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Calculation of Relative Extrusion Pressure for Circular Section by Local Coordinates System by Using Finite Element Method F.E.M

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ABSTRACT - Large development that happens in computers technology leads to the use of modern programs and pollutant about different forming processes from through design and analysis for geometric forms by using Finite Element Method F.E.M, which gives accurate results which approaches experimental results. This study depends on local coordinates system by using rotation of local coordinates for nodes on region contact length between metal and die. This is to calculate relative extrusion pressure and study the effect of relative die length on the relative extrusion pressure for reduction of area (20%, 40%, 60%, 80%) with friction factor (0.1) by using software ANSYS program. The contours for distribution of stresses and plastic strains were obtained, to obtain perfect die length that is needed to less extrusion pressure. The results of this study are compared with experimental result and upper bound theory and have shown a good agreement with a minimum discrepancy.

Keyword: - Relative extrusion pressure, Local coordinates system, Finite element method.

1. INTRODUCTION

The extrusion process is an attractive production method in industry for its ability to achieve energy and material saving, quality improvement and development of homogenous properties throughout the component [(1)]. Extrusion process is one of the important forming processes where put mass of metal in container and it is pushed by using external load which makes the substance flow from a hole which represents shape of product [(2)] , extrusion processes are divided into two types depending on the direction of motion for metal, the first type is called direct extrusion which is used in this study as shown in Figure 1. and the second type is called indirect extrusion and be direction of product which is the inversion direction of the motion of punch [3], in both types, the friction is high because of the compound of friction absence between die and the container and that for absence the relative motion between them. In extrusion process, heat can be used in extrusion process [4], but in this study extrusion on cold is used. Over the last years the field of metal forming is characterized by dynamic development. There are several reasons for this, but one of the most significant undoubtedly is the use computers and powerful software, which radically changed the approach and the way of process design and planning [5]. In nearby time from now upper bound theory has been used to calculate pressure of extrusion, it includes velocity field on inlet and outlet of the die and it results from reduction of area and change of metal flow [6] , and through which forming energies can be calculated. This theory is so complex as compared with finite element method F.E.M gives accurate solutions through the using of engineering analysis and depends on F.E.M in the applications of mechanical engineering by using developed computer program [7], because direct connection with computers through mathematic equations and steps of running. There are many software programs (Mark, Msc, ANSYS) are used and stored in the computers, in this study ANSYS program is used, and analyze this program which does not take much time for analyzing accomplishment, and there are many techniques are used in extrusion processes such as (Contact element, Gab element and Interface element). In this study the technique of local coordinates system will be adopted.

Using this technique, the minimal forming stress can be determined for circular section with respect to reduction area, die geometry, material properties and frictional factors.

The nonlinear analysis is important to get plastic deformation for the metals in forming region, and from prompt obtain minute results for calculate extrusion pressure.

In this study, the axisymmetiric element for the building of extrusion model will be used for modeling circular section of the product. As the potential structural automotive and aerospace application of aluminum extrusions expanded, so the need of mechanical and physical properties become a very important factors to study. For current study, the specifications of aluminum are ($E = 71GNm^{-2}$, $\sigma_y = 50MNm^{-2}$) .

2. FINITE ELEMENT METHOD

Numerical methods provide a general tool to analyze arbitrary geometries and loading condition. Among the numerical methods, Finite Element Method F.E.M has been extensively used with success; however, this kind of analysis requires the generation of a large set of data in order to obtain reasonably accurate results and consumes large investment in engineering time and computer resources [8] .

The finite element method F.E.M for elastic - plastic material property is considered to be an accurate method, but is generally not very well suited for the severe material deformation typical in many metal forming processes, and also result in long CPU time carry out the computations [9].

The deformation state and material flow characteristic can be found both by experimental method and by computer assisted numerical modeling. The finite element method allows the evaluation of the deformations and of the extrusion fields with the practical experiments, the highly depended on the correct establishment of the limit conditions and also on the homogeneousness of the real part characteristics [10].

The finite element method can be briefly described through taking the system for the purpose of solution when the system is divided for elements connected with some points are called nodes. There are different shapes of elements which are used in the systems. They depend on system shape and complexity degree, which can be shaped (triangle walled at three nodes, square or rectangle are walled at four nodes) and another type is found from elements which is called axisymmetiric element which is used in this study.

3. THE INFLUENT PARAMETERS ON THE EXTRUSION PRESSURE

There are influent parameters appliance on the extrusion pressure:-

1- Percentage reduction of area ($R\%$):- is defined as the ratio of change in section area in extrusion process to total section area and depends on material type, material properties and shape of product.
2- Semi die angle (α):- amount represents slant of die wall with extrusion axis.
3- Friction factor (AM):- amount represents the resultant friction because of metal sliding on internal walls of the die.
4- Relative die length (R_L): -it can be calculated from:-

$$R_L = \frac{L_p}{R_p} \text{-------------------------} (1)$$

4. NONLINEAR ANALYSIS

Most materials, when subjected to high stress levels, show plasticity in behavior, i.e. when all the forces acting on the body are removed, the body does not return to its original shape, but has some permanent plastic deformation associated with it (11).

Forming methods are subjected to the nonlinear laws to obtain the geometrical solution. Nonlinear analysis happens in many forms, first: is a substance nonlinear or physical shape nonlinear, second: is a body geometry nonlinear and the third: including the both types (substance nonlinear or physical shape nonlinear and body geometry nonlinear) which used in this study to obtain on the large strains and displacement (plastic deformation).

5. PROCEDURE AND ANALYSIS

In this study the extrusion model is built by using finite element method through the use of ANSYS program, by which quarter of model is drawn at two dimensions because of axisymmetric model. The model is divided into many parts that represent elements and are walled by nodes, and these elements are different in number, shape and size. Many small elements are used to obtain accurate values, choosing shape and size for element depends on complexity degree for model. In this study axisymmetric element is used, figure 2 shows the axisymmetrical geometrical model of the sample in the process of extrusion. The plane quadrangular eight-nod element is adopted to plot out the griddling (12). Material properties are also gives in nonlinear analysis, and the relationship between true stress and true strain of material.

6. TECHNIQUE OF LOCAL COORDINATES SYSTEM

In this study, technique of local coordinates system is used specify the boundary conditions to calculate the extrusion pressure. The coordinates are rotated from (X,Y,Z) to $(\bar{X},\bar{Y},\bar{Z})$ on the length of contact region between metal and die, then boundary conditions for all nods are given to make free motion in the direction $(\bar{X})$ which represents the metal and fix $(\bar{Y})$ (no motion) which represent the die (13), as shown Figure 3.

