TOMSK POLYTECHNIC UNIVERSITY

Department: TAMP

COURSEWORK

“Metrology, Standardisation and Sertification”

STUDENT’S GROUP NO: 158Л1А .

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1. CALCULATION OF INTERFERENCE FIT

Data:

1	Torque	$M_{кр}$	400	Nm
2	Axial force	P_0	50	KN
3	Nominal diameter of mating parts ~~connection~~	d_{HC}	60	mm
4	Internal diameter of shaft (hole)	d_1	30	mm
5	External diameter of sleeve	d_2	75	mm
6	Pairing length	L	80	mm
7	Coefficient of friction	f	0,08	
8	Module of elasticity of sleeve	E_D	$2x10^{11}$	N/m^2
9	Module of elasticity of shaft	E_d	$2x10^{11}$	N/m^2
10	Poisson coefficient of sleeve	μ_D	0,3	
11	Poisson coefficient of shaft	μ_d	0,3	
12	Yield strength of sleeve	σ_{TD}	$38x10^8$	N/m^2
13	Yield strength of shaft	σ_{Td}	$38x10^8$	N/m^2
14	Roughness of sleeve	R_{aD}	1.25	μm
15	Roughness of shaft	R_{ad}	0.8	μm

Material of sleeve is steel 40

Material of shaft is steel 50

1) Minimum stress on mating surface:

$$[P_{min}] = \frac{\sqrt{{P_0}^2+\left(\frac{2M_{кр}}{d_{HC}}\right)^2}}{\pi * l * f * \partial_{HC}} = \frac{\sqrt{(50*10^3)^2+\left(\frac{2*400}{60*10^{-3}}\right)^2}}{3.14*60*10^{-3}*50*10^{-3}*0,08} = \frac{51747,24}{7,53*10^{-4}} = 68,7 * 10^6 \frac{N}{m^2}$$

Where,

P_0 – longitudinal axial force, N

$M_{кр}$ – Torque, Nm

l – Length of contact of the mating surfaces, (m)

f – Coefficient of friction

2) On the basis of the value of $[P_{min}]$ we determine the smallest estimated interference:

$$N^l_{min} = [P_{min}]*d_{HC}*\left(\frac{C_1}{E_1} + \frac{C_2}{E_2}\right)$$

Where,

E_1 and E_2 yield strength corresponding to the shaft and hole respectively, N/m^2

C_1 and C_2–Lame coefficients which can be determined by the formulae below

For shaft: $C_1 = \frac{1+\left(\frac{d_1}{d_{HC}}\right)^2}{1-\left(\frac{d_1}{d_{HC}}\right)^2} - \mu$; $C_1 = \frac{1+\left(\frac{30}{60}\right)^2}{1-\left(\frac{30}{60}\right)^2} - 0,3 = 1,36$

For sleeve: $C_2 = \frac{1+\left(\frac{d_{HC}}{d_2}\right)^2}{1-\left(\frac{d_{HC}}{d_2}\right)^2} + \mu$; $C_2 = \frac{1+\left(\frac{60}{75}\right)^2}{1-\left(\frac{60}{75}\right)^2} + 0,3 = 4,85$

$N^l_{min} = 68,7 \times 10^6 \times 0,060 \times \left(\frac{1,36+4,85}{2*10^{11}}\right) = 12,8 \times 10^{-5}$ m = 128 μm ~~$8,5 \times 10^{-6}$ m~~

3) Determining the minimum permissible interference taking into account adjustment:

$[N_{min}] = N^l_{min} + \gamma_r + \gamma_{dis} + \gamma_t$

To define γ_r ($\gamma_{roughness}$), we take the value of the roughness of the sleeve and the shaft below:

because from the formula γ_r =2×k×(Rzd+RzD),

Where: k=1,2 (rate guarantee) ;

Rad=0,8 μm for 6 grade of shaft tolerance, so Rzd=4×0,8=3,2 μm;:

RaD=1,25 μm for 7grade of hole tolerance, so RzD=4×1,25=6 μm;

γ_r =2×k×(Rzd+RzD) = 2×1,2× (3,2+6) = 5,52μm

Taking into account reducing of diameter when disassembling: γ_{dis} = 10μm;

γ_t=0, because coefficient of temperature extension of the shaft and the sleeve diameter is equal (material is the same (steel 40X)).

