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Finite Element Analysis of Wire Drawing Process with different die contours

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ABSTRACT:

Finite element method is a numerical analysis tool for analyzing complex problems. It was originally developed as a tool for structural, Thermal; fluent analysis and magnetic, electrical current flow analysis but the theory and formulation has been progressively gives approximate solutions. I have taken the problem of understanding wire drawing process from theory of pure plasticity and Avitzur's theory of law's 'Wire Drawing through Conical Dies of small cone angles and large cone angles' This theory was used to obtain the drawing load. Wire is drawn through dies with different die contours viz. plain die with die land, Convex die, Concave die. Hence I found least wire drawing defects and die life increased. Loads were applying to the finite element model treating the problem to be axi symmetric. The problem to be solving by using ANSYS 10 classic a popular FEA software package.

Keywords—FEA, ANSYS, wire drawing, plane die with Land, Convex die, Concave die**.**

I. INTRODUCTION TO WIRE DRAWING

Wire is one of the most important products required by man. Endless lengths of wire are used in the form of conductors in communication and power transmission. Enormous quantities of wire are used for fencing, cables for bridges and hoists. The products require correct dimension, surface finish and mechanical properties. Sizes vary from fraction of an inch to thousands of an inch. Wires are produced by the process of wire drawing.

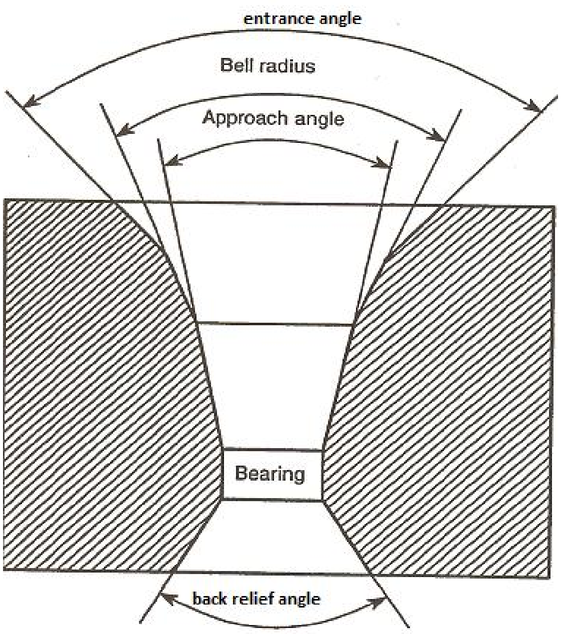
Process

Drawing involves pulling metal through a tapered die by a tensile force applied at the exit side of the die. Most of the plastic flow is caused by compressive forces arising from the reaction of metal with die walls. Raw material for wire drawing is generally a rolled wire or rod. The dimensional accuracy and surface finish obtained are superior compared with rolling. Hence rolling is followed by drawing, The raw material is first cleaned of scale and rust by mechanical or chemical treatment. It may then be coated with a good lubricant. An end is chamfered to enter the die , so that it can be clamped and pulled. Wire drawing machinery with draw bench or coiler and uncoiler are generally used.

Wire drawing dies

It is necessary to be aware that a good die is a prime requirement for the process. Even the best lubricant will fail when a poor die is used. In general a drawing die profile can be described by the five important parts of the die cross section. The nomenclature is shown in the diagram.

The function of the entrance angle is to direct the flow of lubricant into the die approach angle where the lubricant is compacted onto the wire surface during drawing. Angles can vary from $40^0$to 80^0.



Bell Radius

Guides the incoming rod if it enters the die contour in a spiral path. The rod contacts the surface before entering the conical approach angle. Angle varies from $30^0$to 40^0.

Approach Angle

It is the most important section of the drawing die. The entire reduction in area occurs in this region. Therefore this surface is made perfectly smooth. The angle must be precision machined. Angle varies from 10^0 to 20^0.

Bearing

This section of the die performs the final control of diameter of drawn wire. It to guarantees roundness, straightness, flatness and smooth finish of the wire. Hence it is also machined to close tolerances. Length would be 35 to 50 percent of bearing diameter. The correct length of the parallel bearing surface helps to extend die life when wire drawn through the die is pulled offline causing additional pressure to one side of bearing surface.

Back Relief

This angle would strengthen the exit of die and prevent breakage of the die. Angles vary from 30^0 to 70^0.

II. PARAMETERS OF DIE AND DIE CONTOURES

Maximum Reduction In Wire Drawing

The reduction in area is given by $R=1-(Da^2/D_b^2)$ from the parameters of die the reduction of area R is 36%.

