# ANALYSIS OF VON- MISES-STRESS FOR INTERFERENCE FIT AND PULL-OUT STATES BY USING FINITE ELEMENT METHOD

**RAHUL G.KARMANKAR**

*Asst.Prof. Mechanical Engineering department-AGPCE-Nagpur-India*

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**ABSTRACT –** *Von-misses stress means stress at yield point. From the reference of von mise stress we can find the value of stress at plastic stage means at yield point stage. Yield point means it is point at where plastic plastic deformation will start. This is also called as Maximum distortion energy theory of failure. It suggests the yielding of ductile materials begin when the second deviatoric stress invariant reachea a critical values. It is a part of plasticity theory that applies best to ductile materials. Materials is said to start yielding when the von-mises stress reaches a value known as yield strength. The von-mies stress is used to predict yielding of materials under complex loading from the result uniaxial tensile test. It is applicable for the analysis of platic defoemation for ductile materials. The idea of von-mises stress was first proposed by Maksymilian Huber in 1904 but received more attention only in 1913 when Richard von mises proposed it again. It was Heinrich Hencky who gave the idea of Von-Mises stress a reasonable physical interpretation. The Point or stress at which the material behavior transforms from elastic to plastic behavior is known as yield stress. The energy is used to distort the shape of a materials is called deviartoric energy. Most often structures are made of materials like steel that shows a plastic deformation and yielding before undergoing fracture. It is always preferred to design structure such that they are within the elastic limit and do not yield.*

**Key Words: Von-mises stress, Interference fit, Finite element method, contact stress**

## 1. INTRODUCTION WITH ASSEMBLY PROCESS

### 1.1 Interference fit

The **interference** is the amount by which the actual size of the shaft is larger than the actual size of finished size of the mating hole in an assembly.

**Fits-**the degree of tightness or looseness between the two mating parts is known as a fit of the parts.

**Allowance-** It is the difference between the basic dimensions of the mating parts. When the shaft is less than the hole size then allowance is positive and when the shaft size is greater than the hole size then the allowance is negative

When two parts are to be assembled the relationship resulting from the difference between their sizes before assembly is called a fit. Depending upon the limits of the shaft and the hole fits are broadly classified into three groups clearance fit, transition fit and interference fit. If the difference between shaft and hole size is negative before assemble an interference fit is obtained. The magnitude of the difference between the maximum size of the hole and minimum size of the shaft in an interference fit before assembly is called the minimum interference. The magnitude of the difference between the minimum size of the hole and the maximum size of the shaft in an interference or a transition fit before assembly is called maximum interference. The shaft is larger than the hole so the assembly results in a force or press fit which has an effect similar to welding two parts. The selection of interference fit depends upon a number of factors such as materials, diameters, surface finish and machining method. It is necessary to calculate the maximum and the minimum interference in each case. The torque transmitting capacity is calculated for minimum interference while the force required to assemble the parts is decided by the maximum value of interference. This papers shows the result of an interference fit pin connection plated through hole by using finite element method. By considering 0.01 mm allowance in pin connection through hole the result are carried out for contact stress and von-mises stress. Typical examples of interference fit are the press fitting of shafts into bearing or bearing into their housing and the attachment of watertight connection to cables. Interference fit also results when pipe fitting are assembled and tightened. In our application with interference fit pin is used to insert in hole. I find it necessary to determine regions of high stress. The regions of high stress may be a source of which lead to crack failure. In order to understand the source of these high stress regions an analysis of the process of the insertion of a pin into through plates's hole is considered. The process is modeled by considering a series of shear and normal loads applied to the inside of the plate where hole is present.. Hereby using FEM von-mises stress and contact stresses has been studied with respect various allowance. Inertia effects are not considered in this analysis. The finite element method is used to determine the solution of this analysis. Shear stress set up at this interference is not large enough to cause cracking. Interference fit pin connections have wide applications ranging from aerospace structure to electric hardware systems and the telephone industry. In order to derive the maximum benefit by the use of interference fit pin. In all such application a complete understanding of their behavior in the regions of joints is essential. The close class of fit in which a mating part is deliberately made slightly oversize for the part into which it will be inserted. Also called a shrink or press fit . It gets its name because the bore is actually smaller than the shaft it is to be mated with. It is the strongest fit possible but require heat or a hydraulic press to install. Interference fit refers to parts that must be compressed to mate. This is achived with presses that can press the parts together with very large amounts of force. Hence the term press fit. The presses are generally hydraulic although small hand – operated presses (such as arbor press) may operate by means of the mechanical advantage supplied by a screw jack. The amount of force applied may be anything from a few pounds for the tiniest parts to hundreds of tons for the largest parts. Often the edge of shaft and holes are chamfered (beveled). The chamfer forms a guide for the processing movements helping