Then $[N_{min}]$ = 128 + 5,52 +10 + 0 = 143 μm ~~24,02 ≈ 24μm~~

4) Determining the maximum permissible pressure, in which there is no plastic deformation on the contact surfaces of the parts. As $[P_{max}]$ we take the smaller of the two values:

For shaft: $P_1 = 0,58*\sigma_{TI}*\left[1-\left(\frac{d_1}{d_{HC}}\right)^2\right]=0,58*38*10^8*\left[1-\left(\frac{30}{60}\right)^2\right]= 16,53*10^8$ N/m^2;

For sleeve: $P_2 = 0,58*\sigma_{TI}*\left[1-\left(\frac{d_{HC}}{d_2}\right)^2\right]=0,58*38*10^8*\left[1-\left(\frac{60}{75}\right)^2\right]=7,93*10^8$ N/m^2;

We choose $[P_{max}] = 7,93*10^8$N/m^2

5) Defining the maximum value of the calculated interference N_{max}:

$N^l_{max} = [P_{max}]*d_{HC}*\left(\frac{C_1}{E_1}+\frac{C_2}{E_2}\right) = 7,93*10^8*0,060*\frac{1,36+4,85}{2*10^{11}}$ = ~~$3,5*10^{-4}$ m~~ =$1,477\times10^{-3}$ m=1500 μm

Defining the maximum value of the calculated interference taking adjustment into account:

$N_{max} = N'_{max}*\gamma_p + \gamma_r$

Where,

γ_p– Enlargement of the specific pressure at the face end of the sleeve. We take γ_p= 0,93.

~~$[N_{max}]$ = 350*0,93+5,52 = 331,02μm ≈ 331μm~~

$[N_{max}]$ = 1500*0,93+5,52 = 1400,52μm ≈ 1400 μm.

6) Choosing a fit from the given data $[N_{min}]$= 143 μm; $[N_{max}]$= 1400 μm; d_{HC}=60mm.

[Choosing a fit from the given data $[N_{min}]$= ~~34~~μm; $[N_{max}]$= ~~331~~μm; d_{HC}=60mm

We choose the fit $\frac{H7}{u7}\left(\frac{+0,030}{\frac{+0,117}{+0,087}}\right)$, for which

$N_{max} = 117\mu m < [N_{max}] =$ ~~331~~ μm;

$N_{min} = 57\mu m > [N_{min}] =$ ~~34~~]

Safety coefficient of the joint:

N_{min}–$[N_{min}]$ = 57–34 = 23μm

Safety coefficient of the parts:

$[N_{max}]$–N_{max} = 140–117 = 23μm

Defining the conditions of press-fit:

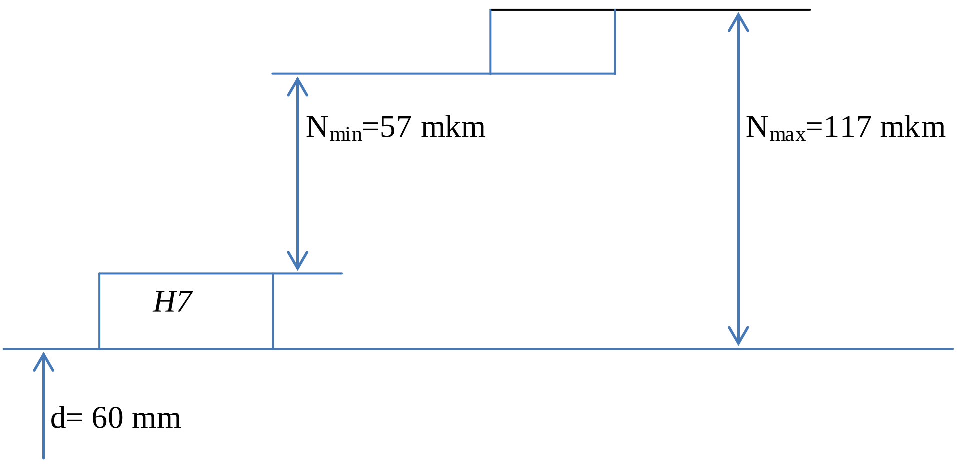
$R_n = f_n*P_{max}*\pi*d*l$, where

f_n = 1,2f = 1,2*0,08 = 0,096 – coefficient of friction during press-fitting

$$P_{max} = \frac{N_{max}-\gamma_{ш}}{d_{HC}\left(\frac{C_1}{E_1}+\frac{C_2}{E_2}\right)} = \frac{(117-5,52)*10^{-6}}{0,060*\left(\frac{1,36+4,85}{2*10^{11}}\right)} \approx 5,9*10^7 \text{ N/m}^2$$

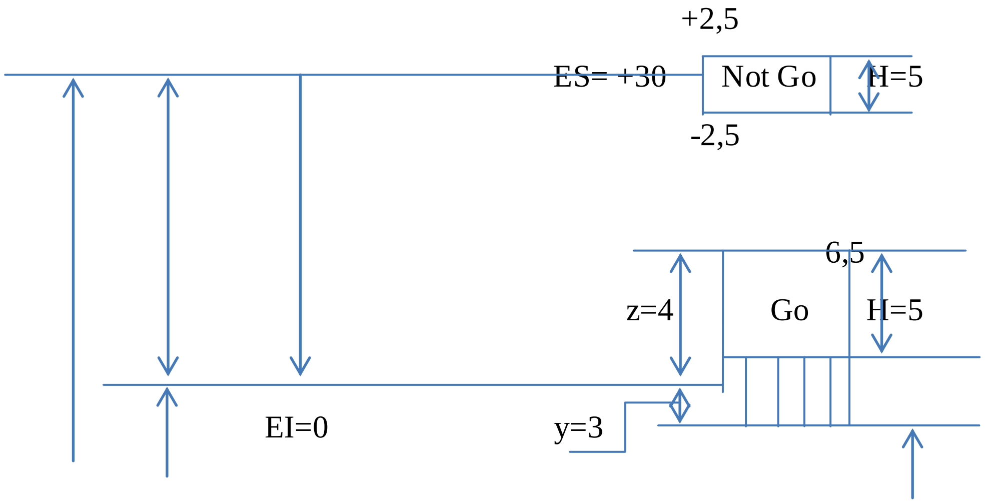
~~Specific pressure~~ Axial force of press at N_{max}

$R_{axial} = 0,096*5,9*10^7*3,14*0,060*0,080 = 5,3*10^3$N ≈ 5 tons



Tolerance zones of the ~~coupled details~~ limit gages.