For an ideally plastic element, R would be 64%.

Most of the wire drawing defect are produced by taken low reduction area and taken low cone angles.

But larger reduction area of wire drawing requires larger draw stress value

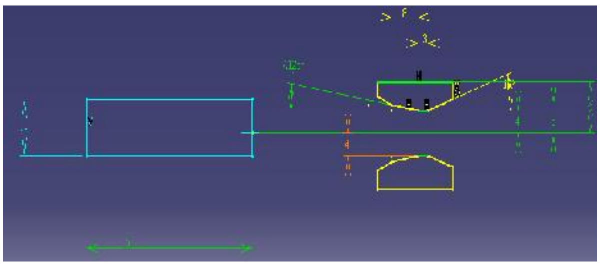


Fig.1 Plane die

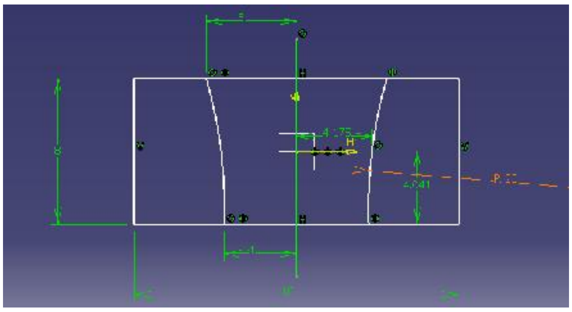


Fig.2 Convex Die

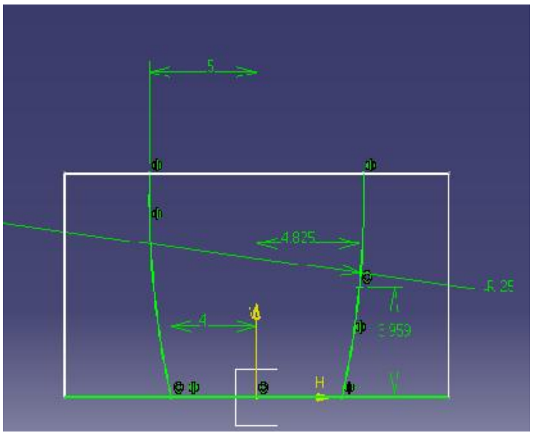


Fig.3 Concave Die

II. MATERIAL PROPERTIES

PROPERTIES	die (sintered alumina)
DENSITY	3980Kg/m3
MODULUS OF ELASTICITY	5.83e5Mpa
POISSON'S RATIO	0.231
TENSILE YIELD STRENGTH	655Mpa
COMPRESSIVE YIELD STRENGTH	5337.5Mpa
ALLOWABLE TENSILE YIELD STRENGTH	225Mpa
ALLOWABLE COMPRESSIVE STRENGTH	2500Mpa

PROPERTIES	wire material(AISI NO 4340)
DENSITY	7850Kg/m3
MODULUS OF ELASTICITY	2.5e5Mpa
POISSON'S RATIO	0.3
TENSILE YIELD STRENGTH	744Mpa
ALLOWABLE TENSILE STRENGTH	1350Mpa

Table.1

III. LOAD CALCULATION PROBLEM DEFINITION

A Wire drawing die of length 8mm is required to reduce a wire from 10mm to 8mm diameter, outer diameter of the die being 18mm. Die material alumina (E=5.83e5N/mm2, Poisson's ratio = .231.Wire material AISI 4340 steel (E=2.5e5N/mm2), (Poisson's ratio = 0.3) (Yield strength = 744MPa). Stress distribution and Deformations are solved in ansys.

The reduction in area is given by $R=1-(Da^2/D_b^2)$ from the parameters of die the reduction of area R is 36%

LOAD CALCULATION FROM THEORY OF PURE PLASTCITY.

For small cone angles
B= μ / tan α = 0.1 / tan 7.125 = 0.8

Where μ = coefficient of friction (taken 0.1 - cold drawing)

Tan α = 1 / 8

Draw stress, $\sigma_{xa} = \sigma_{x0}$ [(1+B) {1 – (D_a / D_b)^{2B} } / B] => 744 [(1+0.8) {1-(8/10)$^{2\times0.8}$} / 0.8] = 502.6 Mpa