7. CALCULATION OF EXTRUSION PRESSURE WITH FRICTION

As a result of metal motion through a die, a friction force is appeared opposite to that motion, so the coefficient of friction has an important effect at the extrusion process. Therefore extrusion pressure must be a function of friction force .

In the present study, the friction can be explained as follows: The reaction force will be produced perpendicularly along the contact (all nodes) between the die and metal through extrusion process. If this force is represented by (N), then the friction force (F) is:

$$F = N.m ------------------------------- (2)$$

This process is repeated many times until arrived the convergent state in the result of the reaction force between die and metal as in fig 3.

8. RESULTS AND DISCUSSIONS

Through using finite element method by the technique of Local Coordinates System, and the procedure of nonlinear analysis to model by using ANSYS program, we got strains and stresses distribution contours, the effect of relative die length (R_L) on relative extrusion pressure (P_r) with friction factor (AM) and relationship between reduction of area ($R\%$) and relative extrusion pressure.

1- EFFECT OF RELATIVE DIE LENGTH ON RELATIVE EXTRUSION PRESSURE

The optimum choosing for die length is one of the important matters for lessening extrusion pressure and redundant work to obtain a good product. By this optimum length of die a good geometrical shape can be achieved.

Figure 4 shows the relationship between relative extrusion pressure and relative die length for reduction of area (20%, 40%, 60% and 80%) with friction factor (0.1), it shows that optimum relative die length that give minimum relative extrusion pressure.

To make a comparison between present work F.E.M, U.B.T and EXP[3], relative extrusion pressure (P_r) is drawn as a function of the relative die length (R_L) as fig 5, the comparison showed that the results obtained by F.E,M is the nearest to the experimental result which is clearly shown in table 1.

2- EFFECT OF REDUCTION OF AREA ON RELATIVE EXTRUSION PRESSURE

Figure 6 shows the relationship between relative extrusion pressure and reduction of area for friction factor (0.1), when relative die length is equal 2, it is shown that relative extrusion pressure is increasing with the increase of reduction of area, because of increasing of relative energy consumption which is resulted from plastic deformation.

3- EFFECT OF RELATIVE DIE LENGTH ON DISTRIBUTION OF STRAINS AND STRESSES FOR EXTRUSION MODEL

The Figures 7a, 7b & 8a, 8b show the contours of the distribution of strains for extrusion model when (AM= 0.1, $R = 40\%$) for relative die length ($R_L = 1.5$, $R_L = 2$). We can see that forming region is in the plastic deformation state, and it is shown that shapes have different distribution of strains because of the change of metal velocity in the region of forming, and high strain in the starting point of the forming region on the surface of the contact region between metal and die because of the resulting high stresses. High friction in contact region due to metal motion to the direction of extrusion force. Value of extrusion pressure equals (40 Mpa) when ($R_L = 1.5$) and equals (35 Mpa) when ($R_L = 2$). When ($R_L = 2$) less extrusion pressure is needed then it can be considered as optimum relative die length.

In Figures 9a, 9b & 10a, 10b we can see the contours distribution of stresses for extrusion model when (AM= 0.1, $R = 40\%$) for relative die length ($R_L = 1.5$, $R_L = 2$). It is shown that high stress be in start of the forming region, and lower stress is after the forming region, because of the change in radius for the metal through extrusion process, we can observe the increase of extrusion pressure will increase stress concentration at the inlet of die.

4- EFFECT OF REDUCTION OF AREA ON DISTRIBUTION OF STRAINS AND STRESSES FOR EXTRUSION MODEL

The Figures ١١a & 11b show the contours of the distribution of strain for extrusion model when (AM= 0.1, $R_L = 2$) and ($R = 20\%$). It is seen that forming region is in the plastic deformation state and show that different shapes of strains distribution is in the region of forming using extrusion pressure of (20 Mpa). After the comparison with figures 8a & 8b when (AM= 0.1, $R_L = 2$) and ($R = 40\%$), using extrusion pressure (35 Mpa), this pressure increase is due to increasing of relative energy consumption which resulted from plastic deformation.

In Figures 12a & 12b we can see the contours distribution of stresses for extrusion model when (AM= 0.1, $R_L = 2$) for reduction of area ($R = 20\%$) it is shown that high stress be in start of the forming region and lower stress after a forming region. After the comparison with figures 10a & 10b when (AM= 0.1, $R_L = 2$) for reduction of area ($R = 40\%$). We can observe that the increase in reduction of area will increase stress concentration at the inlet of die and lead to increase the extrusion pressure because of the change in section area before and after forming.

9. CONCLUSION

Through using the finite element method by technique of local coordinates system for extrusion of circular section.

1- The optimum die length gives less relative extrusion pressure for reduction of area different (20%, 40%,60% and 80%) and friction factor (0.1)
2- The reduction of area leads to the increase of plastic deformations in the forming region., also lead to increase of relative extrusion pressure.
3- The choice of optimum geometrical shape of die is needed to less extrusion pressure.
4- Technique of local coordinates system is need of less time to calculate extrusion pressure if it is compared with another method.
5- Local coordinates system technique shows a good agreement with the available experimental results comparing with the upper bound theory.

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SYMBOLS DESCRIPTION AND UNITS

Symbols	Description	Units
AM	Friction Factor	___
E	Young's Modulus	N/mm^2
F	Friction Force	N
L_P	Pass Length for Die	mm
m	Friction Coefficient	___
N	Reaction Force	N
P_{Ext}	Extrusion pressure	N/mm^2
P_r	Relative Extrusion pressure	___
$R\%$	Percentage Reduction of Area	___
R_L	Relative Die Length	___
R_O	Radius of Section before Extrusion	mm
R_P	Radius of Section after Extrusion	mm
σ_y	Yield Stress	N/mm^2
α	Semi Die Angle	Degree
CPU	Central Processing Unit	___
EXP	Experimental Results	___
F.E.M	Finite Element Method	___
U.B.T	Upper Bound Theory	___

Table (1): Compare between (U.B.T), (F.E.M) and (EXP) where $R = 60\%$ and AM=0.1

R_L	(P_r)U.B.T	(P_r)F.E.M	(P_r)EXP
1	1.7	1.6	1.4
1.5	1.5	1.4	1.25
2	1.4	1.3	1.1
2.5	1.45	1.35	1.15
3	1.5	1.38	1.23
3.5	1.52	1.4	1.3
4	1.6	1.5	1.35

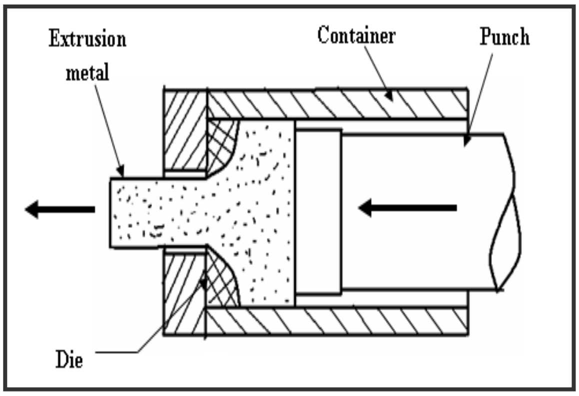


Fig. (1): Direct extrusion process.