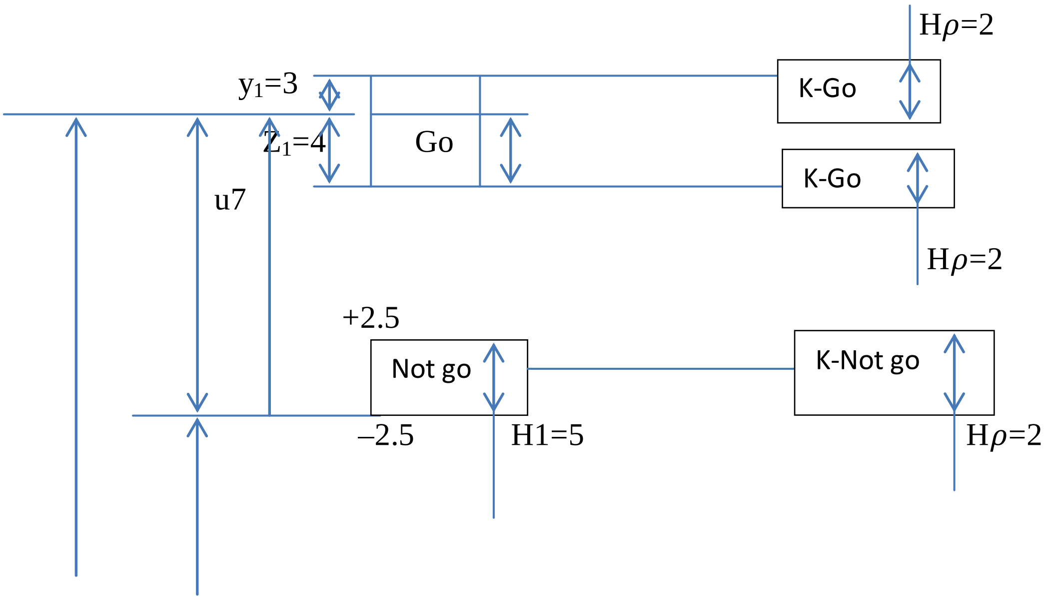
Hole Ø60H7 H=5; y=3; z=4



Ø60H7Not — 60,030 ± 0,0025 — 60,0325 $_{-0,005}$ mm

Ø60H7Go — 60,000$^{+0,0065}_{+0,0015}$ 60,0065$_{-0,005}$mm

Shaft Ø60u7 H_1=5, H_p=2, y_1=3, z_1=4



Ø60u7Not go	60,057±0,0025	60,0845$^{+0,005}$mm
Ø60u7Go	60,117$^{-0,0015}_{-0,0065}$	60,1105$^{+0,003}$mm
Ø60u7K–Not go	60,087±0,001	60,088$_{-0,002}$mm
Ø60u7K–Go	60,113±0,001	60,114$_{-0,002}$mm
Ø60u7K–Go	60,120±0,001	60,121$_{-0,002}$mm

2. ASSIGNMENT OF CONTROLLED PARAMETERS OF GEAR

Data:

Table 2:

1	Module, MM	M	2,5
2	Teeth No.	Z_1	40
3	Teeth No.	Z_2	80
4	center distance	A_W	150
5	width of gear	B	25
6	d_5,MM		50
7	d_8,MM		64
8	accuracy of manufacturing of gear		8–7–7–B
9	Assignment of reducer		Automotive

8–degree of accuracy on norms of kinematic accuracy

7–degree of accuracy on norms of smoothness of work

7–degree of accuracy on norms of teeth contact

B–type of interface

Controlled parameters of a gear are: kinematic accuracy, smoothness of work, completeness of contact. The control of kinematic accuracy includes: the verification of kinematic error in a single profiled engagement, cumulative pitch error, and radial run-out of the ring gear. The control of the smoothness of work includes the measurement of the local kinematic errors, deviations and errors of step profile. The control of complete contact includes measurements of total contact area, the axial step directions tooth error.

Controlled parameters of a gear

Table 3.

Controlled Parameter	Tolerance, MM		Type of Instrument
	Z1=40	Z2=80	18 20 БВ–5033 БВ–5053,БВ–50360 БВ–936, УКМ–5 and others
Control of kinematic Accuracy			
kinematic error in a single profiled engagement	74	103	18 20 БВ–5033 БВ–5053,БВ–50360 БВ–936, УКМ–5 and others
radial run-out of the ring gear	45	63	25 36 25003, Б–10М, БВ–5015,БВ–5050,БВ–5060,БВ–5061
Control of the smoothness of work			
Tolerance on the local kinematic errors	25	30	БВ–5024, БВ–5053 and others ШМ–1, БВ–5079. КЭУМ, БВ–5057, БВ–5062, БВ–5078 and others
Deviations of step ±			
Error of profile			
Control of complete contact			
total contact area: –along the length of the tooth not less than –along the height of the tooth not less than	 60% 45%		control-flow forming of machines and equipment