LOAD CALCULATION FROM THEORY (AVITZUR) LAW

Large cone angle

Semi Cone Angle α = 7.125^0

$$f(\alpha)=\frac{1}{\sin^2\alpha}\left[1-(\cos\alpha)\sqrt{1-\frac{11}{12}\sin^2\alpha}+\frac{1}{\sqrt{11\cdot 12}}\ln\frac{1+\sqrt{\frac{11}{12}}}{\frac{\sqrt{11}}{\sqrt{12}}\cos\alpha+\sqrt{1-\frac{11}{12}\sin^2\alpha}}\right]$$

For α =7.125^0, f(α) =0.9369, For back pull σ_{Xb} =0, land L=0

Draw stress

$$\sigma_{Xf}=\sigma_0\frac{\left\{2f(\alpha)\ln(\frac{R_0}{R_f})+\frac{2}{\sqrt{3}}(\frac{\alpha}{\sin^2\alpha}-\cot\alpha)+2\mu((\cot\alpha)[1-\ln(\frac{R_0}{R_f})]\ln(\frac{R_0}{R_f})+\frac{L}{R_f})\right\}}{(1+\frac{2\mu L}{R_f})}$$

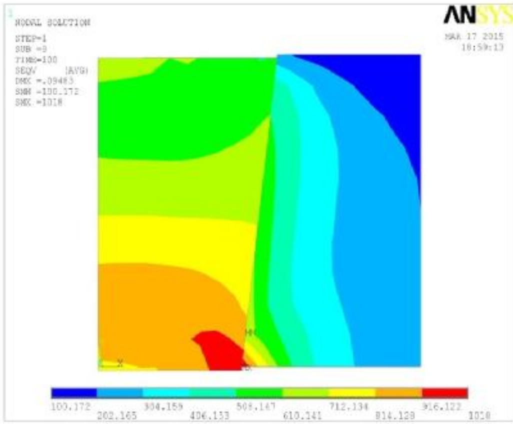
$\frac{\sigma_{Xf}}{\sigma_0}$ = 0.7865, σ_{Xf} = 585.156 N/mm^2

In the field of engineering analysis finite element analysis programs occupy a major computational activity. Dr.Swanson developed Analysis System ANSYS. The ANSYS program has many finite element analysis capabilities ranging from a simple, linear static analysis to non linear, dynamic analysis problems for different engineering disciplines.

IV. ANSYS SOLUTION, RESULTS AND COMMENTS

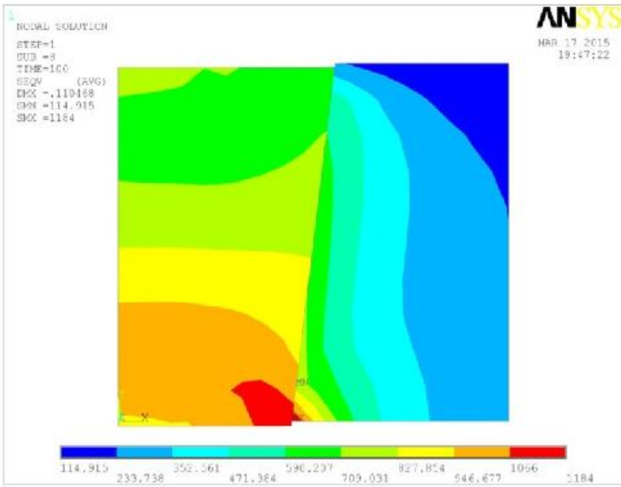
CASE -1 WIRE DRAWN THROUGH PLANE DIE

a) Assuming small cone angle



COMMENT: Von Mises stress in die has crossed allowable limits at exit. In wire stress is very large than that is necessary to cause uniform yielding.

b) ASSUMING LARGE CONE ANGLES (AVITZUR)

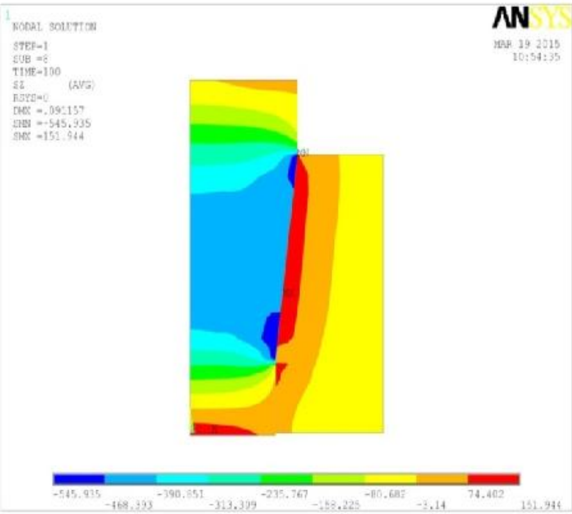


COMMENT: Stress in die has crossed allowable limits at exit. In wire stress is very large than that is necessary to cause uniform yielding.