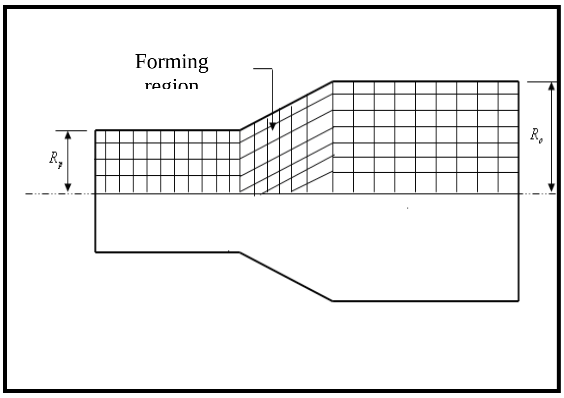


Fig. (2): Axisemmetric element.

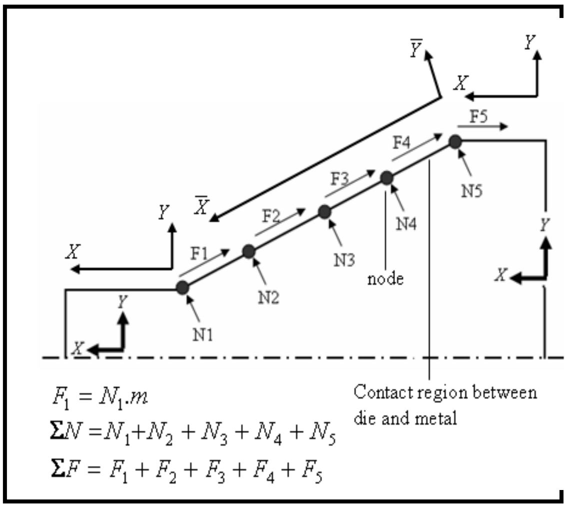


Fig. (3): Friction force for local coordinates system.

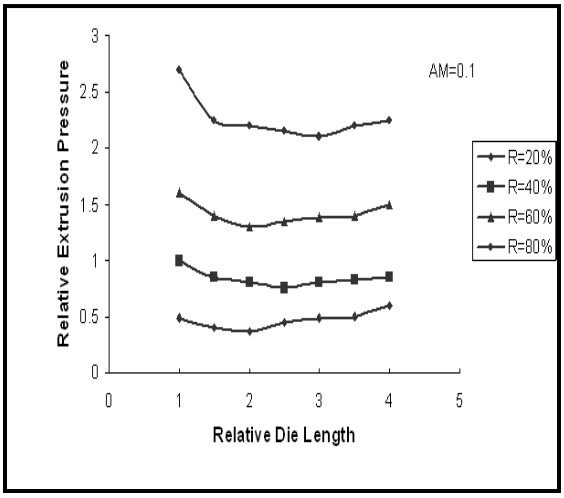


Fig. (4): Relationship between relative extrusion pressure and relative die length.

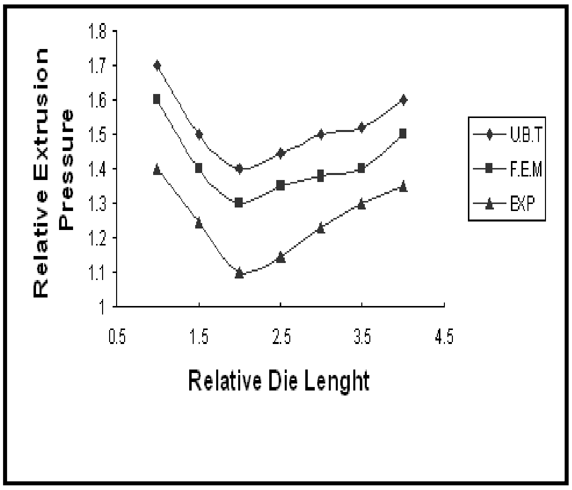


Fig. (5): Compare between (U.B.T), (F.E.M) and (EXP)[3]