3. CALCULATION OF DIMENSIONAL CHAIN

Basic data:

A_1=33 mm

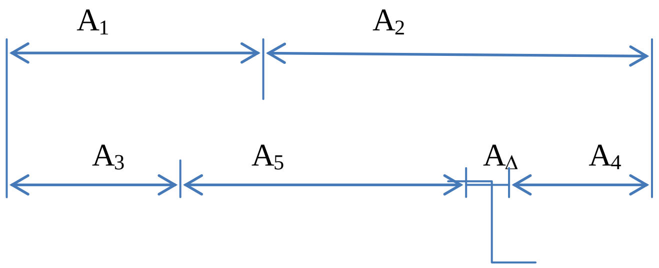
A_2=40 mm

A_3=8 mm

A_4= A_3= 8 mm

A_5=56 mm

$A_0=1\pm0{,}7$ mm



We define the character of the links of the chain:

A_1, A_2 – increasing links (sizes);

A_3, A_4, A_5 – decreasing links (sizes).

3.1. Calculation of the dimensional chain is carried out with the method of complete interchangeability. This calculation is carried out by the method described in (3 pg. 23).

We have the nominal value of the tolerance of the closing link T_{A0}=1,4 mm

$$T_{A_0} = \sum_{i=1}^{5n} T_{A_i}$$

We find the coefficient of accuracy of the producing link:

$$a_n=\frac{T_{A_0}}{\sum_{i=1}^{5n} i_n} = \frac{1400}{1{,}56+1{,}56+0{,}9+1{,}86+0{,}9} = 206{,}5$$

Where,

I_{Ai}–value of unit of tolerance for the dimensions: A_1, A_2, A_3, A_4, A_5.

According to table 1.8 (2 Pg.45) we find that values of unit tolerances like these exist, for example the 13-th quality equals 250.

Defining the tolerance according to the 13-th quality.

T_{A1}=0,39

T_{A2}=0,39

T_{A3}=0,22

Assigning the deviation to all links apart from A_4:

A_1=33±0,195

A_2=40±0,195

A_3=8-0,22

A_4=8-0,22

Calculating the lower deviation of link A_5

$\Delta^{B}_{A_0} = (\Delta^{B}_{A1} + \Delta^{B}_{A2}) - (\Delta^{H}_{A3} + \Delta^{H}_{A4} + \Delta^{B}_{A3})$

+0,7=(+0,195 + 0,195) – ((0,22) + Δ^{H}_{A4} + (–0,22))

Δ^{H}_{A4}= –0,7 + 0,83= +0,13

Calculating the upper deviation of link A_4

$\Delta^{B}_{A_0} = (\Delta^{H}_{A1} + \Delta^{H}_{A2}) - (\Delta^{B}_{A3} + \Delta^{B}_{A4} + \Delta^{B}_{A3})$

–0,7=(–0,195–0,195)–(0 + Δ^{B}_{A4} + 0)

Δ^{B}_{A4}=0,7–0,39=0,31

Finding the tolerance A_4

Δ^{B}_{A4}–Δ^{H}_{A4}=+0,31–0,13=0,18

Verifying:

T_{A1}+ T_{A2} + T_{A3} + T_{A4} + T_{A3}=0,39 + 0,39 + 0,22 +),22 + 0,18=1,4 mm =T_{A0}

Accepted dimensions of links:

A_1=33±0,195

A_2=40±0,195

A_3=8–0,22

$A_4=56^{+0,31}_{+0,13}$

4. TOLERANCE ZONES OF PAIRING SHAFT AND ANTI-FRICTION BEARING

Basic data:

Internal diameter of bearing d_6=55 mm

External diameter of bearing D_1=90 mm

Class of accuracy of bearing P_5,

Width of bearing B=18 mm

Fit along–D_1–G7,

Fit along d_6–h6.