Case-2 WIRE DRAWING THROUGH PLANE DIE WITH DIE LAND

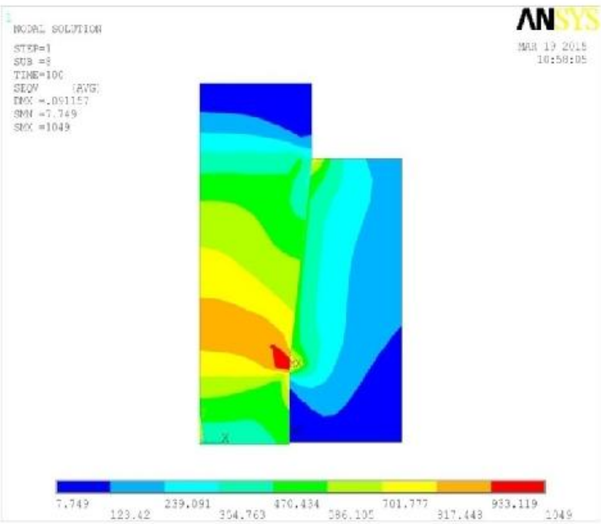
a) Assuming small cone angle

Z – Component stress



COMMENT: Hoop Stress in die is just beyond the allowable limits.

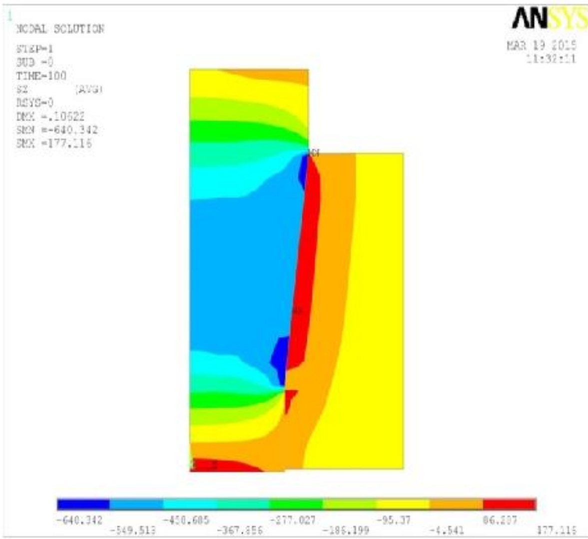
von mises stress



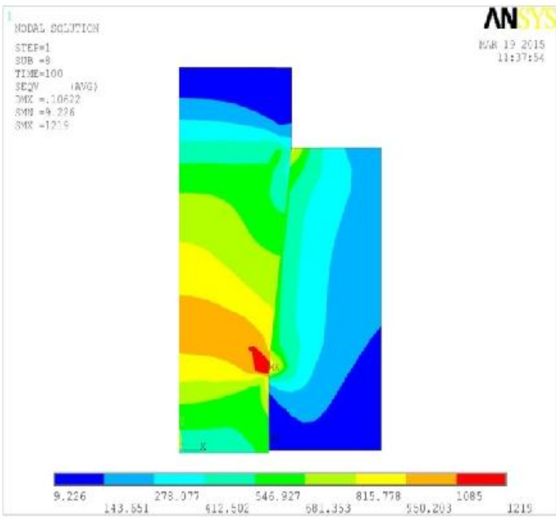
COMMENT: Vonmises stress in wire is sufficient enough to cause yielding of the wire uniformly

b) FOR A LARGE CONE ANGLES

Z – Component Stress



COMMENT: Hoop Stress in die within the allowable limits.

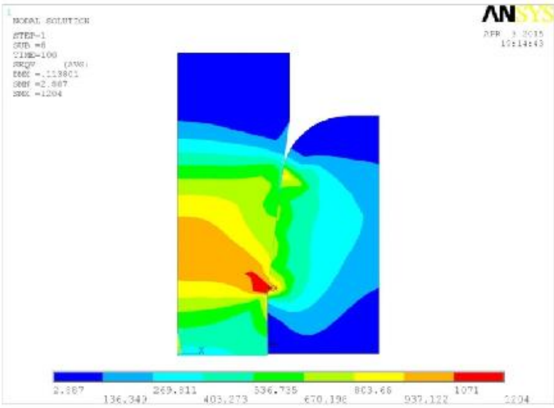


COMMENT: Von Mises stress in die has crossed allowable limits at exit. In wire stress is very large than that is necessary to cause uniform yielding.

