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50. Internationales Wissenschaftliches Kolloquium
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Deformation of parts with thin walls in assembly process

Keywords: contact of parst with thin walls, surface roughness, stresses analysis

Labour productivity promotion of devices today increased its reliability claim to design new, more improved devices with higher quality production. Geometrical accuracy of details has a great influence, that is, dimensions and forms deviations, surfaces displacement-roughness.

Theses values affect strenght, hardness, assembled details'relative position accuracy in compression joints.

The details in many units of machines and devices are joined by interference fit. In general assembly of compression joint is connected to change details surface properties and frequently to demage one or several details units.

One of the assembly processes of compression joint is pressing. As a result of pressing is deformation of assembled details. Due to deformation arise normal pressers and friction forces, so that slip or movement does not occur between the mated surface during operation or under load. The value of pressure is accordingly dependent on deformation character. Both the parts may be with elastic deformation either one of them has an elastic deformation or elastic – plastic deformation.

It is necessary to evaluate the following details parametrs to guarantee successful unit assembly process:

- the shape of the component;
- the material from which the component is going to be made;
- the quality of the component; that is, the dimensional accuracy, the geometrical accuracy, and the surface finish;
- any heat- treatment processes, and any corrosion-resistant, wear- resistant, or decorative finishing processes.

A model of contact of parts with thin walls

The parts with thin walls have broad application in various types devices and more subjected to deformations arrised contacting two hard solids in the presence of friction.

Interference fit are playing the huge role in the assembly process. Load resistance in compression joints depends on interference. To much interference will cause distortion of the inner or outer assembly component. To arrive at a correct fit, such variables as the material ,the thickness of details and the thickness of details wall must be carefully considered.

Due to interference at the surface contact presser p arise , which depend on deformation's character of assembled details. Conditions for the deformation's character are given in tabule 1., where D, d_0 and d cm by figure 1; σ_{1T} un σ_{2T}- material surface tension parametrs.

The value of presser affects wear- resistance of assembled details. Besides arised tangential tensil stress and compressive stresses on the details surfaces promote reduction of wear.

Deformation's character	
Inner component	Outer compnent
Elastic	
$\frac{p}{0{,}58\sigma_{1T}} < \left[1-\left(\frac{d_0}{d}\right)^2\right]$	$\frac{p}{0{,}58\sigma_{2T}} < \left[1-\left(\frac{d_0}{D}\right)^2\right]$
Elastic-plastic	
$\frac{p}{0{,}58\sigma_{1T}} \geq \left[1-\left(\frac{d_0}{d}\right)^2\right]$	$\frac{p}{0{,}58\sigma_{2T}} \geq \left[1-\left(\frac{d}{D}\right)^2\right]$

Tab. 1. Deformation's character.

The actual interference is determined by nominal diameter of inner 1 (Fig.1) and outer components to taking no account surface micro asperity. Although due to the details surface micro cracks formation as the result of press reduced interferance and simultaneously specific presser as well. Therby a joint relaxtion can occur.

In laboratory experiments are determined that interference changes occur because of e_1 inner diameter and e_2 outer diameter reduction.

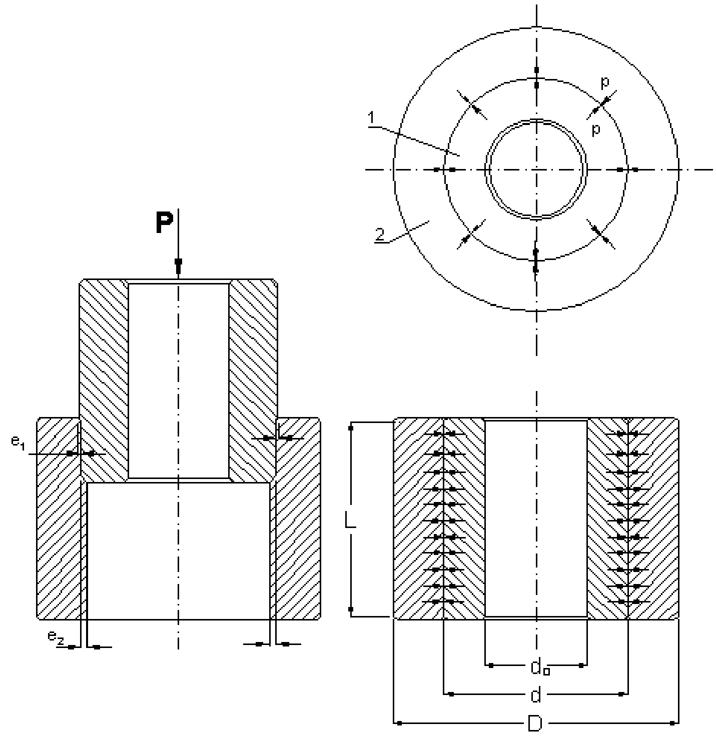

Fig. 1. Model of compression joint.

Hereto, if surface roughness of assembled details are equal and the material from which the components are going to be made are equal also then increase of inner diameter of outer component will be more then reduction of outer diameter of inner component.

It is necessary to know R_{z1} and R_{z2} – mean of surface asperity heights to determined interference taking into account micro asperyties . If difference between both details interference fit is Δd, then teoretical interference fit will be

$$\omega = \Delta d - k(R_{z1} + R_{z2}),$$

where k- coefficient, which depend from roughness. For mechanical pressing k=0,1 ... 0,2; for pressing by heating the detail k=0,6 ... 0,8.

It is necessary to determine a preesing and out-preesing load to make technology of assembly by guaranteed interference fit, because engineered units and devices for operation of assemble performance have theses parameters.

More pressing load P, which is needed for component assembly by guaranteed interference fit, can be found by

$$P = f_{pr}\pi p d L \ \text{kg},$$

where f_{pr} – friction coeficient;

p- specific presser on the surface contact, kg/mm^2;

d- inner component diameter, mm;

L- pressing length, mm.

The specific presser p on the surface contact

$$p= \frac{1}{d} * \frac{\omega 10^{-3}}{\left(\frac{C_1}{E_1}+\frac{C_2}{E_2}\right)},$$

where - ω teoretical interference, μk;

E_1 un E_2- elastic constant of assembled details materials;the values $C_1$and C_2 are found out to determined μ_1 and μ_2 –Puasson coeficients.

To get an out-pressing load use above existing formula, just replace f_{pr} with f_{outpr} friction coeficients.

Waviness of assembled details surfaces have essential importance to the pressing load which reduce the pressing load because the actual contact of mating surfaces reduced.

Automatic assembly process is connected to change of details location. The mistakes, which occures by pressing is frequently the reason of crack development or details relative position accuracy failure. Therefore, it is necessary to predict appropriate location mode of the details in assembly process.

Surface roughness

One of the most important quantities characterizing a normal functioning of a compression joint is surface roughness which determines the distribution of a normal and tangential forces within the contact area. The main portion of friction surfaces is formed by surfaces of irregular nature of roughess which in the process of wear within some contact micro volumes tend to create stresses varying in time. The variable stresses brought about by load some points of the surface layer may exceed a limit beyond wihich, within the material ander wear, a process of gradual accumulation of faults take place, which results in the formation of micro cracks, their growth and the separation of wear particles. The starting of micro cracks in the final analysis, will occur in those points of the material's surface layer, which would satisfy a destruction criterion which takes into account the value of stresses caused by elastic and plastic deformation as well as the properties of the contacting material.

The contact scheme in this case can be examined by geometric imposition of two random field $h_1(x,y)$ and $h_2(x,y)$, Fig.2,a.

The interference fit between the surfaces at any arbitrary chosen point is

$$\delta (x, y)= l-(h_1+h_2),$$

where l is the distance between the mean planes of contacting surfaces, the height of roughness asperity h(x, y) has a normal probability distribution.

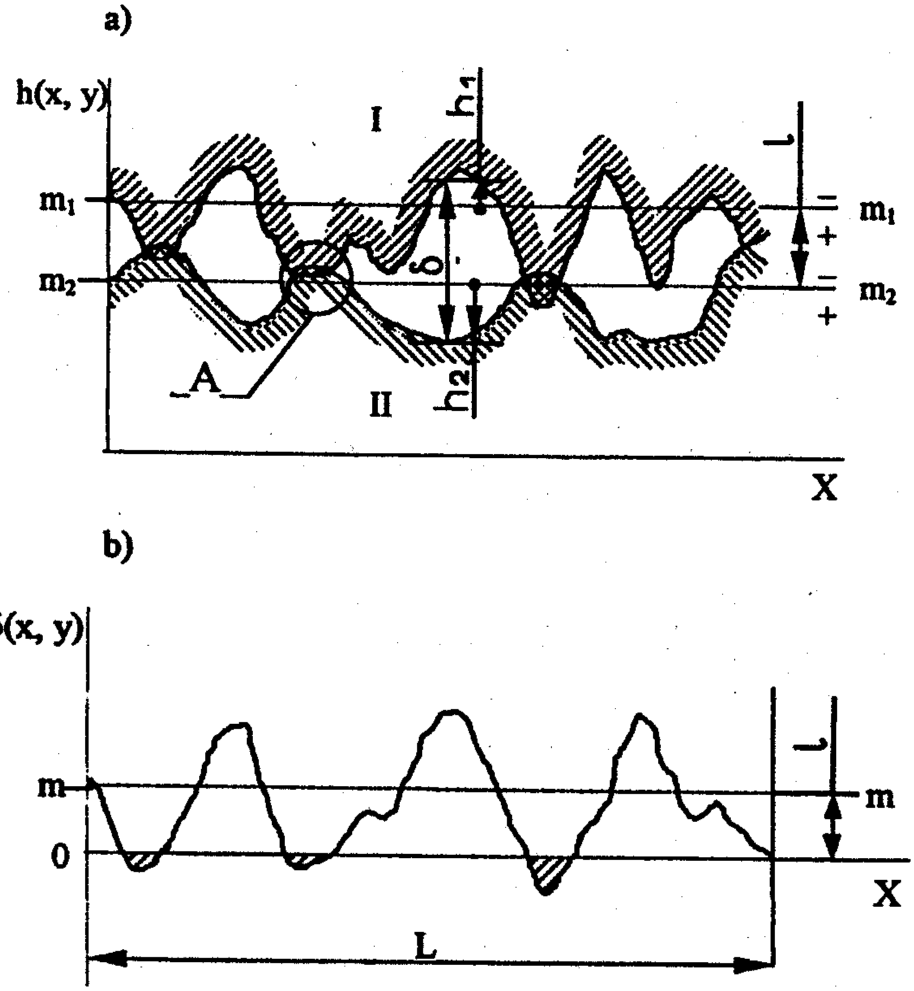

Fig.2. Schematic picture of contacting rough surfaces: (a) imposition of two rough surfaces; (b) variation of interference fit.

Mathemathical expectation of the random field δ(x, y) is

$$E\delta(x,y)=l,$$

and root-mean-square deviation

$$\sigma\{\delta\}=\left(\sigma^2\{h_1\}+\sigma^2\{h_2\}\right)^{1/2},$$

where $\sigma\{h_1\}$, $\sigma\{h_2\}$ - root-mean-square deviation of fields $h_1(x,y)$, $h_2(x,y)$.

Variation of the interference fit, as shown in figure 2(b), has negative values at places of surfaces contact. Thus on the basis of interference fit variation, we can examine the contact process of two rough surfaces.

The palstic contact area of two surfaces we can determine as area of field δ(x, y) section with zero plane and mathemathical expectation is

$$E\{\eta_l\}=1-\Phi(\aleph),$$

where $\aleph=\dfrac{l}{\sigma\{\delta\}}$.

The plastic flow of micro asperities occur when its deformation exceed some critical value a- critical interference of the surface. It can be calculated by the diference between two values of separation γ and γ_0 developed for two loads causing the deformation:

$$a = (\gamma_0 - \gamma)\sigma\text{'}$$

where σ- root mean square deviation of the field h(x, y).

As result of press arised the details surface micro asperities smoothing, therby a joint relaxtion can occur, that is undesirable. The value of micro asperities smoothing is dependent on assembled surfaces treatment and interference fit.

Stresses analysis with FEM

Stress analysis is used to ensure a component or assembly which achieves its expected life. In most of the cases, where the loads are applied many times, we often speak of durability and fatigue strength, the latter being a material property. Stress analysis calculations require materials data, component geometry and applied loads. These calculations attempt to determine a suitable structural design for a component. Engineering stress is fundamentally expressed as load divided by area, with SI units of Newtons per metre squared [N/m^2]. This can be compared with the physical quantity pressure. It expresses the severity of loading experienced by the material from which a part is made. For every engineering material, the strength (or more specifically ultimate tensile strength (UTS), yield strength or fatigue strength) defines a particular value of stress (i.e. how much force can occur over a unit area of the material) that can be sustained before failure. Stress is never uniform in engineering components, and there often can be small regions of stress in a component that are in excess of the strength of the material, whereas elsewhere the stresses are relatively low. Stress analysis or calculations determine the magnitude and locations of these stresses.One of the objects of work is to find the are of stresses appering under each local contact of any two asperities in friction as well as to evaluate conditon of surface layer of the material under possible destruction.

A COSMOSWorks package was used to solve the contact problem and to predict parts deformations as well as forces and stresses due to assembly.

The two parts with thin walls assembled by interference fit was used for solution of problem. The model of parts with thin walls by interference fit 0,232 mm and equivalent materials- Alloy steel was performed . The outer and inner diameter of inner component are 90,232mm and 56mm, respectively; the outer and inner diameter of outer component are 90,00mm and 140mm ,respectively; the primary contact lenght is 67 mm.

The finite element mesh consists of 11303 nodes and 7521 elements; FFEPlus-solver type was used; contact option include friction with friction coefficient 0,08.

In figures 3 and 4 the folowing results are represented, which describe various stresses and resultant displacement at different contact lenghts of components. The von Mises stress is computed from the six stress components as follows:

$$VON = \{0.5\ [(SX - SY)^2 + (SX-SZ)^2 + (SY-SZ)^2] + 3(TXY^2 + TXZ^2 + TYZ^2)\}^{(1/2)}$$

Or equivalently, from the three principal stresses,

$$VON = \{0.5\ [(P1 - P2)^2 + (P1 - P3)^2 + (P2 - P3)^2]\}^{(1/2)};$$

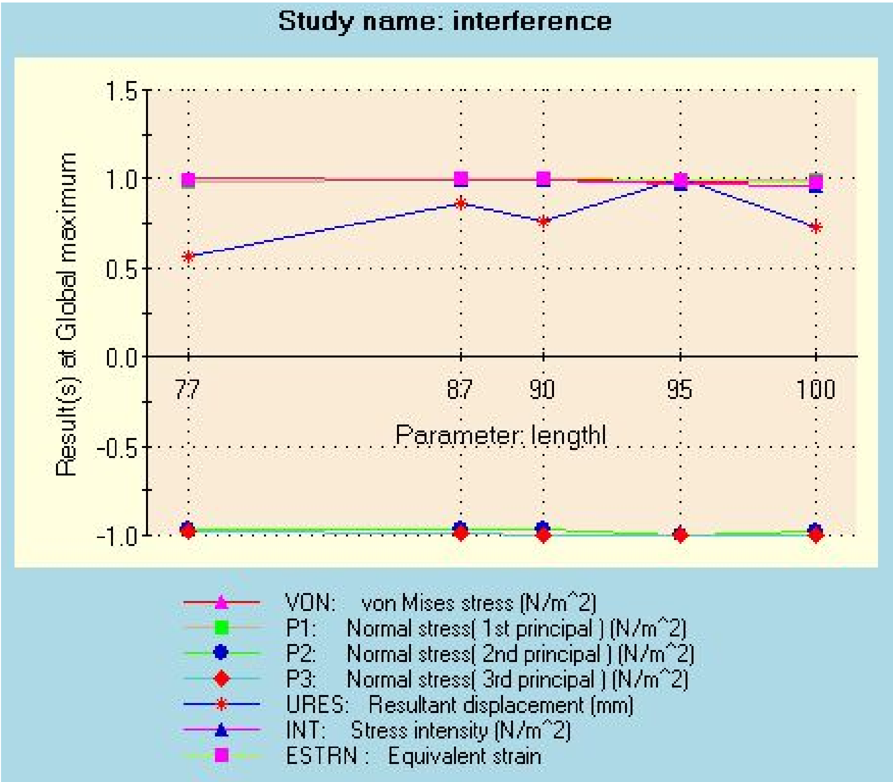

Fig. 3. Curves of stresses and displacements.

Input Parameters	**Units**	Set1	Set2	Set3	Set4	Set5
lengthI of inner component	mm	77	87	90	95	100
lengthII of outer component	mm	77	87	90	95	100

Results	**Units**	Set1	Set2	Set3	Set4	Set5
Result Status		**Summary**	**Summary**	**Summary**	**Summary**	**Detailed**
Global maximum for the whole model						
VON: von Mises stress	N/m^2	4.0642E+008	4.0822E+008	4.1239E+008	4.059E+008	4.076E+008
P1: Normal stress(1st principal)	N/m^2	2.884E+008	2.943E+008	2.9472E+008	2.9189E+008	2.9329E+008
P2: Normal stress(2nd principal)	N/m^2	-1.51E+008	-1.5165E+008	-1.5158E+008	-1.5675E+008	-1.5381E+008
P3: Normal	N/m^2	-4.1677E+008	-4.197E+008	-4.2431E+008	-4.2307E+008	-4.2336E+008

stress(3rd principal)						
URES: Resultant displacement	m	0.00018793	0.00028718	0.00025349	0.00033472	0.00024534
INT: Stress intensity	N/m^2	4.368E+008	4.3282E+008	4.3252E+008	4.2274E+008	4.2106E+008
ESTRN : Equivalent strain		0.001507	0.001521	0.0015198	0.0015053	0.0014951

Fig. 4. Stresses and displacements results.

Obviously ,changes of contact length effects stresses and displacements results.

In a figure 5 the stress distribution are shown. The max von Mises stress is 4,076e+008 N/m^2 at 100mm contact length and the inner dia of inner component is more subjected to streses.

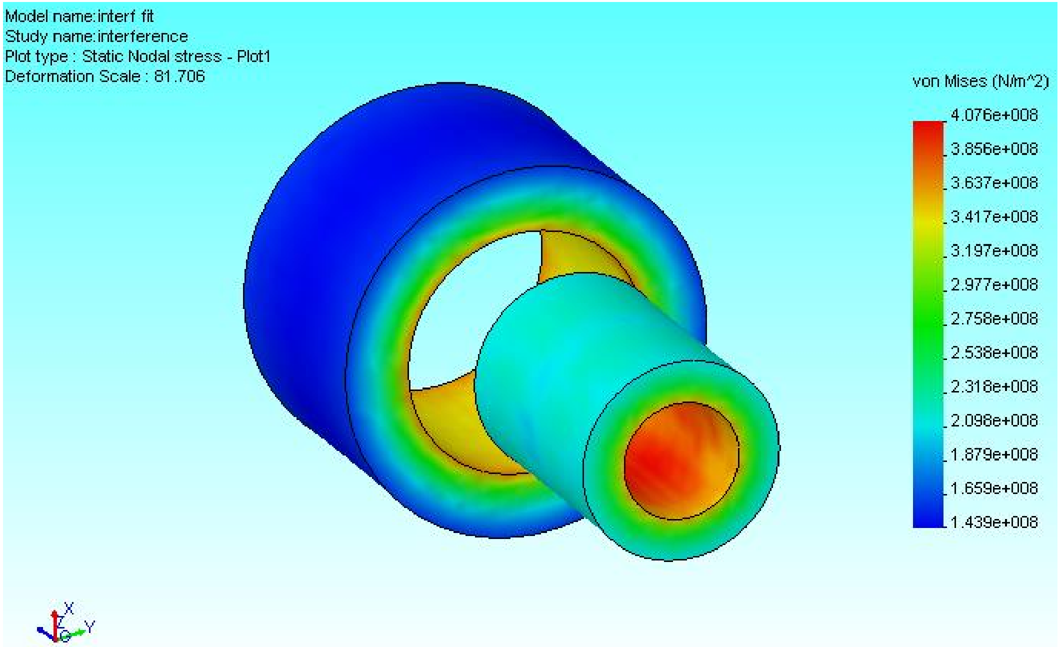

Fig. 5. The stress distribution

The inner component is subjected to compresive stress and outer component to tensile stress. The radial displacement of inner component -0,0502mm and one of outer component 0,0654mm at the 67mm contact lenght was obtained . It is obvious that the outer dia of inner component has changed less then inner dia of outer component. But if the materials from which the components are going to be made are Alloy Steel for inner part and Gray Cast Iron for outer part then the results obtained with FEM are following: the radial displacement of outer dia of inner component is -0,0226mm and one of inner dia of outer component is 0,0933mm at the 67mm contact lenght.

The friction and normal forces of both models consisted of parts which are made for equivalent and different materials was obtained.

So, on the basis of interference variation and stresses analysis, we can examine the contact process of assembled details.

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