METHOD OF CALCULATION OF PROBLEMS OF JOINTS WITH KEYS AND GEAR (SLITS).

Abdukhakim Nigmatovich Abdullayev
Ph.D., Associate Professor of the Department of "Technology and Methodology of Professional Education" of the National Pedagogical University of Uzbekistan named after Nizami.
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Annotatsiya: tishlarning ishchi yuzasi ezilishi va yeyilishi ayni bir xil parametrga – ezilish kuchlanishi bilan bog‘liq. Buni ezilish va yeyilishni hisoblashda umumlashma mezon sifatida ko‘rib chiqishga imkon beradi, bunda o‘xshash konstruksiyalarni ishlatish tajribasi asosida qabul qilingan. Bunday hisoblash umumlashma mezon bo‘yicha soddalashtirilgan.

Kalit so‘zlar: ezilishning joiz kuchlanishi, shlisli birikmalar, prizmasimon shponkalar, segment shponkalar, shtiftli birikma, shlisli birikma, shlisning geometrik o‘lchamlari, ikkita valni biriktiruvchi vtulkali mufta

Аннотация: износ рабочей поверхности зубьев связан с одним и тем же параметром – напряжением износа. Это позволяет рассматривать его как обобщенный критерий расчета износа, принятый на основе опыта эксплуатации аналогичных конструкций. Такой расчет упрощается за счет обобщенного критерия. Цилиндрическая шестерня крепится к валу цилиндрическим штифтом. Если крутящий момент, передаваемый шестернями, равен t, проверьте штифт на срез.

Ключевые слова: допустимое напряжение смятия, шлицевые соединения, призматические шпонки, сегментные шпонки, штифтовое соединение, шлицевое соединение, геометрические размеры паза, муфта, соединяющая два вала

Annotation: the wear and tear of the working surface of the teeth are related to the same parameter - the wear stress. This allows us to consider it as a generalized criterion for calculating wear and tear, which is accepted based on the experience of using similar structures. Such a calculation is simplified by the generalized criterion. The cylindrical gear is fixed to the shaft using a cylindrical pin . If the torque transmitted by the gears is t, check the pin for shear

Key words: allowable crushing stress, slotted joints, prism-shaped keys, segment keys, pin joint, slotted joint, geometric dimensions of the slot, sleeve coupling connecting two shafts

Results: select a shaft spline joint (involute splines) and check it for strength, with a transmission torque t = 1.5 10^3 n m; shaft diameter d = 60 mm. The working surface of the splines is specially heat treated. The length of the gear hub is taken as l = 60 mm.

Solution. 1 for involute splines, we select a spline joint with t = 3 mm from (the number of teeth at t = 1.5 mm will be too large).

Thus, d = 60 mm, t = 3 mm, z = 18.

2 for a spline joint with specially heat treated teeth, the tensile strength at rest = 80 mpa.

3 the geometric dimensions of the slot are calculated by the formula:

D m = m·z = 3·18 = 54 mm , h = m = 3 mm.

4 we check the joint for compression.

$$\sigma_{CM} = \frac{2 \cdot 10^3 \cdot T \cdot K_3}{z \cdot h \cdot d_m \cdot l} = \frac{2 \cdot 10^3 \cdot 1{,}5 \cdot 10^3 \cdot 1{,}3}{18 \cdot 3 \cdot 54 \cdot 60} = 22{,}3 \text{ mpa.}$$

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This $[\sigma_{CM}]$ less than.

Discussion: examples of solving the problem. For a gear coupling with a shaft d = 55 mm, select a prismatic key according to the standard (fig. 1). Gear material — steel 40x, key material — steel 45, sleeve length l_{st} = 72 mm, transmitted torque under constant reversible load t = 500 n·m.

Solution. 1 according to the standard, we select a key with the following dimensions for a prismatic key: b = 16 mm, h = 10 mm, t_1 = 6 mm. Taking into account the sleeve length, we determine the key length $l = l_{st}$ — 10 mm = 62 mm, then select the key length from the standard series l = 63 mm; calculated length $l_p = l_p$ — b = 63 – 16 = 47 mm.

"gost 23360 - 78 key" was accepted.

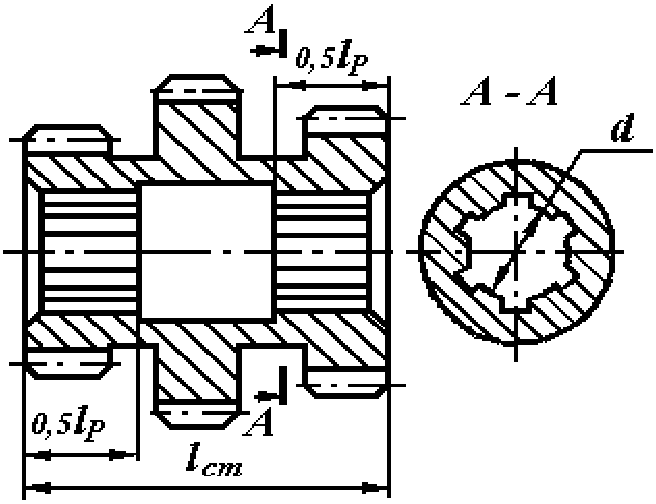
2 we find the permissible compressive stress. Key material – for steel 45 (as given) [s] = 2,5.

$[\sigma_{см}] = \sigma_т / [s]$ = 290 / 2,5 = 116 mpa.

3 we check the compound for crushing:

$$\sigma_{CM} = \frac{2 \cdot T}{d \cdot (h - t_1) \cdot l_P} = \frac{2 \cdot 500 \cdot 10^3}{55 \cdot (10-6) \cdot 47} = 96{,}7 \text{ МПа} < [\sigma_{CM}] = 116 \text{ МПа}$$

Consistency condition met.



Examples of solving problem 2.

Choose a splined joint for the gearbox transmission shaft and gear block (fig. 2). The calculated diameter of the shaft is d = 35 mm, the working length of the block bushing l_P = 65 mm. The joint transmits t = 200 n·m at rest. Shaft material — steel 45 ($\sigma_т$ = 290 mpa), gear block material – steel 40x ($\sigma_т$ = 600 mpa). The working surfaces of the teeth are hardened (hb ≥ 350). The gear unit does not rotate under load.

Solution. 1 we choose a joint with a flat edge spline as a widespread type. We assume centering on the inner diameter for the teeth found.

2 we find the dimensions of the joint in the middle series from the table, since this is recommended if the bearings do not change under load. For the shaft diameter d = 35 mm, z× d× d = $8 \times 36 \times 42$ mm; f = 0,4 mm.

3 for a joint in motion at rest [σ $_{см}$] = 80 mpa

4 the geometric dimensions of the slot are calculated by the formula:

$$d_m = (D+d)/2 = (42+36)/2 = 39 \text{ mm},$$

$$h = \frac{D-d}{2} - 2\cdot f = \frac{42-36}{2} - 2\cdot 0{,}4 = 2{,}2 \text{ mm}.$$

Conditional calculation stress of crushing:

$$\sigma_{CM} = \frac{2\cdot 10^3 \cdot T \cdot K_3}{z\cdot h\cdot d_m \cdot l} = \frac{2\cdot 10^3 \cdot 200\cdot 1{,}3}{8\cdot 2{,}2\cdot 39\cdot 65} = 11{,}65 \text{ mpa},$$

This $\sigma_{см} < [\sigma_{см}]$ satisfies the condition.

Conclusion: the solution of the problem can be carried out in the following order.

1) the cross-sectional dimensions of the keys or the dimensions of the splined joint and the number of teeth are determined based on the shaft diameter d.

2) the permissible crushing stress [σ $_{см}$] yield strength σ_t and depends on the type of loads applied and the characteristics of the materials of the contacting parts. [σ $_{см}$] the value is selected based on the material with the lowest strength among the materials in contact. In that case

$[\sigma_{см}] = \sigma_{т} / [s]$,

Here $\sigma_{т}$ — yield strength, mpa;; [s] — is the reserve coefficient.

The reserve factor in non-reversible loading that changes little in value [s] = 1,9... 2,3 is considered to be, with frequent starts and stops — [s] = 2,9... 3,5; in reverse loading, the reserve factor is increased by 30%.

Permissible shear stress for clamps, usually, $[\tau_{cp}]$ = 60… 100 mpa (a lower value is accepted for dynamic loads).

The actual stresses for slotted joints are strongly dependent on the coordinates of the point being considered in the slot and therefore are much higher than the average. This can be taken into account by reducing the allowable stresses by increasing the safety factors. The allowable compressive stresses for static loads with a slot surface hardness of hb ≤ 350 are $[\sigma_{см}]$ = 80… 120 mpa, the surface hardness of the splines is hb > 350. $[\sigma_{см}]$ = 120… 200 mpa. The permissible stress for a movable joint is reduced by half.

3) check the strength of the joint elements in accordance with the types of damage.

A) prism-shaped keys have a right-angled cut. The standard provides for certain dimensions of the key cross-section for each shaft diameter. Therefore, in design calculations, the dimensions b and h are taken from the table and l_p the calculated length of the key is determined

$$L_p \geq \frac{2\cdot 10^3 \cdot T}{d\cdot [\sigma_{CM}]\cdot (h-t_1)}.$$

Key length $l = l_p + b$ is selected from the standard array. The length of the spike $l_{ст}$ 8...10 mm larger than the length of the dowel. According to the calculation results of the keyed joint

$L_{ст} \geq 1{,}5$ d if the length of the joint is taken, then it is more appropriate to use a slotted joint or a tension joint instead of a keyed joint.

In addition to normal plastic deformation, plastic displacement (shear) caused by large compressive stresses can also cause the failure of a keyed joint.

In this case, the keys are checked for shear:

$$\tau_{CP} = \frac{F_t}{A} = \frac{2 \cdot T / d}{l_p \cdot b} \leq [\tau_{CP}].$$

However, if the cross-sectional dimensions of the key are selected from the normal series depending on the shaft diameter, then there is no need for such a calculation, since the shear strength condition is automatically fulfilled.

B) segment keys. It is recommended to select the dimensions of segment keys in accordance with the table data. The calculation of the key segment is carried out in a check form and is carried out according to the same methodology as for calculating the crushing resistance for prismatic keyed joints..

Then $\sigma_{CM} = \dfrac{2 \cdot T}{d \cdot l \cdot (h - t_1)} \leq [\sigma_{CM}].$

Checking the joint for shear, in this $l_p = l$ is taken as

C) pin joint.

Diameter $d_Ш$ and pin (cylindrical key) calculation length l_p to a first approximation, it is assumed to be proportional to the shaft diameter d:

$d_Ш \approx (0,13 \ldots 0,16)\, d$; $l_p \approx (3 \ldots 4)\, d_Ш$

And is specified in accordance with gost.

- the pin is located parallel to the axis of rotation of the joint, which ensures the transmission of the rotational moment t.

When the longitudinal section of the pin is loaded with an external moment, shear stresses arise, which should not exceed the shear strength limit.

The shear strength condition for an axial pin joint can be written as follows:

$$\tau_{CP} = \frac{2 \cdot T}{d \cdot d_Ш \cdot l_P} \leq [\tau_{CP}].$$

The condition of the absence of plastic deformations (crushes) caused by normal stress on the contact surface is written in the following form:

$$\sigma_{CM} = \frac{F}{A_{CM}} = \frac{\frac{2 \cdot T}{d}}{l_Ш \cdot \frac{1}{2} \cdot d_Ш} = \frac{4 \cdot T}{d \cdot l_Ш \cdot d_Ш} \leq [\sigma_{CM}].$$

Given the diameter or length of the key, its length or diameter can be determined according to the formulas given.

- the pin is installed in the radial direction.

Here, each shear surface consists of a circle. As mentioned above, these surfaces react to the shear moment with a shear stress equal to the yield point in shear. In this case, the shear resistance condition takes the form: $\tau_{CP} = \dfrac{8 \cdot T}{\pi \cdot d \cdot d_{Ш}{}^{2} \cdot i} \leq \left[\tau_{CP}\right]$,

Where i is the number of cutting surfaces.

C) splined joint.

The wear and wear of the working surface of the teeth are determined by the same parameter - the wear stress $\sigma_{см}$ билан боғлиқ. This $\sigma_{см}$ allows to consider as a generalized criterion in the calculation of crushing and bending, where $[\sigma_{см}]$ is accepted based on the experience of using similar structures. Such a calculation is called a simplified calculation according to the generalization criterion.

In the design calculation of splined joints, after the dimensions of the tooth cross-section are selected according to the standard, the tooth length l is determined according to the condition of resistance to crushing stress:

$$\sigma_{CM} = \frac{2 \cdot 10^{3} \cdot T \cdot K_{З}}{z \cdot h \cdot d_{m} \cdot l} \leq [\sigma_{CM}],$$

Here $k_З$ – coefficient of unevenness of load distribution between teeth (depending on the accuracy of preparation and operating conditions), $k_З$ = 1,1-1,5.

The geometric dimensions of the slit are calculated depending on the joint with the slit. So for straight-edged slits $d_{m} = \dfrac{D+d}{2}$, $h = \dfrac{D-d}{2} - 2 \cdot f$;

For involute $d_m = m \cdot z$, $h = m$.

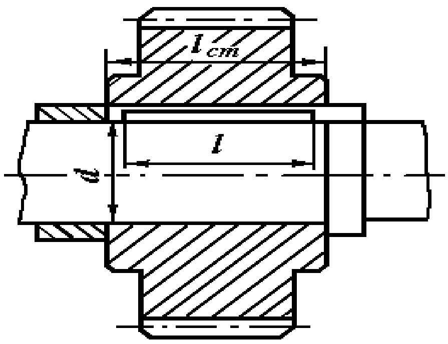


Figure 1

If l > 1.5·d is obtained, then the dimensions, thermal performance are changed or another type of connection is adopted.

The length of the sleeve depends on the design of the connection $l_{ст}$ = l + 4... 6 mm and above.

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