Case-3 WIRE DRAWING THROUGH PLANE DIE WITH LAND & FILLET AT ENTRY

a) Small cone angles

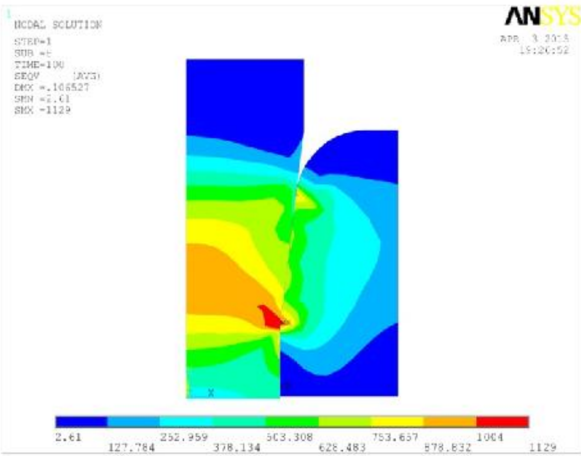
Von Mises stress



COMMENT: Von Mises stress in wire is excessively larger than yield value for a load of 502.16Mpa.Hence the load was reduced to smaller values and tried.

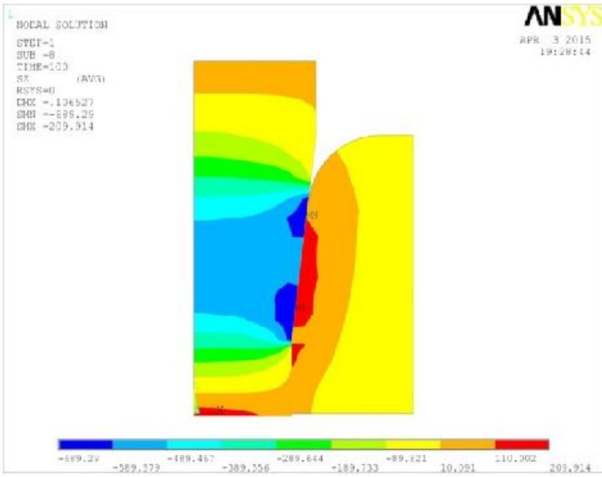
b) Load was reduced to 470Mpa and tried solution

Von Mises stress



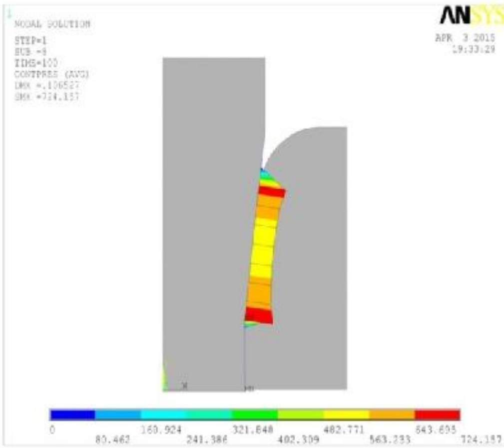
COMMENT: We now find that Von Mises stress is sufficient enough to cause proper yielding. Hence yielding is found to occur at lower stress. This ensures more die life also.

Z – Component Stress



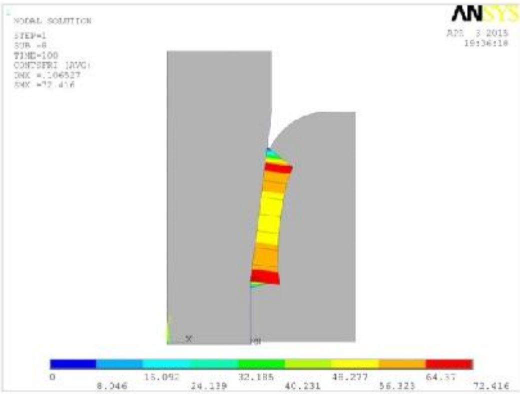
COMMENT: Hoop stress in die is below the allowable limits.

Contact pressure



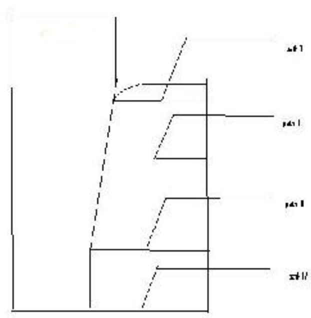
COMMENT: Contact pressure was found to gradually increase from entry unlike what has happened without fillet.