1] To distribute force evenly around the circumference of the hole 2] to allow the compression to occue gradually instead of all at once , thus helping the pressing operation to be smooth , to be more easily controlled and to require less power, less force at any one instant of time. Most material expand when heated and shrink when cooled. Enveloping parts are heated ( such as with torch or gas ovebs) and assembled into position while hot then allowed to cool and contract back to their former size except for the compression that result from each interfering with the other. Railroad axels, wheels and tires are typically assembled in this way. Alternatively the envelopes part may be cooled before assembly such that it slides easily into it's mating part. Upon warming it it expands and interferes. Cooling is often preferred as it is less likely than heating to change materials properties eg. Assembling a hardened geat onto a shaft where heating the gear would alter its hardness. For metals parts in particular the friction that holds the parts together is often greatly increased by compression of one part against the other which relies on the tensile and compressive strength of the materials. An interference fit is generally achieved by shaping the two mating parts so that one or other or both slightly deviates in size from the nominal dimension. When the shaft is pressed into the bearing the two parts interfere with each other's occupation of space the result that they plastically deform slightly each being compressed and the interference between them is one of the extremely high friction so high that even large amount of torque cannot turn one of them relative to the other. They are locked together and they turn in unison. Formulae's exit to compute the allowance that will result in various strength of fit such as loose fit, light interference fit and interference fit. The value of allowance depends on which material is being *used*, how big the parts are and what degree of tightness is desired.

### 1.2 APPLICATION

Table-1

| Sr. No | Shrink fit-Heavy drive fit | Press fit |
|---|---|---|
| 1 | Wheel sets | Coupling on shaft ends |
| 2 | Tyres | Bearing bushes in hubs |
| 3 | Bronze crowns on worm wheel hubs | Valves seats |
| 4 | Coupling under certain conditions | Gear wheels |
| 5 | Rail Road axles | |
| 6 | Aerospace industries | |
| 7 | Telephone industries | |

## 2. BRIEF VIEW OF ANSYS

Dr. John Swanson founded ANSYS in 1970 with vision to commercialize the concept of computer-simulated engineering, establishing himself as one of the pioneers of finite element analysis [FEA]. ANSYS Inc supports the ongoing developments of innovative technology and deliver flexible , enterprise-wide engineering system that enables companies to solve the full range of analysis problem maximizing their existing investment in software and hardware. ANSYS Inc continues its role as a technical innovator. It also supports a process –centric approach to design and manufacturing allowance user to avoid expensive ant time consuming "build and break cycles". ANSYS analysis and simulation tools give customer ease of use, data compatibility, and multiplatform support and coupled field multi physics capabilities. The ANSYS program allows engineer to construct computer models or transfer CAD models of structures, product, components or system apply operating loads or other design performance conditions and study physical response such as stress levels, temperature distribution or impact of electromagnetic field. In some environments prototype testing is understand or impossible. ANSYS design optimization enables the engineering to reduce the number of costly prototype, rigidly and flexible to meet objective and the proper balance in geometric modification competitive companies look for ways to produce the highest quality product at lowest cost. ANSYS FEM can help significantly by reducing the design and manufacturing cost and by giving engineers added confidence in the conceptual design . It is also useful when used in later in manufacturing process to verify the final design before prototyping.