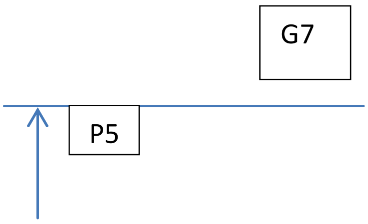
According to GOST, the bearing is N111

Determining the deviations of the dimension of the internal and external diameters of the bearing of class of accuracy P_5.

$$\varnothing 55^{0}_{-0,009}$$

$$\varnothing 90^{0}_{-0,010}$$

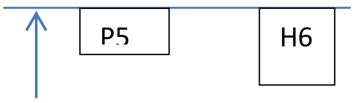
Tolerance zone for outer (external) ring P5 → p5 (**hole** diameter of the body (case) G7):



Location of the maximum deviation of the outer ring of the bearing and hole in the case.

Guaranteed clearance 12μm.

Tolerance zone for internal ring P5 (diameter **of shaft** H6 → h6):



Location of the maximum deviation of the inner ring of the bearing and shaft.

Maximum ~~interference~~ clearance 9 μm

Minimum interference 19 μm

Tolerance on the dimension of the hole: T_D=9-0=9 μm

Tolerance on the dimension of the shaft: T_d=19-0=19 μm

Determining the average quadratic deviation of interference

$$\delta_r = \frac{1}{6} * \sqrt{T_D^2 + T_d^2} = \frac{1}{6} * \sqrt{19^2 + 9^2} \approx 3{,}5$$

Medium interference $N_m = m_d - m_D$ = (-9,5) – (-4,5) = - 5 μm.

Determining the limit of integration

$Z = \frac{N_m}{\delta_r} = -\frac{5}{3,5} \approx -1,43.$

Using the table, we find the value of the integration of probability when z= –1,43

$F_{(1,43)}$= –0,4236

Because z<0 we find

Probability of ~~interference~~ clearance P'_S=0,5–F_Z=0,5–0,4236=0,0764;

Probability of ~~clearance~~ interference P'_N=0,5+0,4236=0,9236.

Consequently, during assembly 92,36% of all connection will be with ~~clearance~~ interference and 7,64% with ~~interference~~ clearance.

Fit of the external ring of the bearing provides the guarantee of a minimum clearance, which facilitates the mounting of bearings into the case but in the absence of axial tightening external clips during work.

5. SPLINED JOINT

Basic data:

Centered diameter D; No. of splines 8; Internal diameter d=56 mm,

External diameter D=65mm; Width of the spline b=10 mm; Fit of centered diameter-D H7/g6;

Fit along the width of spline b F8/h6

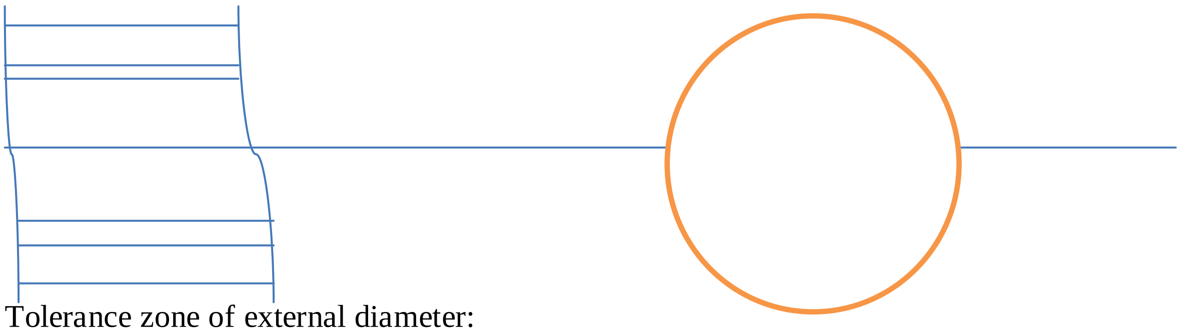
Tolerance along the diameter d when centered along the diameter D standard is undefined, but diameter d must not be less than d1 (groove to release the grinding wheel), that corresponds to approximately h17; tolerance on the hole H11.

