

Experimental Research of Assembly Features of Cylindrical Parts Set by Interference Fit

Oskars Lininsh¹, Zita Dreija², Natalija Mozga³, ¹⁻³Riga Technical University, Institute of Mechanical Engineering

Abstract – To design assembly automates for pressed parts the capacity of power needed for pressing-in shall be defined. Reserve of pressing power is necessary to provide the assembly of details with interference fit by pressing. The current method for calculation of the pressed part interference fit is not accurate enough considering that cylindrical details are a dimensional object; therefore, roughness parameters corresponding to real surface shall be defined. The demand for a more precise calculation method is facilitated by development and progress of mechanical engineering, which asks for more and more accurate equipment and resistant parts with high durability.

Keywords – friction, mathematical model, pressed parts, surface roughness.

I. INTRODUCTION

Pressing-in assembly of cylindrical parts set by interference fit in manufacturing of equipment is a frequently applied method of details assembly that accounts for about 35% of the total amount of the details assembly. Development of technologies in mechanical engineering and metal-working, in particular, the demand for higher accuracy in manufacturing of details for fields of mechanical engineering conditions the increasing use of such assemblies. Trajectory assembly movement of cylindrical parts is rather simple. It provides possibility to get such parts in assembly automates.

One of the most labour-consuming stages of the assembly process in assembly automates aimed at obtaining the mating of cylindrical parts of the required quality is provision of the correct orienting and location of assembly details in the position of assembly. Researches on the accuracy of mutual orientation of cylindrical details and safety of the technological process of assembly have been performed by several authors: A. Rabinovich, K. Mucenieks, Fr. Sudnieks, A.Malov, V. Kosilov, M. Novikov, and N. Gusejnova [1-3]. Researches prove that pressing-in with vibration impulses increases the strength of connections in comparison to regular pressing-in (in press). However, this method is less effective due to reduction of the surface roughness of mating details in the course of pressing of details. Analysis of literature demonstrates that notwithstanding the existing research, condition of automatic assembly of cylindrical parts set by interference fit defining admissible allowance in assembly of details is insufficiently researched. The reviewed works have not considered the parameters of surface roughness Ra and Sm , which affect the process of assembly substantially.

The results of research of the assembly process obtained in work [4] and the developed method of engineering calculations for cylindrical parts set by interference fit may be useful for

professionals in the field of mechanical engineering manufacture related to elaboration of assembly process technology and design of equipment in a specific production unit. The abovementioned method of engineering calculations is developed based on the contact model of 3D regular case field theory of two rough surfaces, which allows viewing the contacting process of the pressed connections with interference in a new perspective by defining roughness parameters corresponding to the real surface. Application of the elaborated coherences allows defining the capacity needed for pressing and parameters of surface roughness for mating at definite conditions more precisely, which is approved by the results obtained in the experiment. It is possible to determine the needed proportion of surface roughness parameters Ra and Sm that is not included in the previously-known calculation methods of mating interference fit.

II. METHOD AND EXAMPLE OF ENGINEERING CALCULATION OF INTERFERENCE FIT FOR CYLINDRICAL PARTS

Calculation schema of interference fit is given in Figure 1.

The new method and example of engineering calculations of interference fit is provided below.

Source data: nominal diameter of connection $d=15$ mm, external diameter of the bush $D=50$ mm, length of connection contact $l=20$ mm. The spindle and the bush are made of the same material S355J2G3, where: $E=2 \cdot 10^5$ MPa, $\mu=0,3$.

By calculations, values of minimal interference following [5] method and the developed method providing the reduced value were obtained. By satisfying conditions of connection strength at axial force $Fa=2$ kN, the minimal interference is $\delta_{min v}=7 \mu\text{m}$ [5]; and in accordance with developed method: $\delta_{min j}=9,5 \mu\text{m}$.