## 3. HOW TO SOLVE THE INTERFERENCE PROBLEM

### A] INPUT METHOD FOR SOLVING THE PROBLEM

1) Element Name
2) Nodes
3) Degree of Freedom
4) Real Constant
5) Materials Properties
6) Surface loads
7) Body loads
8) Special features
9) KEYOPTS

### B] SOLUTION METHOD

1) Nodal Solution
2) Element Solution
3) Non-linear Solution
4) Overcoming convergence problems
5) Meshing
6) Boundary condition
7) P- Method structure static analysis
8) Solid modeling
9) Coupling
10) Automatic time stepping

### C] BASIC STEPS TO SOLVE INTERFERENCE PROBLEMS BY USING FEM

1) Problems specification
2) Problem Description
3) Build Geometr steps
4) Define material property and element types steps
5) Load step- 1
6) Load step-2
7) Post processing steps

## 4. VARIOUS ELEMENTS USE TO SOLVE THE INTERFERENCE FIT PROBLEM

1) SOLID 92 2) TARGET 170 3) CONTA 174

4.1] **SOLID 92-** Solid 92 has a quadratic displacement behavior and is well suited to model irregular meshes(such as produces from various ( CAD/CAM) system . The element is defined by ten nodes having three degree of freedom at each nodes, x,y,z direction. The element also has plasticity, creep, swelling, stress stiffering, large deflection and large strain capabilities.

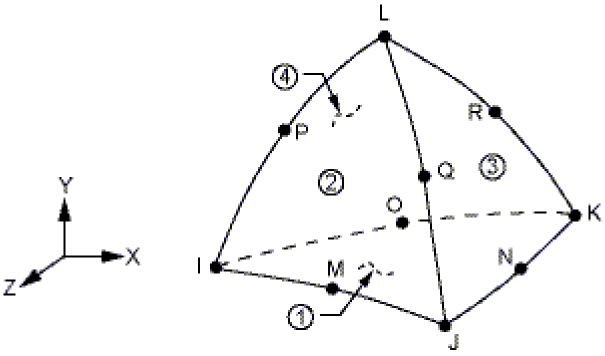


**Fig.1-Solid -92**

### 4.2] TARGE- 170

Targe 170 is used to represent various 3 D target surface for the associated contact element (Cont 173, Cont174, Conta 176). The contact element themselves over lag the solid element describing the boundary of a target segment element (target 170). This target surface is discredited by a set of target segment (target 170) and is paired with its associated contact surface via a shared real set. It can improve any transnational or rotational, displacement, temperature, voltage and magnetic potential on the target segment element. For rigid target surface these elements can easily model complex target shapes. For flexible target these elements will overlag the solid elements describing the boundary of the deformable target body.