Contact friction stress



COMMENT**:** Contact Friction Stress was found to gradually increase from entry unlike what has happened without fillet.

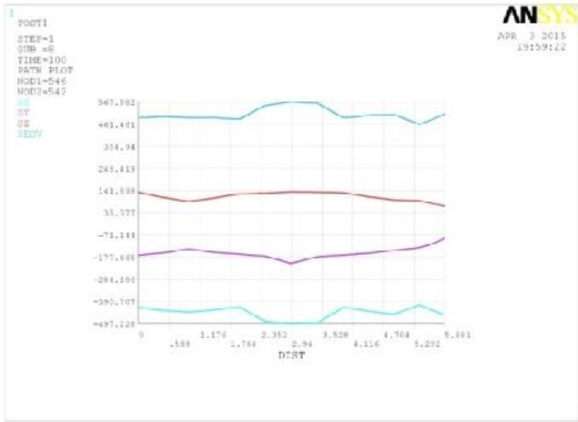
Stress Distribution Diagram



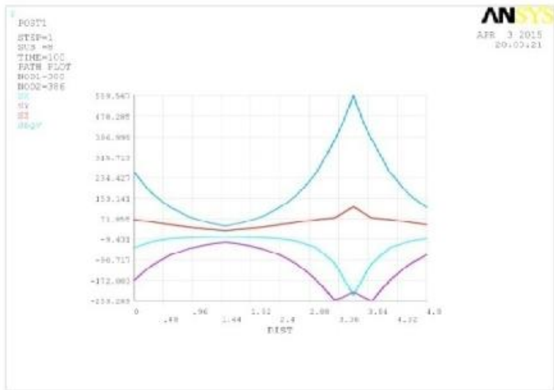
Path 1: Entry, Path 2: Middle, Path 3: Exit at land, Path 4: Exit

Stress distribution

The die at middle



the die at Exit at land



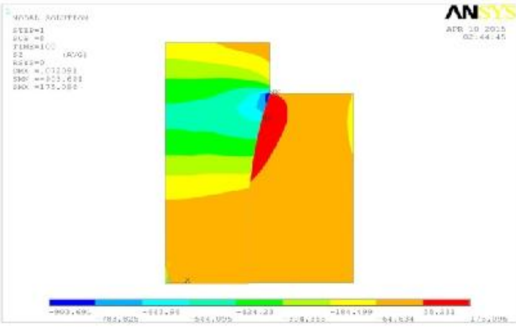
COMMENT: The Die is made up of brittle material (Sintered Alumina). The failure of such material follows maximum principal stress theory. The maximum principal stress in this case is the hoop stress, which is found to be with in the limits. Hence with the changes incorporated (Die land and Fillet), the Die is safe for drawing wire of required reduction ratio.

All the stresses in the die are found to be within allowable limits.

CASE-4 WIRE DRAWING THROUGH CONVEX DIES

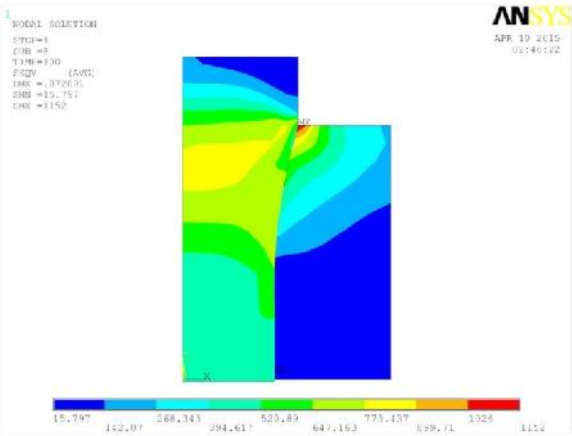
a) Assuming small cone angle.

Z – Component stress



Comment: Hoop stress is with in the limits

Von Mises stress

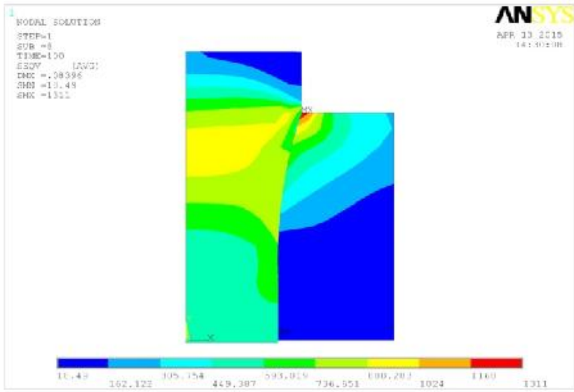


COMMENTS: Von Mises stress in wire is not reached in complete wire at any cross section i.e. some portion of the wire in the core has reached the yield value but the skin has not reached the yield value. Wire drawing defects are likely to occur.

