STANDARDIZATION OF PARAMETERS AND EXACTNESS OF THE SHEET BILLETS OF THE HOUSINGS OF LARGE-DIMENSION APPARATUS

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The quality of large-dimension pieces of apparatus (LDA) is inseparably bound up with the exactness of their fabrication. A comparison of the standards for the fabrication of large-dimension apparatus with respect to domestic and foreign standards has shown that, at the present time, there are no generally accepted recommendations for the value, the laws governing the variation, and the structure of the tolerance. The absence of specific recommendations makes it difficult to make a correct estimation of the factors which affect the exactness of the elements of the apparatus, which leads to a considerable volume of fitting work during assembly, and lowers the quality. In view of this, to assure high quality, the development of new methods for the calculation and standardization of the parameters of the elements of large-dimension apparatus and the tolerances for them is of great importance.

For welded, large-dimension apparatus, the width of the sheet-type billets is determined from the condition for its congruence with the height of the apparatus, and its length from the condition for the congruence with the diameter. The diameter and the height of large-dimension apparatus are given unambiguously in the form of actual values, calculated taking account of the necessity of carrying out the engineering process with the highest efficiency and, for a given quality of the raw material and the final process (with the limitations imposed), they are constant.

The tolerances for welding of the joints are given by considerations of strength, engineering feasibility, and consistency with the exactness of parts of other joints. The tolerance for the length of the shells, making up the housing, is determined from a dimensional analysis.

The selection of the length and width, as well as the tolerances of the sheet billets of the butt-joints of welded sheets, must be based on a guarantee of the high quality of the final article.

The optimal length l of the sheet billets, entering into the welded sheet, must be selected from three conditions for the assurance of the economical fabrication of large-dimension apparatus: The number of sheets making up the expanded shell (with respect to the length) must be a whole number; the calculated length of the sheet part must be maximally close to the length of standardized sheets; the number of welded seams in the total sheet must be minimal.

The optimal width h of a sheet-type billet for the height of the apparatus is calculated on the basis of minimization of the cost of the housing C_h, made up of supplementary expenditures for the sheet material, arising as a result of an increase in the geometrical parameters of the sheet with respect to the base parameters, and expenditures for its fabrication.

The mathematical model for calculation of the optimal width of a sheet-type billet will have the form

$$\begin{cases} C_h = C_1 + C_2 + C_3; \\ h \leqslant h_0, \end{cases}$$

where $C_1 = f(S, h)$; $C_2 = f(h, S, d, H)$; $C_3 = f(S, h, d)$ is the cost, respectively, of the sheet-type billets of the cylindrical part of the housing, the fabrication of the cylindrical part of the housing, and the fabrication of the bottom, including expenditures for material; H, d, and S are the height, the diameter, and the wall thickness of the housing, determined during the construction stage, starting from the functional designation of the apparatus; h_0 are the limitations on the width of the sheet-type billets, imposed by the standard documentation for the mutual arrangement of the welded seams and the geometrical dimensions of standard sheets.

As a result of differentiation of the target function with respect to h and of equating the first derivative to zero, an equation is obtained for calculating the optimal width of a sheet of a billet:

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$$h^2 (h-2)^{-0.34} = \frac{k k_b m_p (1106.51 S^{1.35} + 6.44)(1 + H_c/100)}{7.59 C_b \cdot 10^{-2} d^{0.07} H^{0.03} S \gamma},$$

where k is the coefficient of the utilization of the sheet material; k_b is a coefficient depending on the brand of steel (for carbon- and low-alloy steels $k_b = 1$; for bimetals and high-alloy steels $k_b = 1.2$); m_p is the average hourly pay of a worker; C_b is the base specific cost of the sheet material; H_c are the expenditures for the content and operation of the equipment (in % of the labor requirement); γ is the density of the sheet material.

With the aim of reducing the calculating time, using this expression nomograms have been developed for determining the optimal width of sheet-type billets made of steels of various brands, depending on the thickness of the sheet, diameter, and height of the housing.

With fitting of the sheet-type billets into the whole welded sheet, the deviation of the dimensions and the form and straightness of the final sheet must be assured within given limits. The calculation of the tolerances for the sheet-type parts must be based on functional and engineering principles. The functional principle assures the reliability of the welding and the strength of the butt joints, while the engineering principle assures the economical fabrication of the housing of the apparatus.

In accordance with the engineering principle, an analysis was made of the actual exactness of the working of the sheet-type billets, the exactness of the laying-out, the cutting, and the machining of the edges for welding was assured, and the mechanism of the development of errors with the formation of the shell from the final welded sheet and the fitting of the sheets into the final welded sheet was established [1].

To assure compliance with the engineering principle, in setting up the system of tolerances with the observance of the standard exactness, as the result of an analysis an arrangement of the sheets in the final welded sheet with leveling and equalization along the length of the sheet was adopted.

The maximal gap Δ_x between the j-th and (j+1)-th sheets with n sheets in the final welded sheet is

$$\Delta_x = |h(\varphi_j' + \varphi_{j+1})| \leq h|\varphi_j'| + h|\varphi_{j+1}|,$$

where φ_j' and φ_{j+1} are the errors in the inclination of the right- and left-hand sides of the sheet.