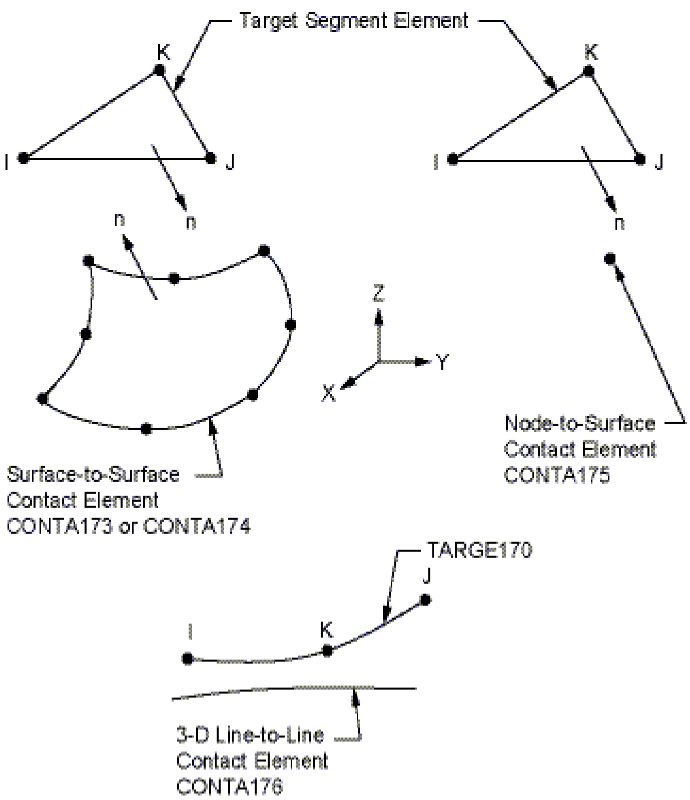


**Fig-2**

### 4.3] CONTA 174

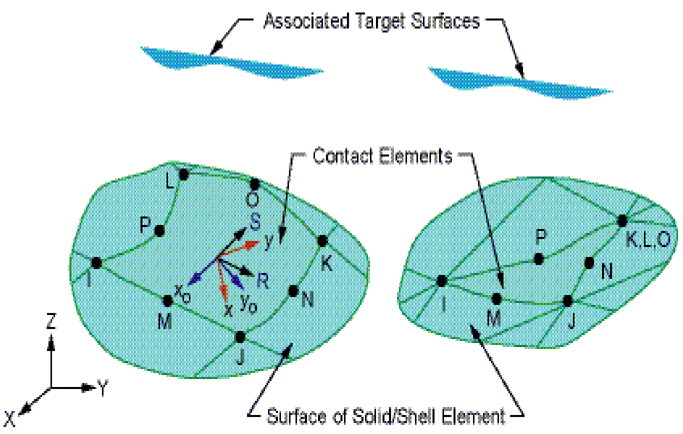


**Fig.3**

1] The 3-D contact element must coincide with the external surface of the underlying solid or shell element.

2]This element is nonlinear and requires a full Newton iterative solution, regardless of whether large or small deflections are specified.

3] The normal contact stiffness factor (FKN) must not be so large as to cause numerical instability.

4] FTOLN, PINB, and FKOP can be changed between load steps or during restart stages.

5] The value of FKN can be smaller when combined with the Lagrangian multiplier method, for which TOLN must be used.

6] It can be use this element in nonlinear static or nonlinear full transient analyses.

7]In addition, it can use it in modal analyses, eigenvalue buckling analyses, and harmonic analyses. For these analysis types, the program assumes that the initial status of the element (i.e., the status at the completion of the static prestress analysis, if any) does not change.

## 5. BRIEF VIEW OF CONTACT STRESS

**5.1- CONTACT PROBLEM CLASSIFICATION**-There are many types of contact problems that may be encountered, including contact stress dynamic impacts, metal forming, bolted joints, crash dynamics, assemblies of components with interference fits, etc. all of these contact problems, as well as other types of contact analysis, can be split into two general classes (ANSYS) .

Rigid – to – flexible bodies in contact
Flexible – to – flexible bodies in contact

In rigid – to flexible contact problems, one or more of the containing surfaces are treated as being rigid material, which has a much higher stiffness relative to the deformable body it contacts. Many metal forming problems fall into this category. Flexible – to flexible is where both contacting bodies are deformable. Examples of a flexible-to flexible analysis gears in mesh, bolted joints, and interference fits.