It is therefore felt to increase the drawing force. The results shown below refer to a drawing load of 585Mpa large cone angles

b) LARGE CONE ANGLES

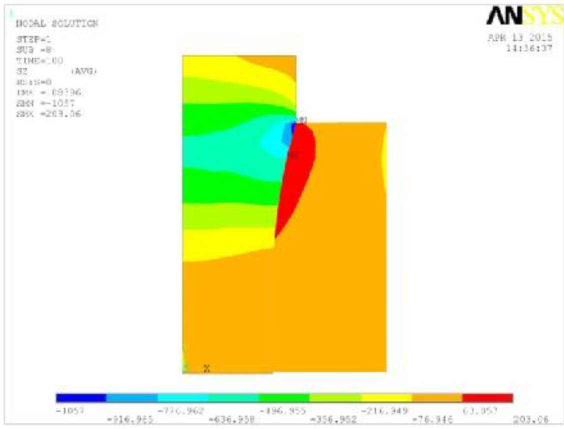
Von Mises stress



COMMENT: The limitations discussed above are now overcome.

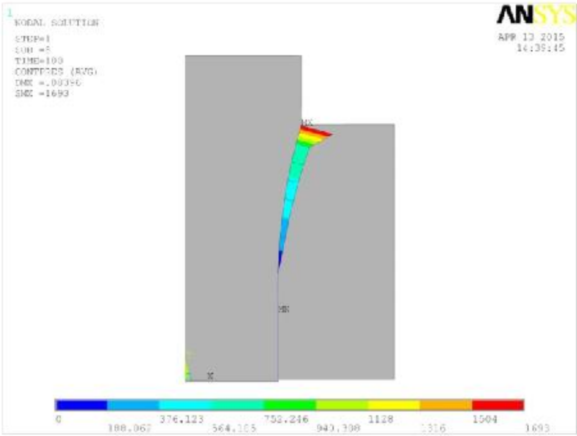
Von Mises stress in wire is reached in complete wire and wire drawing defects are reduced

Z – Component stress



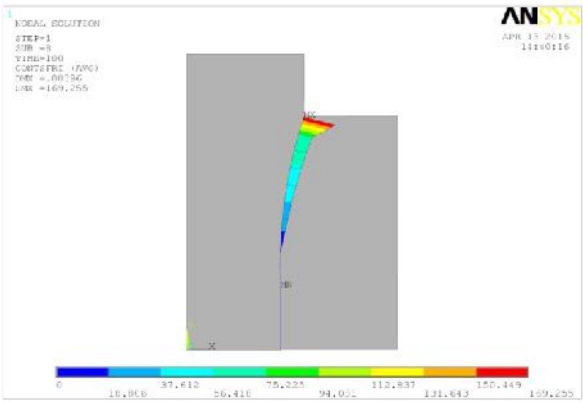
COMMENT: Stress in die is just beyond the allowable limits.

Contact pressure



COMMENT: Peak contact pressure was observed at entrance of the die.

Contact friction stress



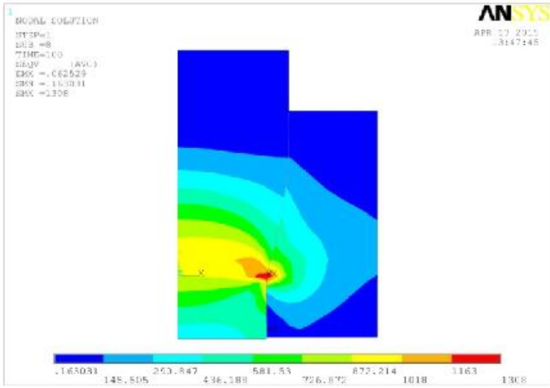
COMMENT: Peak contact pressure was observed at entrance of the die.