The exactness of two sheets is assured if $\Delta_x < T_x$ (here T_x is the tolerance for the welded gap). It is then required that

$$|h\varphi_j'| < \frac{T_x}{2} \text{ and } |h\varphi_{j+1}| < \frac{T_x}{2}.$$

The joining of two shells is possible in the case where the vertical gap Δ_y between the sheets being butt-welded does not exceed the welding gap T_y (i.e., $|\Delta_y| < T_y$). The difference of the perimeters u of the two shells determines the value of the shift of the edges being butt-welded. To assure the reliability of the assembly and welding of the apparatus, the following condition must be satisfied:

$$|u_{i+1} - u_i| < T_u,$$

where $T_u = 2\pi T_s$ is the allowance for the difference in the perimeters of the two shells; T_s is the allowance for the shift of the edges being butt-welded.

The latter condition must be satisfied with a certain reliability: $1-\beta$, where $\beta = \alpha/(m-1)$; $1-\alpha$ is the reliability of the welding of a housing consisting of m shells.

Let the nominal diameter of a shell $u_0 = nl$; then

$$\Delta_u = u - u_0 = \sum_{j=1}^{n} \Delta l_j + 0.5 \sum_{j=1}^{n} |h(\varphi_j' + \varphi_{j+1})|.$$

Assuming that the values of Δl_j, φ_j', and φ_{j+1} are independent in the set and have a normal distribution, and giving for Δ_u the mathematical expectation $M|\Delta_u| = nh\sigma_\varphi/\sqrt{\pi}$ and the dispersion

$$D|\Delta_u| = n\sigma_l^2 + 0.5 n h^2 \sigma_\varphi^2 (1 - 2/\pi)$$

(here σ_l, σ_φ are the mean-square deviations of the errors of the dimensions and form of a sheet, respectively), we obtain

$$\Phi\left(\frac{\dot{T}_{n}}{\sqrt{2D\,|\,\Delta_{n}\,|}}\right)=\Phi\,(t)=1-\beta,$$

where $\Phi(t)$ is the integral of the probabilities.

Thus, from the given reliability of the assembly of the whole housing, we determine the relationship between φ_l and σ_φ and the permissible shift of the edges of the butt-welded elements. This relationship is used to select the above-mentioned mean-square deviations (taking account of the technology of the fabrication) by selection of their optimal values.

The allowance for the width of the sheet (the length of the shell) T_h is determined by the method of equal allowances in one of the statements:

determined

$$\dot{T}_h=\frac{1}{m}\left[\dot{T}_H-(m-1)\,(\dot{T}_b+\Delta''-\Delta')\right];$$

stochastic (probability)

$$T_h=\frac{1}{k_h}\sqrt{\frac{T_H^2\,k_H^2-k_b^2(m-1)\,T_b^2+k_\Delta^2(m-1)(\Delta'-\Delta'')^2}{m}},$$

where T_H is the allowance for the length of the housing of the apparatus; T_V is the allowance for the value of the welding gap; Δ'', Δ' are the values of the shrinkage of the welded seam, calculated using the data of [2], respectively with the least and greatest permissible values of the welding gap; k_h, k_H, k_b, k_Δ are coefficients of the dispersion, characterizing the degree of difference between the determination of the error and a Gaussian determination.

On the basis of the calculating method developed and the data of an investigation of the exactness, with respect to functional and engineering criteria, the following criteria have been developed for standardization of the system of tolerances for sheet-type parts: a) the basis of the system (as the calculating dimension of sheet-type parts there were taken the basic parameters of the internal surfaces, i.e., the diameter, the perimeter); b) the location of the field of the allowance f or sheet-type parts is two-sided (with respect to the zero line); c) there are three standardized series of allowances: the first series applies to two-layer parts, the second to single-layer parts, and the third to sheets for the fabrication of apparatus which do not have standard limitations, which are determined by agreement between the designers and the fabricators (the numerical values of the parameters and allowances for sheets of the third series can be calculated using the method given above); d) series of allowances for sheet-type details have been calculated and are given in tables for elements whose dimensions were determined at a temperature of 20°C, close to the temperature of the working rooms of equipment-building plants. On the basis of the principles formulated, a system of allowances has been developed, drawn up in the form of tables for a branch standard.

The results of the work were used in the VNIIPTkhimnefteapparatur in the development of Guiding Technical Materials 26-306–79 "Housings of dimensionless apparatus. Technology, equipment, and fittings," which has been put into effect in plants of the branch as of July 1, 1979.

The introduction of the calculating method and standardization of the parameters and tolerances for sheet-type parts makes it possible to lower considerably the waste of sheet-type parts material (steel) with their machining and the labor requirements for fitting operations due to the use of the principle of interchangeability, as well as to increase considerably the reliability of a butt joint. The savings resulting from the introduction of the method set forth above in the leading plants of the branch is 151.2 thousand rubles per year.

LITERATURE CITED

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