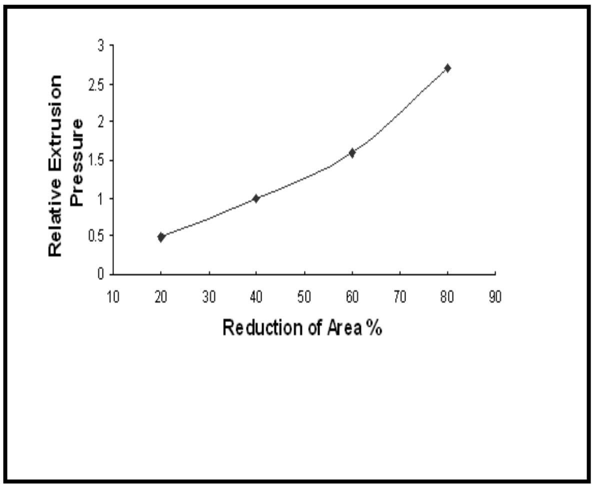
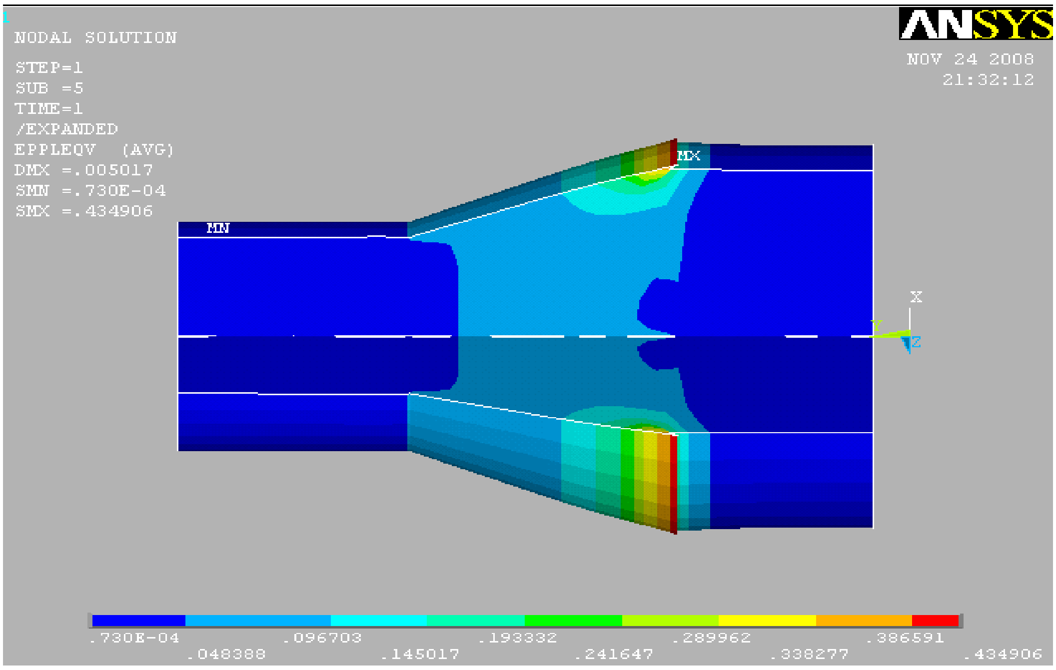
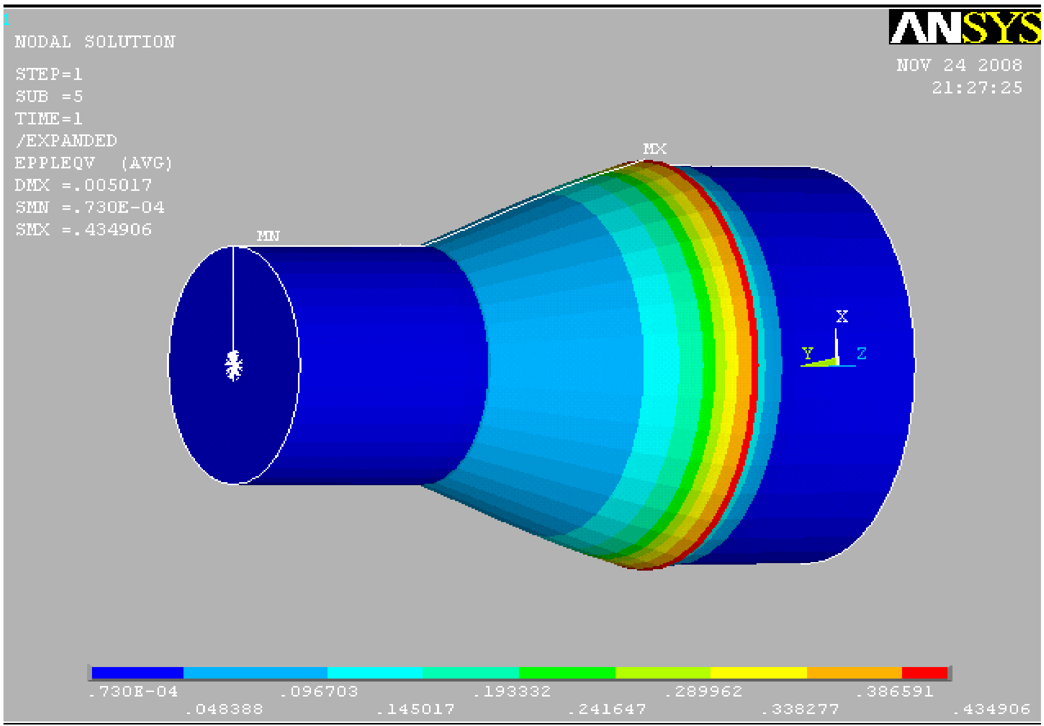


Fig. (6): Relationship between relative extrusion pressure and reduction of area%



((3/4) Expansion , $P_{Ext} = 40 Mpa$)

Fig. (7a): distribution of plastic strains where $R = 40\%$ **,** AM=0.1, and $R_L = 1.5$



(Full Expansion , $P_{Ext} = 40 Mpa$)

Fig. (7b): distribution of plastic strains where $R = 40\%$ **,** AM=0.1 and $R_L = 1.5$**.**

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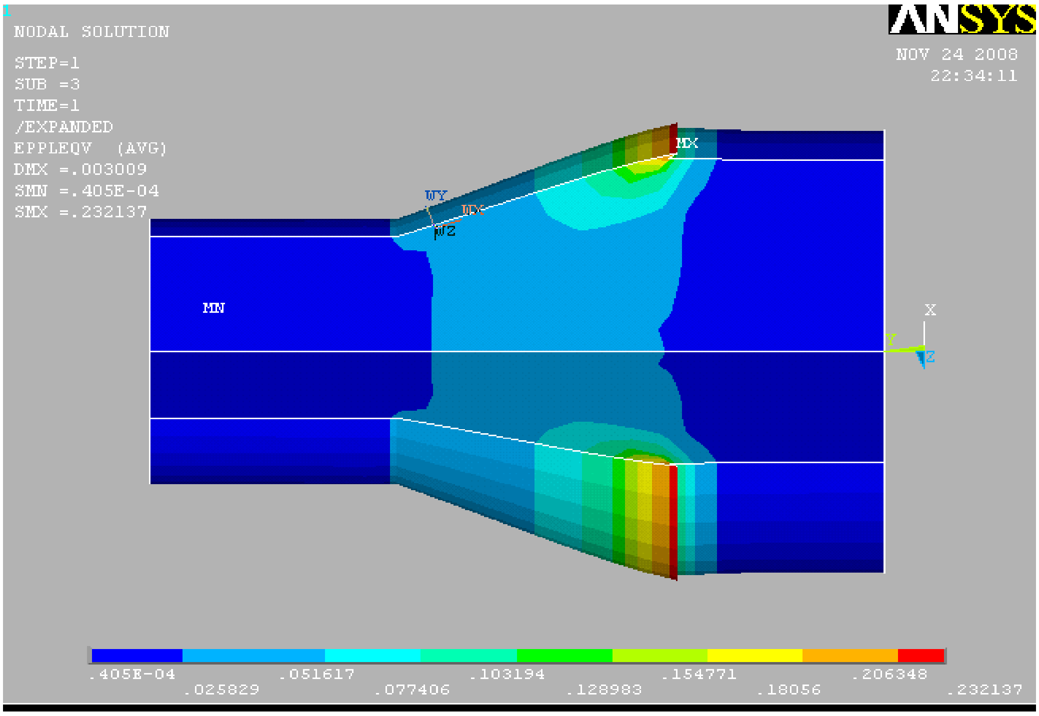
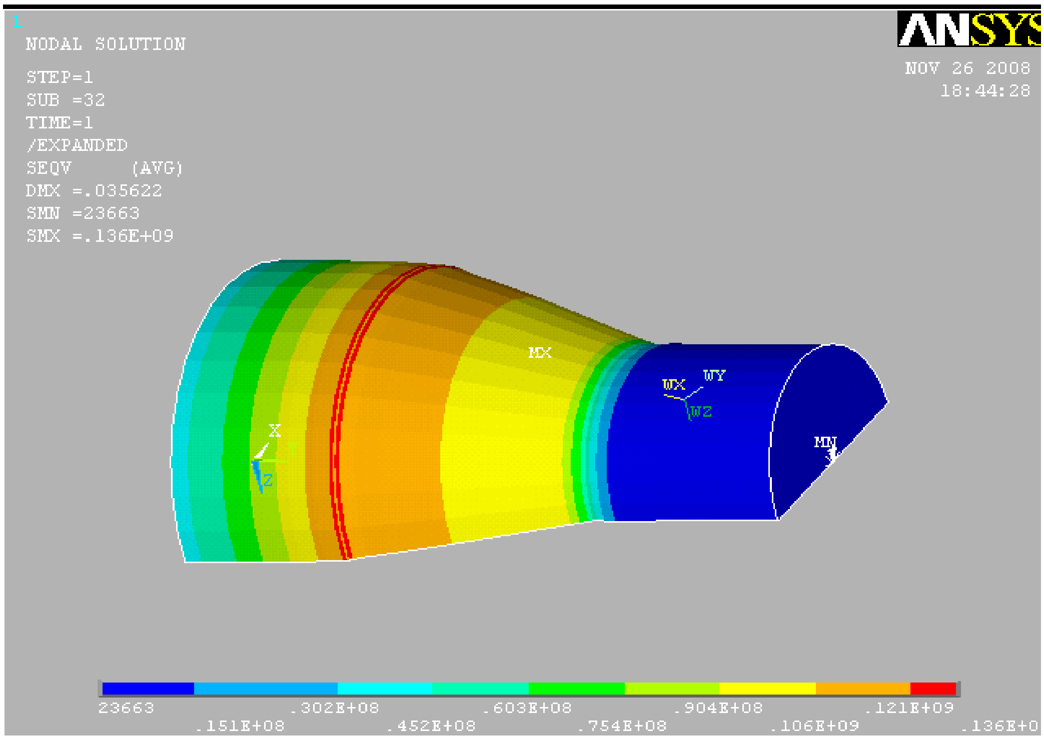