CASE-5 WIRE DRAWING THROUGH

CONCAVE DIE

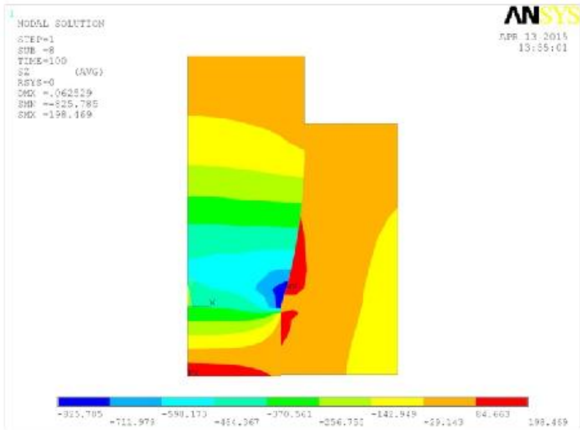
a) **Assuming small cone angle**

Von Mises stress



COMMENT: Von Mises stress in wire is die is very large near beginning of land (load502.16Mpa).This can cause localized yielding And produce drawing defects Hence drawing with smaller loads is tried. A load of 420MPa was found to be optimum.

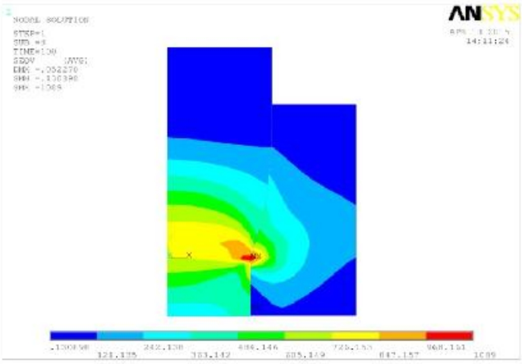
Z – Component stress



COMMENT: Hoop Stress in die with in the allowable limits.

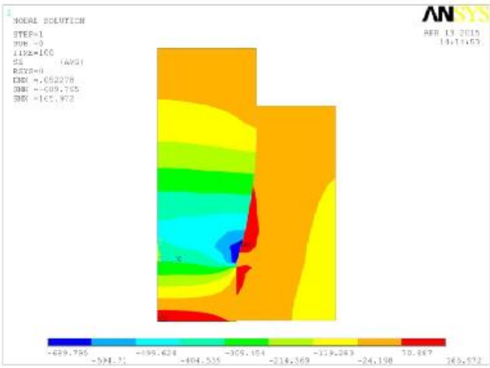
b) **The following results refer to 420mpa load.**

Von Mises stress



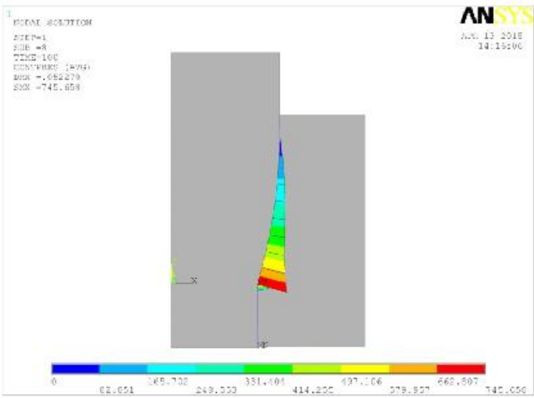
Comment: The von mises stress value is sufficient for uniform yielding at beginning of land

Z – Component stress



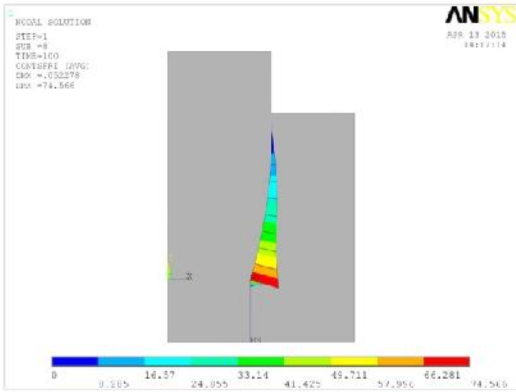
COMMENT: Hoop Stress in die is within the allowable limits.

Contact pressure



COMMENT: Peak contact pressure was observed at beginning of the die land.

Contact friction stress



COMMENT: Peak contact friction stress was observed at beginning of the die land.

VI CONCLUSIONS

Theory of wire drawing was sufficiently studied. Performing the analysis of both wire drawing process and die contours enabled us to understand what is the drawing load required to carry out the drawing process fruitfully i.e. with no wire defects and safe die. Dies with different contours revealed that smooth contours definitely reduce the stress spikes. Further Concave dies show clean flow of material. But from Die point of View, .Convex Dies are better with less stress spikes. Both these ideas led to further improvements i.e., incorporation of die land and filleting at the entry. The use of the powerful tool ANSYS Contact Analysis has helped to observe the stresses in the wire suitable for yielding. We observed that yielding occurred at lower drawing loads than that predicted by theory, making the die safer and work for longer length of wire drawn.

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