TABLE I

COMPARISON OF ENGINEERING CALCULATIONS FOR CYLINDRICAL PARTS SET WITH INTERFERENCE FIT

Interference $\delta_{maxj}, \mu\text{m}$	$Sm/ Ra, \mu\text{m}$	Contact load p_j, MPa	Interference [2] $\delta_{maxv}, \mu\text{m}$	$Ra, \mu\text{m}$	Contact load p_v, MPa
30.2	100/1.25	186	31.3	1.25	186
27		169	28.6		169
24		145	25		145

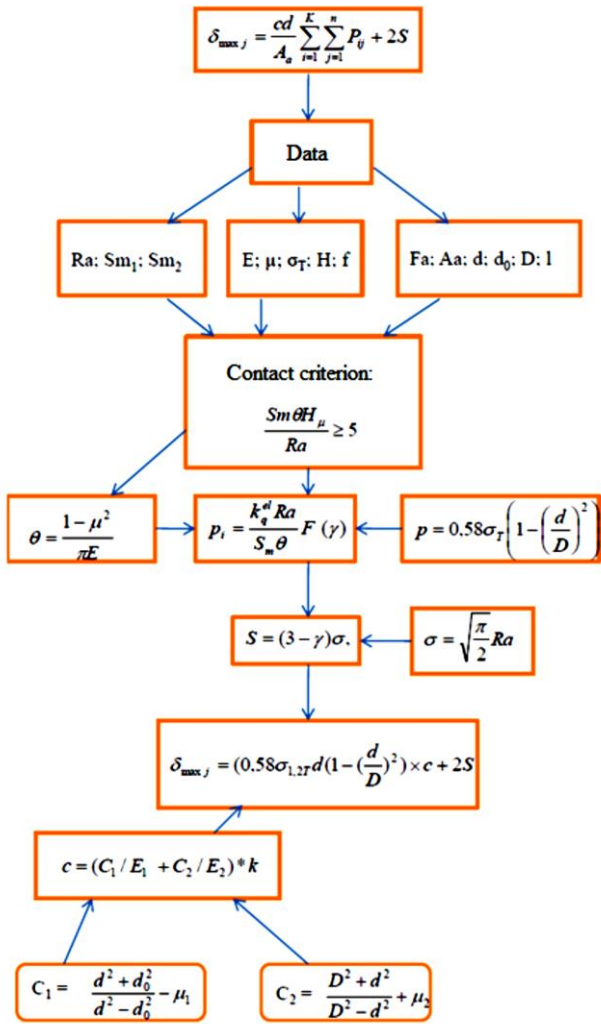


Fig.1. Calculation schema of interference fit.

In Table I the results of calculations for cylindrical parts set with interference fit are summarized. At equal loads, interference calculated by the method of S. P. Timoshenko is a little higher. Difference in results is explained by the following:

1) By approximation dimensions of the contacting surfaces. In accordance with the method of Timoshenko, it is 1.5 times bigger. In the second case, approximation of surfaces is calculated by formula [5], where relative level of deformation of the surface roughness, until which the roughness is deformed, is defined. It depends on the pressure in contact and surface roughness parameters Ra and Sm as well as material properties E and μ ;

2) In the developed method for calculation of interference fit, surface roughness proportion Ra/Sm is included, which was not considered in the method of S. P. Timoshenko and which is an important value characterizing the roughness of the surface profile and deformation type of contact of rough surfaces. This proportion characterizes also the choice of the needed type of processing. As more accurate processing technologies have entered modern manufacture, they permit obtaining the details with desirable surface roughness parameters. In addition, the method of engineering calculation for cylindrical parts set with

interference fit offered in this article allows defining the proportion of Ra/Sm needed for definite requirements of mate. Characterizing values of contact: load, approximation of surfaces, and dimension of interference depend not only on a separately taken surface roughness parameter Ra but also on the step parameter Sm and their proportion.

The abovementioned confirms that the developed method for calculation of interference provides more accurate and more realistic calculation results in comparison with method [6-8]. The demand for a more accurate method of calculation is facilitated by development and progress of mechanical engineering, which demands manufacturing of more and more accurate equipment and resistant parts with high durability.

III. EXPERIMENTAL RESEARCH

Here the experimental research of changes in geometric dimensions and surface roughness of cylindrical parts (Fig.2) set by interference fit in the process of assembly is presented.