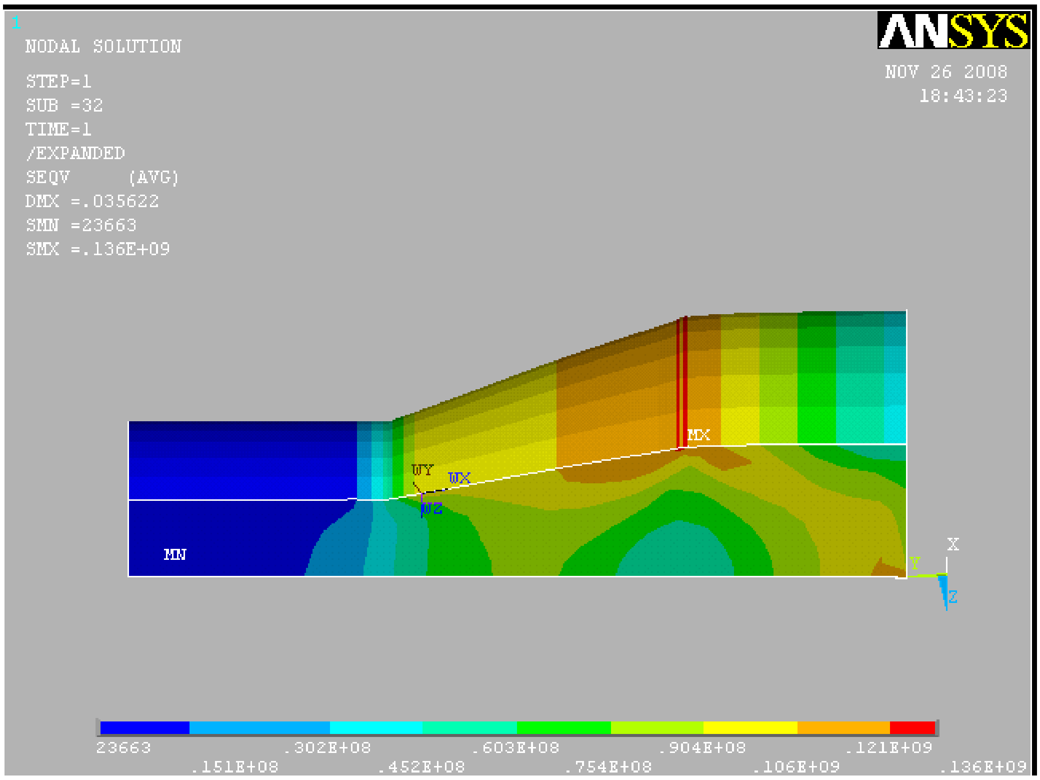
((3/4) Expansion , $P_{Ext} = 35Mpa$)

Fig. (8a): distribution of plastic strains where $R = 40\%$, AM=0.1 and $R_L = 2$.