Designation:

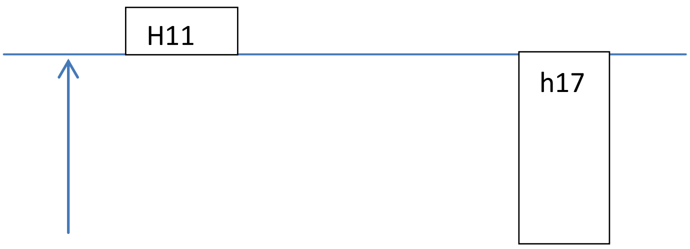
–spline connection $D–8 \times 56\frac{H11}{h17} \times 65\frac{H7}{g6} \times 10\frac{F8}{h6}$

–spline shaft D–8 × 56h17 × 65g6 × 10h6

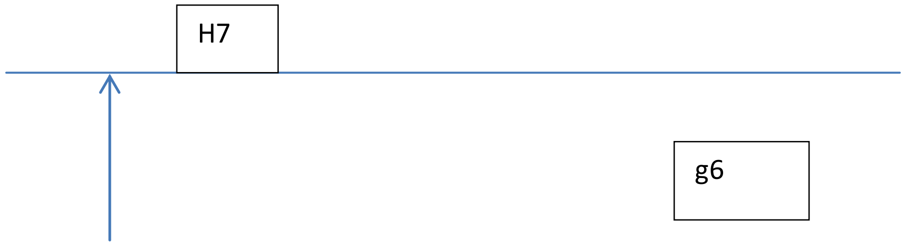
–spline hole D–8 × 56H11 × 65H7 × 10F8



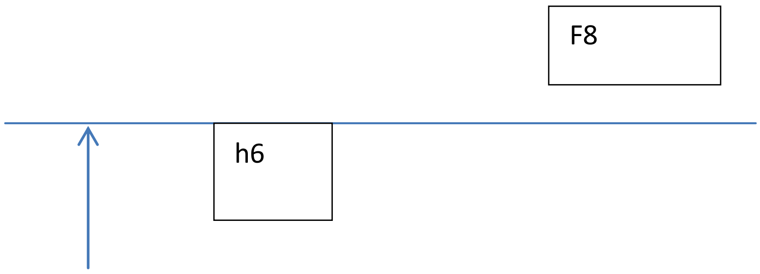
Tolerance zone of external diameter:



Tolerance zone of internal diameter:



Tolerance zone of width of spline:



Control of the spline joint is a complex multilayered gauge.

6. KEY FIT

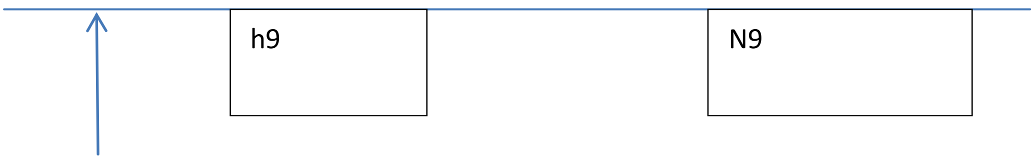
Basic data:

d_7=50 mm; b_1=14 mm; h=9 mm; l_3=82 mm; b_2=10 mm; h_1=8 mm; l_4=82 mm; l_5=110 mm

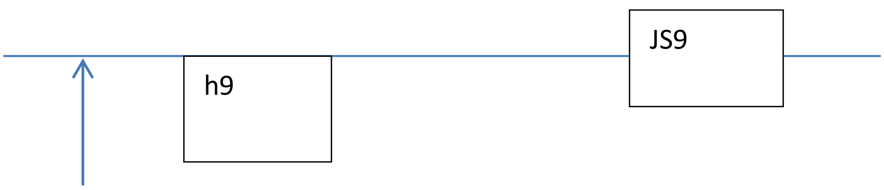
Tolerance zone and quality of shaft d_7–J_S7; Fit of key in the groove of the shaft $\frac{N9}{h9}$

For the groove of sleeve of the connecting element, we assign fit $\frac{J_S9}{h9}$ based on the recommendation of GOST 26360(1 pg. 206).