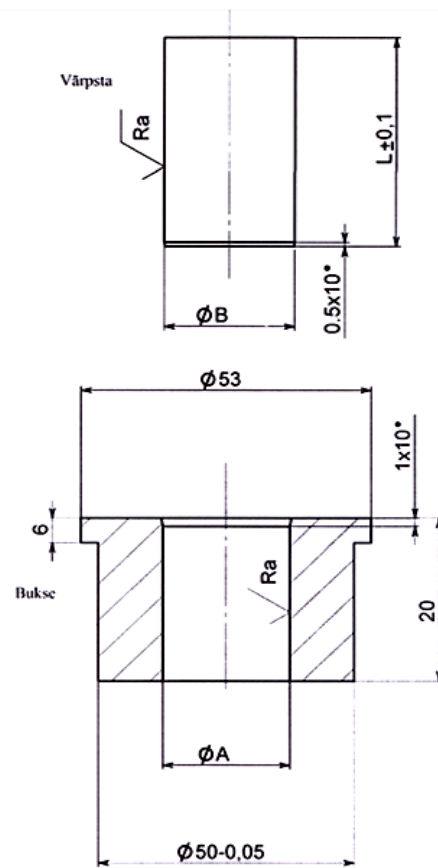


Fig. 2. Samples for experiments.

The aim of the experiment is to test the developed method of engineering calculations for interference fit with results obtained in praxis. For the experiment, 15 samples from different materials and with different dimensions of details were prepared. To define the parameters of the surface roughness profile before assembly and after it, Taylor Hobson surface measurement unit Taylor Hobson Form Talysurf Intra 50 was applied, which allows viewing the surface roughness as

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a 3D model (Table II). For every experiment, 3 measurements in different sections were made; thus providing conformity of measurement track bases. The average result was accepted as the result of measurements.

Figures 3 and 4 show the profiles of experiment sample 1-20B obtained applying this unit.

The results of geometric dimensions and surface roughness [9] of cylindrical details with interference obtained in the experiment are summarized in Table III. The specific experimental sample 1-20B shown in Figures 3 and 4 has the initial average arithmetical deviation of surface roughness 2,89 μm while after pressing – 0,98 μm (-67 %). Meanwhile, the spindle of the same sample 1-d20 has initial deviation 1.17 μm and after pressing – 0.43 μm (-63 %). Obviously, the changes in the roughness of the bush are bigger. The value of the surface roughness smoothing of every sample was impacted by different factors: deviations of detail forms, material, geometric accuracy, and assembly failures.

TABLE II

PARAMETERS OF SURFACE ROUGHNESS PROFILE OF THE ASSEMBLED DETAILS BEFORE AND AFTER PRESSING

	$\varnothing d$ un $\varnothing D$, mm no virzės	L, mm	E, Mpa	μ	Ra, μm Before pressing	Ra, μm after pressing	S _{m1} , μm	S _{m2} , μm
Spindele, $\varnothing d$								
1-d12	0,038	10	(Material: S3355)	0,29	1,205	0,62	67	37
2-d12	0,038	10			1,45	0,75	65	36
3-d12	0,037	20			1,52	0,64	60	33
4-d12	0,029	20	2*10 ⁵		1,46	0,72	68	38
5-d12	0,032	25			1,27	0,617	62	35
Bush, $\varnothing d$								
1-d12 BM	0,002	20	(Material: S3355)	0,33	1,09	0,3	90	72
2-d12 BM	0,0015				1,12	0,25	91	73
3-d12 BM	0,002				0,8	0,19	85	62
4-d12 BM	0,0015		1,05*10 ⁵		0,74	0,15	89	60
5-d12 BM	0,002				1,11	0,2	93	70
Spindele, $\varnothing d$								
1-d15	0,037	20	(Material: S3355)	0,29	3,52	1,52	110	80
2-d15	0,036	20			3,65	1,58	100	79
3-d15	0,039	20			3,25	1,43	112	85
4-d15	0,038	20	2*10 ⁵		3,15	1,32	105	73
5-d15	0,037	20			3,36	1,15	102	76
Bush, $\varnothing d$								
1-d15 B	0,003	20	(Material: S3355)	0,29	4,23	3,98	97	69
2-d15 B	0,002				4,33	4,05	102	82
3-d15 B	0,003				3,67	3,52	100	96
4-d15 B	0,001		2*10 ⁵		4,26	4,02	105	82
5-d15 B	0,002				3,63	3,49	98	65
Spindele, $\varnothing d$								
1-d20	0,04	10	(Material: S3355)	0,29	3,28	1,23	78	52
2-d20	0,039	10			3,02	1,19	85	55
3-d20	0,042	20			3,12	1,25	79	63
4-d20	0,041	20	2*10 ⁵		3,21	1,33	87	69
5-d20	0,0395	25			2,98	1,06	84	70
Bush, $\varnothing d$								
1-d20 B	0,001	20	(Material: S3355)	0,29	5,21	4,52	150	100
2-d20 B	0,0015				5,29	4,35	155	110
3-d20 B	0,002				5,05	4,29	162	120
4-d20 B	0,002		2*10 ⁵		5,25	4,43	167	134
5-d20 B	0,001				5,28	4,16	158	125