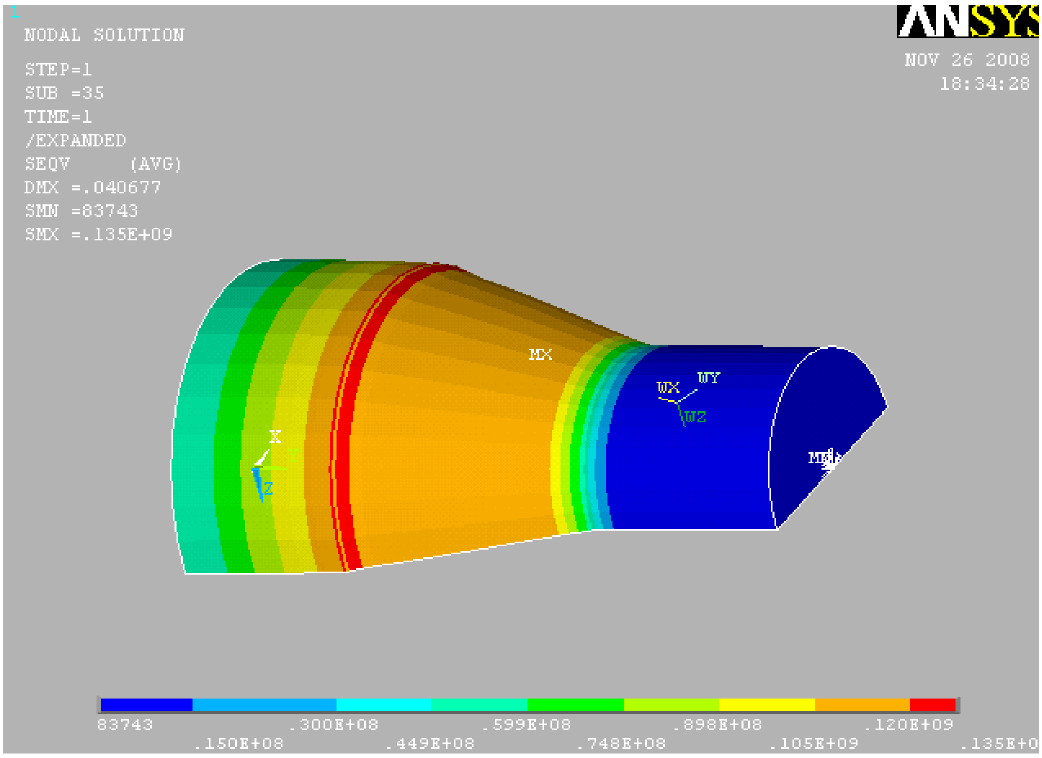
((1/2) Expansion , $P_{Ext} = 40Mpa$)

Fig. (9a): distribution stresses where $R = 40\%$, AM=0.1 and $R_L = 1.5$.



((1/4) Expansion $P_{Ext} = 40 Mpa$)

Fig. (9b): distribution stresses where $R = 40\%$ **,** AM=0.1 and $R_L = 1.5$**.**



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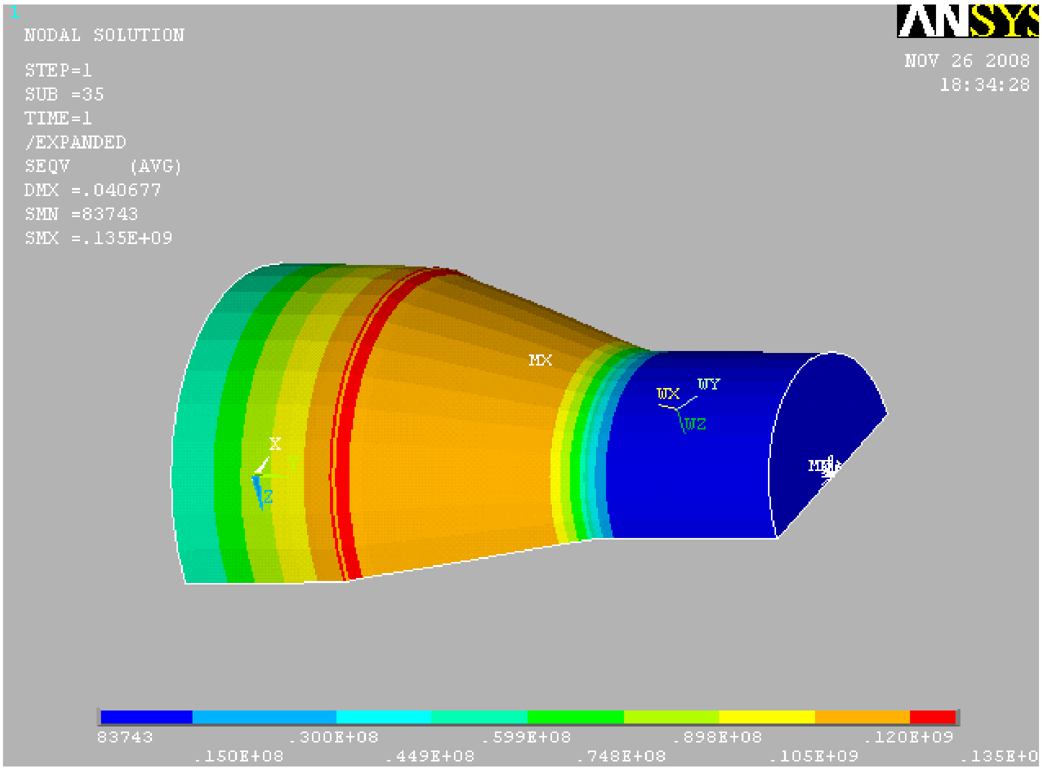
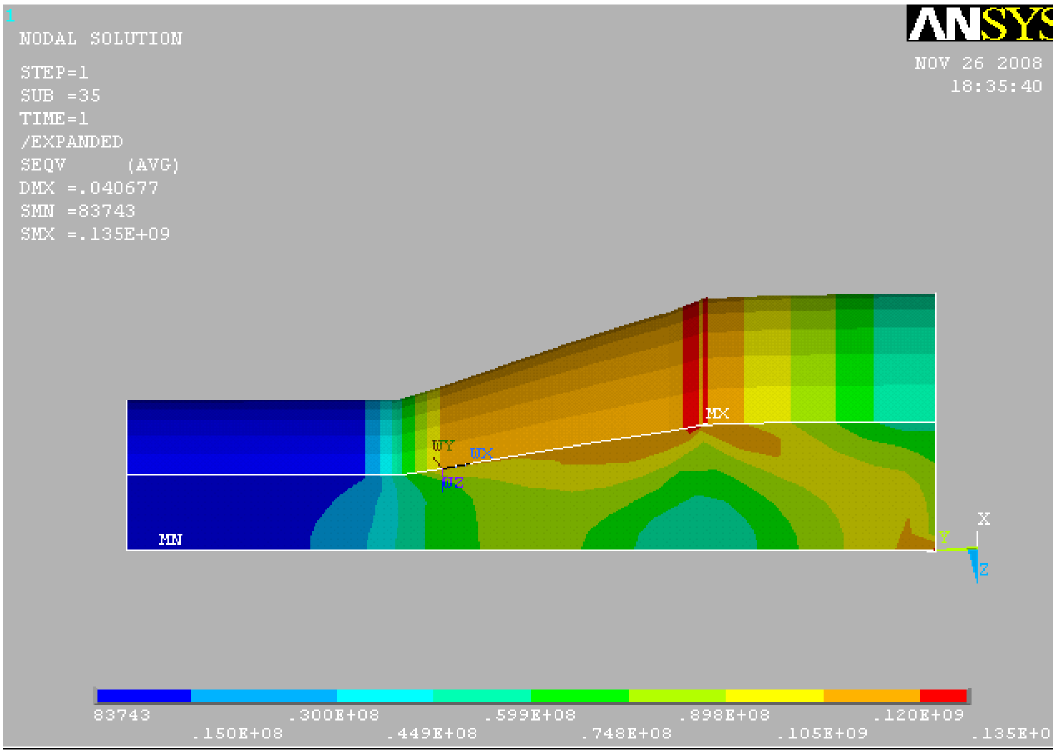
((1/2) Expansion , $P_{Ext} = 35 Mpa$)

Fig. (10a) distribution stresses where $R = 40\%$ AM=0.1 **and** $R_L = 2$



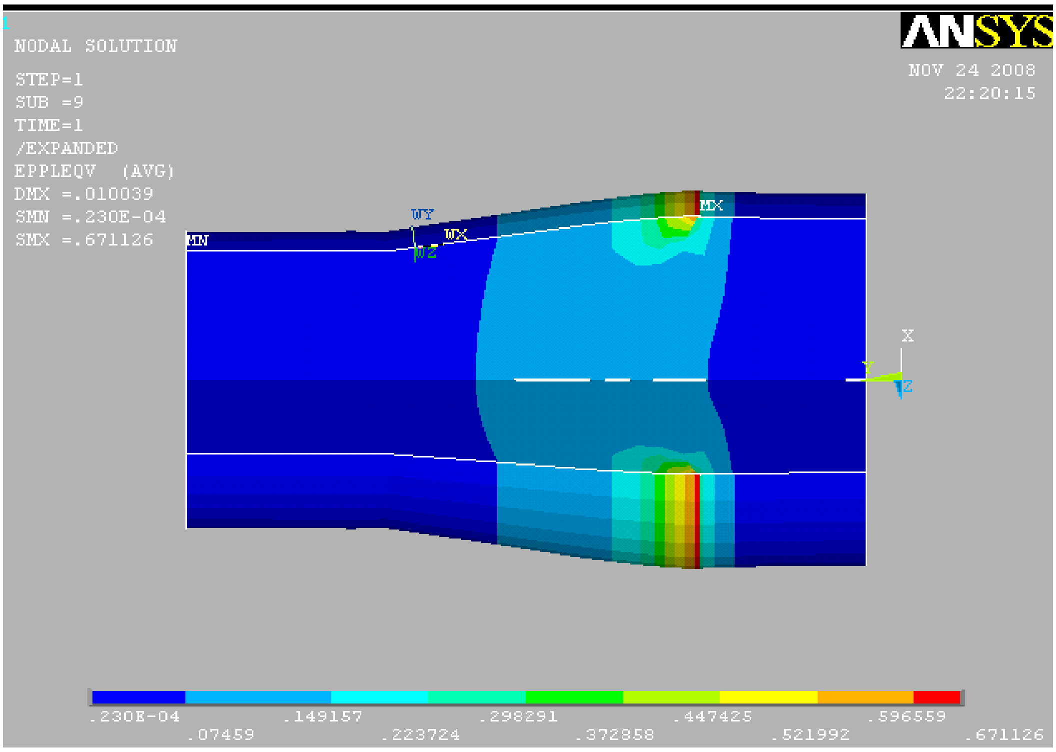
((1/2) Expansion , $P_{Ext} = 35Mpa$)

Fig (10a): distribution stresses where $R = 40\%$, AM=0.1 and $R_L = 2$



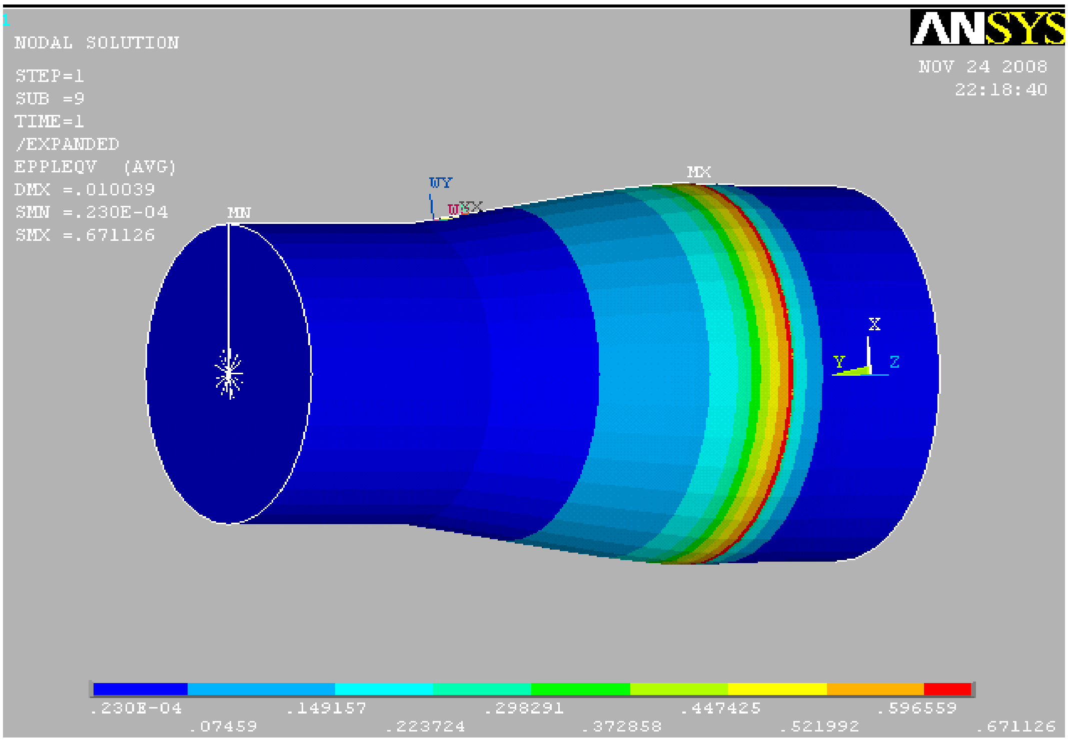
((1/4) Expansion , $P_{Ext} = 35Mpa$)

Fig. (10b): distribution stresses where $R = 40\%$, AM=0.1 and $R_L = 2$.



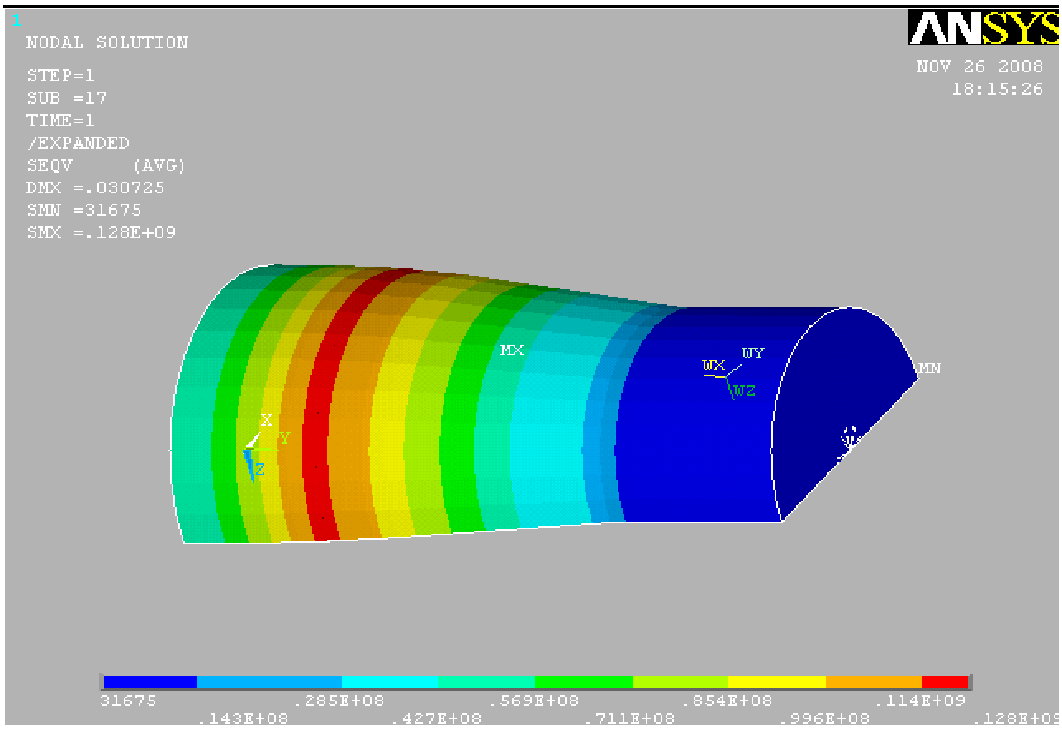
((3/4) Expansion , $P_{Ext} = 20 Mpa$)

Fig. (11a): distribution of plastic strains $R = 20\%$, AM=0.1 and $R_L = 2$.



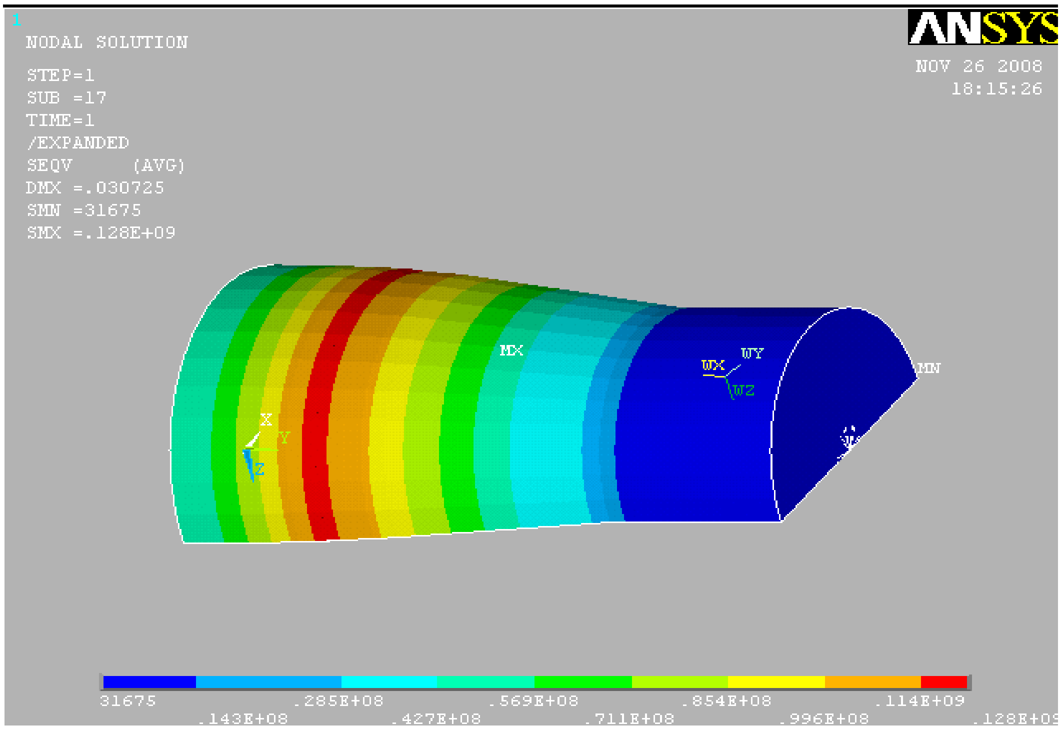
(Full Expansion , $P_{Ext} = 20 Mpa$)

Fig. (11b): distribution of plastic strains $R = 20\%$, AM=0.1 and $R_L = 2$.



((1/2) Expansion , $P_{Ext} = 20Mpa$)

Fig (12a): distribution stresses where $R = 20\%$, AM=0.1 and $R_L = 2$



((1/2) Expansion , $P_{Ext} = 20Mpa$)

Fig. (12a): distribution stresses where $R = 20\%$, AM=0.1 and $R_L = 2$.

استخدام تقنية نظام الإحداثيات الموقعية لبثق المقاطع الدائرية بواسطة طريقة العناصر المحددة

جبارقاسم جبار
مدرس مساعد
كلية الهندسة– جامعة ديالى

الخلاصة

أن التطور الكبير الذي حدث في مجال تكنولوجيا الحاسبات أدى إلى استخدام برامج متطورة وحديثة في عمليات التشكيل المختلفة خلال تصميم وتحليل الإشكال الهندسية باستخدام طريقة العناصر المحددة التي تعطي نتائج دقيقة مقاربة للنتائج العملية. اعتمدت هذه الدراسة على نظام الإحداثيات الموقعية بتدوير الإحداثيات الموقعية للعقد على طول منطقة التماس بين القالب والمعدن لحساب ضغط البثق للمقاطع الدائرية ودراسة تأثير طول القالب النسبي على ضغط البثق النسبي لنسب التخصر بالمساحة (٢٠ % ، ٤٠% ، ٦٠ %، ٨٠ %) وعامل احتكاك (٠.١) من خلال استخدام برنامج (ANSYS) حيث تم الحصول على أشكال توزيع الاجهادات والانفعالات اللدنة لعملية البثق وكذلك الحصول على طول القالب المثالي الذي يحتاج إلى اقل ضغط بثق. النتائج في هذه الدراسة قورنت مع النتائج العملية ونظرية الحد الأعلى وأظهرت تطابق جيد مع تناقض قليل