate systems, stress does not depend on the material stiffness of the rod, will speak about the alignment of stresses and deformations. Use in this case, the circuit shown in Fig. 4, and will try to compensate for the uneven distribution of the strains are the dimensions of the part and its stiffness. That is, replace rod of equal strength and hardness, but of different diameters, a rod of equal strength and diameter but of unequal hardness.

The result is a virtual terminal, consisting of different stiffness sections. Almost a pin (in a strictly defined properties of real substances limits) can be made of different materials, but we are interested in a virtual object, the value of E_i in areas which can take any value.

Thus, having satisfied the requirement of the newly introduced restrictions, that is, keeping intact the diameter of the rod elements, using the FEM package, sensitive to the variability of elements sizes to adjust the values of $E_1, ..., E_i, ..., E_n$, provides approximately (with any predefined accuracy) equal strain along the length of the rod. Note that this, the most time consuming part of the calculations performed by the computer and the designer. Now remained outside of the package, using the ratio $D_i = f(E_i)$, derived for σ = const, using the known values E_i to determine values of D_i for each element of the core, restoring the equality of the stiffness for all elements. The project real web optimal design is ready.

Virtual object with a compensating external loading. We fix the average value of equivalent stress $\bar{\sigma}_{eq\,i}$ in i-th element when the estimated loading force P and the acceleration of gravity g. We then mentally change the loading, selecting such values $P_1, \dots, P_{i-1}, P_{i+1}, \dots, P_n$ and $g_1, \dots, g_{i-1}, g_{i+1}, \dots, g_n$, which provide close to the stress $\bar{\sigma}_{eq\,i}$ value of all the other elements. The load in turn applied to all the elements simultaneously, but each loading provides a predetermined value $\bar{\sigma}_{eq\,i}$ only their element; the other elements at the time of the application «alien» load stress will differ from $\bar{\sigma}_{eq\,i}$ that in the framework of this method does not matter.

Thus, the dimensions of the rod the same way as in the previous case, remain at this stage unchanged, which gives the possibility to use for the selection of the loadings are sensitive to the dimensional parameter software package.

The result is a series of virtual external forces $P_1, \ldots, P_{i-1}, P, P_{i+1}, \ldots, P_n$ and the virtual acceleration of gravity $g_1, \ldots, g_{i-1}, g, g_{i+1}, \ldots, g_n$, which is already outside of the package can be converted into a number of rod diameters equal tension, reducing the singular values of the external force and the acceleration of gravity, i.e., making the rod very real.

As can be seen from the figure 4, in the three-factor case, the compensation of the error in one factor can be made due to the misalignment of the second or third factors individually or their combined action [7].

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