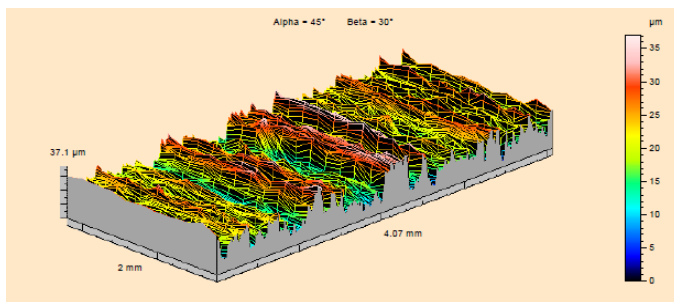


Fig. 3. Bend-cleared dimensional figure of the surface of sample 1-20B before pressing (It is turned for 45° around vertical axes and for 30° against axes x and y).

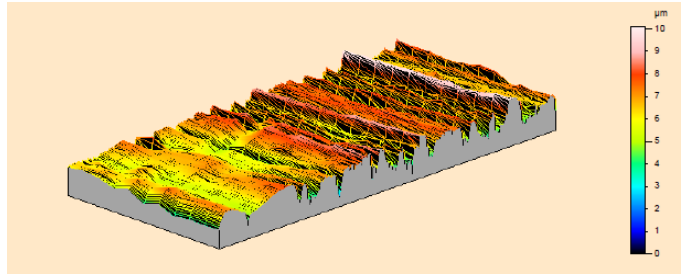


Fig. 4. Bend-cleared dimensional figure of the surface of sample 1-20B after pressing (It is turned for 45° around vertical axes and for 30° against axes x and y).

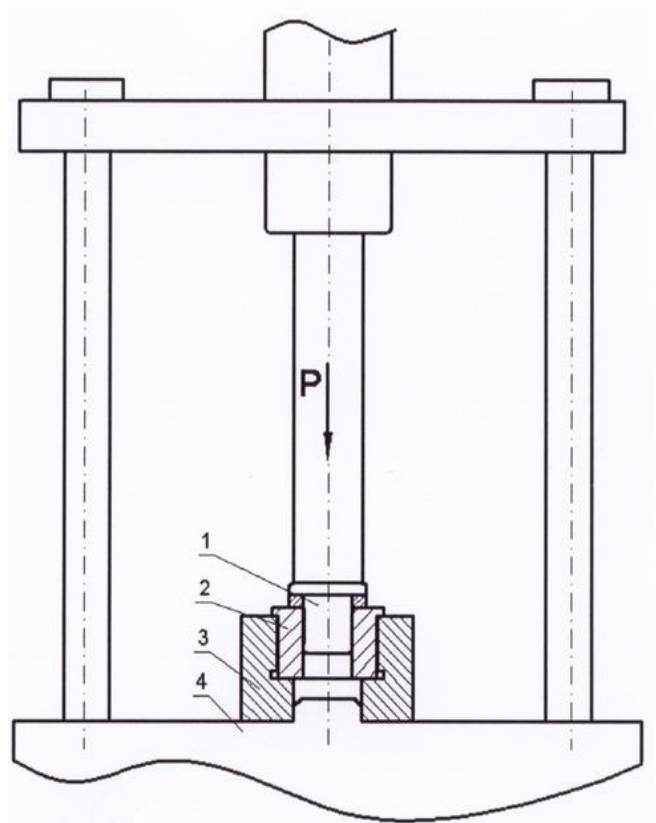


Fig. 5. Scheme of equipment ZwickZ100 (1 – spindle, 2 – bush, 3 – based detail's extra equipment, 4 – frame).

Experiment of mating durability was performed to 5 parties after assembly for about 24 hours on equipment ZwickZ100 (Fig. 5) designed for testing of static loads of electromechanical details with maximal load up to 100 kN. In the process of research, maximal force of pressing P was stated; and it corresponds to the beginning of spindle transfer. The obtained data of the experiment were used as source data for defining the value of interference by the new method and by the method of S. P. Timoshenko. Afterwards, the calculated interferences will be compared with the value of interference obtained in praxis (Tables III, IV). Details produced for the experiment conformed by main values of the chosen field of allowances. Therefore, comparing by values of the maximal interference is possible.

TABLE III

ROUGHNESS PARAMETERS OF CONTACTING SURFACES

Group Nr.	Detail	Ra, μm	S _{m1} , μm	S _{m2} , μm
1.	Spindle	1,52	110	80
	Bush	1,58	100	79
2.	Spindle	1,43	112	85
	Bush	1,32	105	73
3.	Spindle	1,15	102	76
	Bush	3,98	97	69
4.	Spindle	4,05	102	82
	Bush	3,52	100	96
5.	Spindle	4,02	105	82
	Bush	3,49	98	65

TABLE IV

COMPARISON OF INTERFERENCE VALUE WITH CALCULATED ONE AND THE ONE OBTAINED IN PRACTICE

Batch No.	Experimental P, kN	$\delta_{\text{max}}, \mu\text{m}$		
		Developed method	Method of S.P.Timoshenko	Measured
1.	15,5	35,8	39,5	34
2.	15,8	36,4	40,1	35
3.	15,9	37,5	41,3	36
4.	16,1	38,2	41,9	37
5.	16,5	38,5	42	37,5

Friction coefficient in connections with interference reduces by increase of pressure in contact and depends on the roughness parameters of contacting surfaces, direction of processing tracks, and materials of details. Currently, there are no such mathematic expressions, which include the impact of the above mentioned factors on the friction coefficient. These conditions exclude the possibility to prognosticate the value of the friction coefficient and to choose the combination of such connection parameters, which provide the needed durability of the connection. It makes to use experimentally obtained friction coefficients in calculations of the pressing force. Load in contact is defined by the equation $p = P/fA_a$, where it is presumed that the friction coefficient $f=0.08$. Interference calculated by the method of S. P. Timoshenko exceeds the one obtained in experiment by ~ 16% (Table III).

Meanwhile, the interference found following the new method is closer to the value obtained in praxis. Such difference in results can be explained: first, by having the friction coefficient presumed. Second, approximation of micro-roughness exceeds the approximation by the developed method by more than 1.5 times.

Data in Tables III and IV attest a better conformity of the new method to the praxis.

IV. CONCLUSIONS

An experiment was conducted with an aim to compare the interference obtained in the experiment with the calculated one, by the developed method of engineering calculations for cylindrical parts set by interference fit; and conclusions were provided. For the measurements of roughness of contact surfaces, surface measurement unit Taylor Hobson Form Talysurf Intra 50 was applied. For checking of mate durability, electromagnetic unit ZwickZ100 for testing of static load of details was used. It was proven that results of the experiment

have a better compatibility to the developed method in comparison to the method of S. P. Timoshenko, which gives smaller values of durability of details. Interference calculated by the method of S. P. Timoshenko is in average by ~ 16 % higher than the one obtained in the experiment. Meanwhile, the interference found by the developed method conforms to the value obtained in the praxis better. The data obtained in the experiment attest that for more precise results of calculation, the proportion of surface roughness parameters Ra and Sm shall be considered. Values characterizing contact: load, approximation of surfaces, and interference depend not only on a separately taken surface roughness parameter Ra but also on the step parameter Sm and their proportion.

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Oskars Lininsh graduated from Riga Polytechnic Institute (now RTU) in 1965, where he got an engineering degree in production technology. He obtained a PhD Engineering Degree in the field of friction and wear in machines at RTU in 1992.

His scientific work started in 1966, when he worked as an assistant at Riga Polytechnic Institute. From 1970 the author started his pedagogical work and since 1973 he continued as a professor assistant in Riga Technical University. In 2001 he was elected associate professor and in 2008 – a professor at RTU Institute of Machine Building. At the same time he worked as the Secretary of Science in the Commission of Production Technology and currently he is the Secretary of the Council of the Faculty of Transport and Mechanical Engineering

The main research fields are calculations of friction and wear in machines and design of apparatuses.

Zita Dreija graduated from Riga Technical University in 2004, where she got a Master of Science Degree in Mechanical Engineering (M.Sc.ing.). She obtained Doctor of Machine Science (Dr.sc.ing.) at Riga Technical University in 2012.

Main research results and developments are presented in the published scientific articles:

1. Dreija Z., Sudnieks Fr., Lininsh O. Deformation of parts with thin walls in assembly process// In: Proceedings of the 50.Internationales Wissenschaftliches Kolloquium, ISBN 3-932633-98-9.- Ilmenau, 2005.- September 19-23, 539.-541. p.
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Natalija Mozga graduated from Riga Technical University in 1994, where she obtained a Bachelor's Degree in Engineering Mechanics. In 1995 she received the Qualification of Mechanical Engineer, in 1997 she obtained Master of Science Degree in Mechanical Engineering (M.Sc.ing.), and in 2004 she

became Doctor of Machine Science (Dr.sc.ing.) at RTU. Since 2003 the author has been conducting her pedagogical work at Riga Technical University.

During a period of time from 2003 till 2012 she published 3 state level books and 12 local level (RTU) books and brochures.

The main field of research covers technological processes for assembly on rotary assembly machines.

Oskars Liniņš, Zita Dreija, Natālija Mozga. Cilindrisko detaļu mezglu ar uzspīlējumu salikšanas raksturojošo parametru eksperimentālā pētīšana

Lai projektētu salikšanas automātu presētiem savienojumiem, jāzina iepresēšanai nepieciešamā spēka lielumu. Detaļu ar uzspīlējumu salikšanas nodrošināšanai, presējot nepieciešama presēšanas spēka rezerve. Pašreiz presēšanas spēka lieluma noteikšana saistīta ar grūtībām, jo tā ietver vairāku parametru noteikšanu, kam ir sarežģīts gadījuma raksturs. Piemēram, berzes koeficienta un saliekamo detaļu virsmas raupjuma parametru izmaiņas presēšanas procesā, kā arī kontakta slodzes noteikšana ir atkarīga no uzspīlējuma. Pašreizējā presēto savienojumu sēžas ar uzspīlējumu aprēķina metode nav pietiekami precīza, ņemot vērā, ka cilindriskas detaļas ir telpisks objekts, tādēļ jādefinē reālajām virsmām atbilstoši raupjuma parametri. Lai raksturotu virsmas profila raupjumu, nepietiek ar vienu parametru Ra. Prasību pēc precīzākas aprēķinu metodes veicina mašīnbūves attīstība un progress, kas prasa izgatavot arvien precīzākas iekārtas, ilgturīgus detaļu mezglus ar lielu izturību. Šā raksta mērķis - veikt teorijas eksperimentālu pārbaudi un novērtēt teorijas un prakses atbilstību, kā arī salīdzināt eksperimentā iegūto uzspīlējumu ar aprēķināto, pēc izstrādātās salāgojuma sēžas ar uzspīlējuma inženieraprēķinu metodes, un izdarīt secinājumus.

Оскарс Линиņш, Зита Дрейя, Наталия Мозга. Экспериментальное исследование характерных сборочных параметров узлов цилиндрических деталей с натягом

Для проектирования сборочного автомата для прессованных соединений необходимо знать величину нагрузки, необходимой для запрессовки. При запрессовке для обеспечения сборки деталей с натягом необходим запас силы запрессовки. В данный момент определение силы запрессовки связано со сложностями, так как оно включает в себя определение различных параметров, у которых сложный случайный характер. Например, изменение коэффициента трения и параметров шероховатости поверхности соединяемых деталей в процессе запрессовки, а также определение контактной нагрузки, которая зависит от натяга. Существующая расчетная методика посадки с натягом прессованного соединения недостаточно точна, принимая во внимание то, что цилиндрические детали – это объемные объекты, и поэтому необходимо определять параметры шероховатости согласно реальным поверхностям. Для описания шероховатости профиля поверхности недостаточно одного параметра Ra. Потребности в более точной расчетной методике способствуют развитию и прогрессу в машиностроении, что требует все более точного оборудования и более выносливых узлов деталей с большим сроком эксплуатации. Цель данной статьи – провести экспериментальную проверку теории и оценить соответствие теории и практики, а так же сравнить натяг, полученный в эксперименте, с натягом, рассчитанным по инженерно-расчетной методике, и дать заключение.