### 5.2:-HOW TO SOLVE THE CONTACT PROBLEM?

In order to handle contact of pin and hole problems in interference fit with the finite element method, the stiffness relationship between the two contact areas is usually established through a spring that is placed between the two contacting areas. This can be achieved by inserting a contact element placed in between the two areas where contact occurs. There are two methods of satisfying contact compatibility: (i) a penalty method and (ii) a combined penalty plus a Lagrange multiplied method. The penalty method enforces approximate compatibility by means of contact stiffness. The combined penalty plus Lagrange multiplier approach satisfies compatibility to a user-defined precision by the generation of additional contact forces that are preferred to as Lagrange forces. It is essential to prevent the two areas from passing through each other. This method of enforcing contact compatibility is call ed the penalty method. The penalty allows surface penetrations, which can be controlled by changing the penalty parameter of the combined normal contact stiffness. If the combined normal contact stiffness is too small, the surface penetration may be too large, which may cause unacceptable errors. Thus the stiffness must be big enough to keep the surface penetrations below a certain level. On the other hand, if the penalty parameter is too large, then the combined normal contact stiffness may produce several numerical problems in the solution process or simply make a solution impossible to achieve. For most contact analyses of huge solid models the value of the combined normal contact stiffness may be estimated [ANSYS] as.

$Kn = fEh$

Where $f$ is a factor that controls contact compatibility. This factor is usually be between 0.01 and 100.

$E$ = smallest value of Young's Modulus of the contacting materials,

$H$ = the contact length

The contact stiffness is the penalty parameter, which is a real constant of the contact element. There are two kinds of contact stiffness, the combined normal contact stiffness and the combined tangential or sticking contact stiffness. The element is based on two stiffness values. They are the combined normal contact stiffness $Kn$ and the combined tangential contact stiffness $K.l$ . The combined normal contact stiffness $Kn$ is used to penalize interpenetration between the two bodies, while the combined tangential contact stiffness $Kl$ is used to approximate the sudden jump in the tangential force, as represented by the Coulomb friction when sliding is detected between the contacting nodes. However, serious convergence difficulties may exist during the vertical loading process and application of the tangential load often results in divergence. A details examination of the model's nodal force during the vertical loading may indicated the problem. Not only are friction forces developing but they develop in random diffractions. This is due to Poisson's effect causing small transverse deflections of the nodes in the contact zone. These deflections are enough to activate the friction forces of the contact elements [1]. The friction forces are developing in various directions because the generation of a tangential friction force facing right on one node would tend to pull the node on its left to the right. This would generate a friction force facing left on this node, pulling back on the other node. This continual tug-of-war cause the poor convergence

This problem was eliminated by applying a small rotation tot the above cylinder model forces as it was displaced and loaded vertically, this rotation ensured that the friction forces would develop in the proper direction. Interference contact problem cab be solved by using the above method. Here for solving the contact problem contact element of CONTA174 is used. Following fig. Shows the basics relationship between the contact and target surface. By using this method we can solve the problem of Interference fit for flexible to flexible contact.

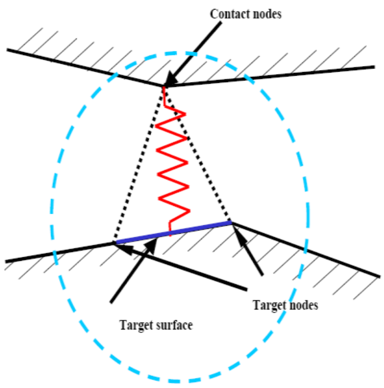


Figure 3-1 Point-to-surface contact element

**Fig-4-Pair to surface contact element**

**Managing Contact Pairs:-**This tool used for proper detection of the contact pair. It also

1 Verify that the normal of the contact and target surfaces are in the correct direction
2 Reverse normal of elements that are not oriented correctly

In addition these elements can be displayed independently or in the context of entire model. In the later case the contact elements are highlighted in a translucent plot the model.

Another important function is to edit the properties of the contact pair(s) as needed. The properties include real constant values and key option values as discussed earlier. The Contact Properties button in the contact manager provides a simple to use interface that allows the properties of the selected contact pair(s) to be reviewed and modified if needed.

### 6. VON- MISES-STRESSS

In this case, a material is said to start yielding when its von Mises stress reaches a critical value known as the yield strength, $\sigma_y$. The von Mises stress is used to predict yielding of materials under any loading condition from results of simple uniaxial tensile tests. The von Mises stress satisfies the property that two stress states with equal distortion energy have equal von Mises stress.Hencky (1924) offered a physical interpretation of von Mises criterion suggesting that yielding begins when the elastic energy of distortion reaches a critical value. For this, the von Mises criterion is also known as the maximum distortion strain energy criterion.

LOAD STEP 1-Load Step 1: Interference Fit – Solution is carried out with no additional displacement constraints. The pin is constrained within the the pinhole due to its geometry. Stresses are generated due to the general misfit between the target (pinhole) and the contact (pin) surfaces.

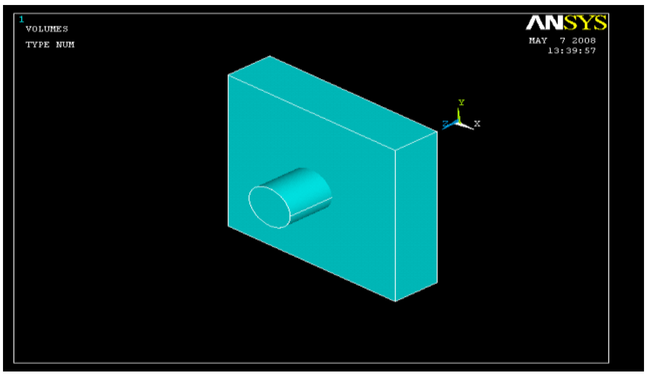


**Fig.5-CONTACT SURFACE**

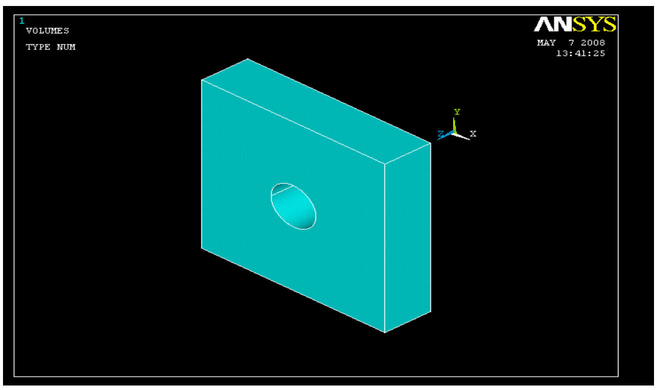


**Fig.6-TARGET SURFACE**

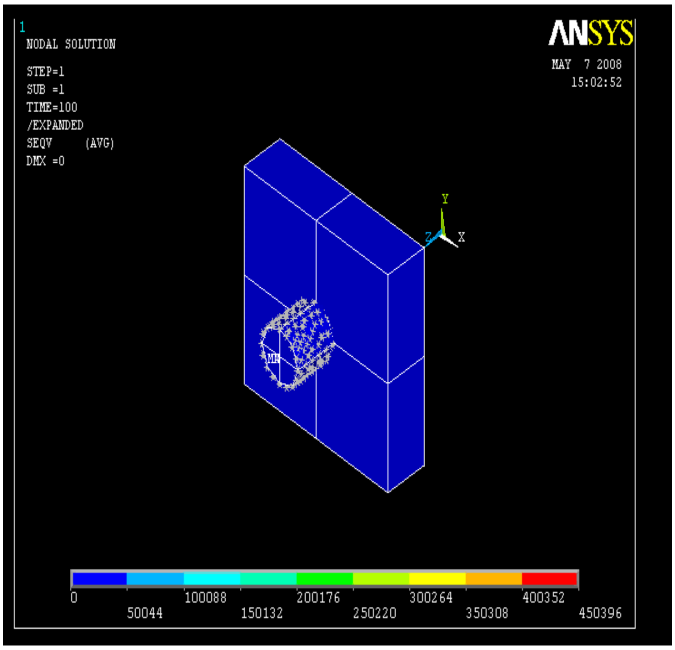


Fig.7-MATTING POSITION-INTERFERENCE FIT AT ZERO DISPLACEMENT

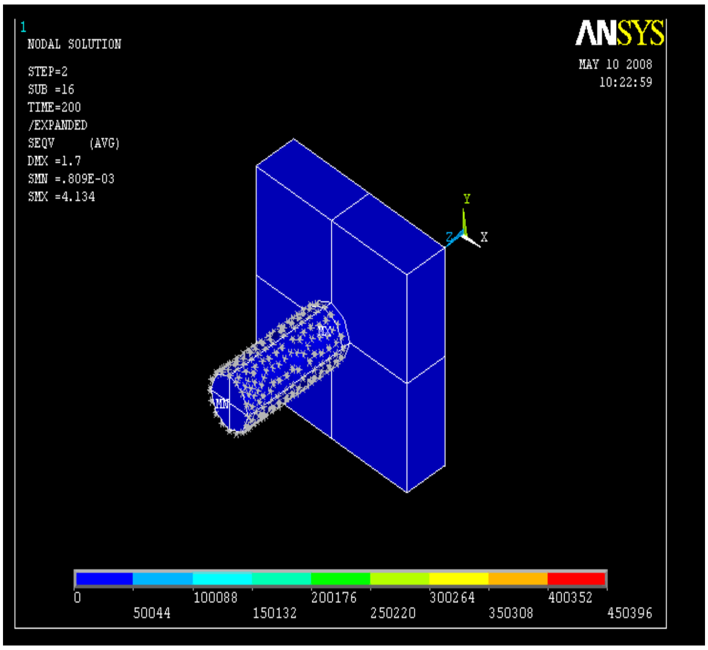


Fig.8-INTERFERENCE FIT AT 1.7 MM DISPLACEMENT

## 7. OBSERVATIONS OF PULL-OUT STRESS

Here the results are carried out for pin which is pulled out from the surface of the hole from distance of 0 mm to 1.7 mm and following figures shows the exact value of stress. Von-mises stress values are varying for various distance and that values are as follows. During the time of matting some part of contact surface may be extend from its initial fit and because of this some stress will be generated at the point of contact and we should know its value to avoid the catastrophic failure. This paper shows the values of von-mises stress at various distance of extended surface from the target surface.

LOAD STEP 2-: Pull-out -- move the pin by 1.7 units out of the block using DOF displacement conditions on coupled nodes. Explicitly invoke Automatic Time Stepping to guarantee solution convergence.

1] Set DOF displacement for pin

2] Define pull-out analysis options

3] Write the results

RESULTS- Hence by using Finite element method exact value of Von-mises stress for Interference fit and pull out pin are as follows

Interference fit-Von-mises stress- 87394E-06 MPa
Pull-out-the pin up to 1.7mm from the surface of the hole-Dmax=1.7mm
Von-mises stress=4.143E-06MPa
Hereby with the help of ANSYS software Interference fit of 0.01 mm allowance shows the bets result as compared to other allowance for 0.49 mm hole and 0.50 pin sizes.

**RESULTS FOR DIFFERENT ALLOWANCE-**

Starting from 0.001 mm to 0.007mm

For improving the accuracy of the result work are carried out for different allowance. Generally smaller value of allowance will shows the best result.

| Allowance in mm | Contact stress in Mpa | Von-mises stress in MPa |
|---|---|---|
| 0.001 | 2160 E-06 | 82779E-06 |
| 0.002 | 3717 E-06 | 189948 E-06 |
| 0.003 | 6598 E-06 | 280476 E-06 |
| 0.004 | 7139 E-06 | 366706 E-06 |
| 0.005 | 8861 E-06 | 452983 E-06 |
| 0.006 | 9961 E-06 | 552983 E-06 |
| 0.007 | 11092 E-06 | 622790 E-06 |

Table-2

**PULL OUT STATES**

A] Graph shows the relationship between allowance and Von- mises-stresss

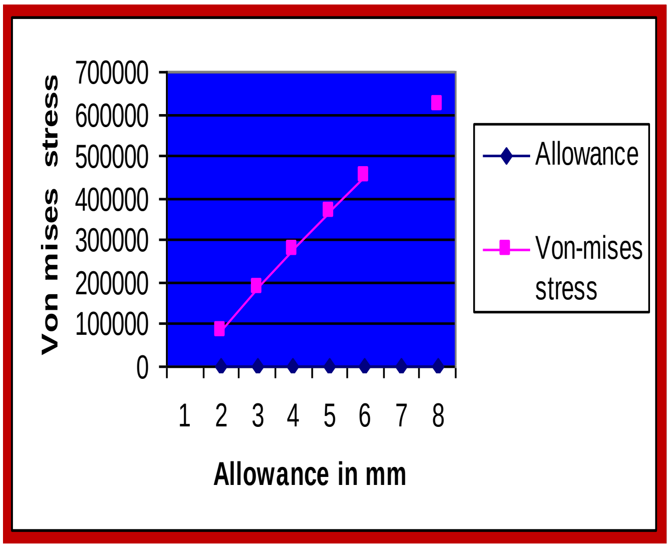


Fig.9

Thus form above graph it is clear that value of Von-mises stress are increases as allowance are increase. But from study it is clear that value of Von-mises stress decrease as if allowance are further increase, thus there are standard value for Interference should be taken as per our requirement.

**8] CONCLUSION-**

By using the strategy of Interference fit in plated through hole we can find out the value of high stress which leads the crack failure criteria. Generally negative allowances are provide for press fit. By using this method we can find suitable value for allowance which will help to design reliable product. This method is used to find the critical value of the Von misses stress, contact stress etc. It help to investigate the critical value of high stress which can avoid the future failure of the product like matting of shaft and bearing, watertight connectors to cables, aerospace structures.

Here the value of Von-mises stress for Interference fit and pull out distance I.e.1.7 mm has been found by considering 0.01mm allowance. Works are also carried out for various allowance means from 0.001mm to 0.007 mm allowance to improve the accuracy of the results.

There are mathematical procedure are also available for the study of the Interference fit but like others FEM also give best results which will help to study the Interference fit with various consideration like temperature , contact pressure, thermal conductivity ,inertia, heat transfer, thermodynamics etc.

**Table-3**

| Allowance in mm | Contact stress in Mpa | Von-mises stress in Mpa | Max. displacement in mm |
|---|---|---|---|
| 0.001 | 2160 E-06 | 82779 E-06 | 0.155125 |
| 0.002 | 4198 E-06 | 146499 E-06 | 0.09775 |
| 0.003 | 30804 E-06 | 211111 E-06 | 0.2125 |
| 0.004 | 2518 E-06 | 322948 E-06 | 0.097751 |
| 0.005 | 10664 E-06 | 369127 E-06 | 0.136001 |
| 0.006 | 25664 E-06 | 399127 E-06 | 0.136001 |
| 0.007 | 43491 E-06 | 458731 E-06 | 0.097752 |

**9] FUTURE SCOPE**

1] Though there are standard values for the allowance but it should be test for various conditions like effect of temperature, heat conductivity, inertia effect, contact stress, on mises stress etc

2] Allowance plays an important role in various leak proof application like Gas, air, liquid etc.

And hence study of Interference is very essential to avoid the catastotropic failure

3] Future work can be carried out by considering the Inertia effect ,temperature effect, heat transfer effect and we can find the reasonable value for allowance.

4] This paper help to find the value of critical stress at contact point which will help avoid future failure.

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**BIOGRAPHY**

Asst. Prof. Rahul G.Karmankar
Agpce -Nagpur
Area of Interest-Heat Transfer