Key joint for the **<u>shaft</u> groove**:



Key joint for the **<u>sleeve</u> groove**:



Control of key joint:

–width of groove of shaft and sleeve plates with sides Go and Not go.

–dimension $53,8^{+0,2}$: cap keyed with steps Go and Not go.

–dimension $44,5_{-0,2}$ ring caliber with steps Go and Not go.

–symmetry of grooves relative to axial plane complex gauge:

7. THREADED CONNECTION

Basic data:

Diameter of thread M24 × 1; Fit of thread $\frac{5H6H}{7e6e}$

Nut

Tolerance zone of the median diameter D_2–5H

Tolerance zone of the internal diameter D_1–6H

Bolt

Tolerance zone of the median diameter d_2–7e

Tolerance zone of the internal diameter d_1–6e

Nominal value of diameters and step threads

d(D)=24;p=1

$d_2=D_2=24-1+0,350=23,35$

$d_1=D_1=24-2+0,917=22,917$

Limit of deviation for bolts:

$d_{2max}=23,35-0,06=23,29(es=60\ \mu m)$

$d_{2max}=23,35-0,22=23,13(ei=220\ \mu m)$

$d_{max}=24-0,06=23,94(es=60\ \mu m)$

$d_{min}=22,917-0,06=22,857(es=60\ \mu m)$

$d_1$min not specified

Limit of deviation for nut:

$D_{2max}=23,350+0,132=23,482(ES=132\ \mu m)$

$D_{2min}=D2=23,35(EI=0)$

$D_{1max}=22,917+0,236=23,153(ES=236\ \mu m)$

$D_{1min}=D122,917(EI=0)$

D_{max} not specified

$D_{min}=D=24(EI=0)$

8. TRANSITIONAL FIT (check ***below information*** your self **ettentively** for self-study work) (there are **mistakes**!!!)

Basic data:

D_5=50 mm

Fit based on the conditions of exploitation:

–accurate centered shaft.

–reduction of gear run-out.

–exclusion of non-rotating sleeve.

–possibility of disassembly etc.

Choosing the transitional fit d50$^{H7}/_{h6}\left(\frac{+0{,}025}{\frac{+0{,}033}{+0{,}017}}\right)$ → d50$^{H7}/_{n6}\left(\frac{+0{,}025}{\frac{+0{,}033}{+0{,}017}}\right)$

(fit $^{H7}/_{h6}$ *as* ***transition*** *fit is wrong*!!!)

Defining the probability of the obtained junction with interference and clearance:

Maximum interference N_{max}=33-0=33 μm

Minimum interference N_{min}=17-25=-8 μm

Medium interference N_m=$\frac{33+(-8)}{2}$ = 12,5 μm

Tolerance on the dimension of the hole T_D=25-0=25 μm

Tolerance on the dimension of the shaft t_d=33-17=16 μm

Determining the average quadratic deviation of the interference

$\delta_n=\frac{1}{6}\sqrt{T_D^2+T_d^2}=\frac{1}{6}\sqrt{25^2+16^2}=5\ \mu m$

Determining the limit of integration

$Z=\frac{N_m}{\delta_r}=\frac{12{,}5}{5}=2{,}5$

From the table, we find the value of the integral function of probability when z=2,5

F(2,5)=0,3938

Because z>0 finding

The probability of interference P_n'=0,5+F(z)=0,5+0,4938=0,9938

The probability of clearance P_S' =0,5-F(z)=0,5-0,4938=0,0062

Consequently, during assembly 99,38% of all junction will be with interference and 0,62% with clearance.

Tolerance zone of interference fit: