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Three-Dimensional Finite Element Analysis of Material Nonlinearity

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ABSTRACT

The structural analysis of any conventional materials are performed under the assumption of linearity. Strictly claiming, no engineering materials purely exhibits linear properties. Many engineering structural problems are analyzed under the treatment of linear approach in order to decrease the time and computational memory. Geometrical, contact and material nonlinear are such important nonlinear approaches the analysts need to consider while analyzing the material response under several loading conditions. The present work is concentrated on material nonlinearity or spring back effect or plasticity effect. The analysis is performed by opting bush and plate model to unfold the effect of plasticity using finite element software ANSYS.

Keywords: Nonlinear, spring back, Finite Element Method, Ansys.

INTRODUCTION

Many engineering applications have been utilizing the finite element analysis in order to reduce the analysis time and cost with promising results. The primary focus of the finite element analysis is limited to linear elastic materials. However, with the increment of powerful computers with finite element software, the applications of finite element methods are extended to the analysis of nonlinear and non-elastic materials. These applications have been promoted to focus on important static analysis of structures where there is need to consider the material properties while designing particular mechanical structures. Unlike elastic metals, plastic materials like polyethylene have very little tensile strength. When compressed, these materials will yield and become permanently deformed due to the locking of deformations. Especially several mechanical, aeronautical and military applications may require FEM to simulate the three dimensional, nonlinear analyses in order to understand the behavior of materials under existing conditions. Successful simulation would provide the opportunity for significant cost reduction in the design process. This article focusses on the spring back effect between the rigid plate and polyethylene bush using the finite element software ANSYS. The relevant literature pertaining to the present work is provided by many authors. Gite et al., [1] studied various parameters affecting spring back effect of such as ratio of die radius to the sheet thickness, sheet thickness, blank holder force and coefficient of friction. Spring back phenomenon application in the forming process is studied through finite element software ANSYS by Prabhakar et al., [2]. Elastic recovery of metal during unloading process is predicted by Amul Biradar and M.D Deshpande [3] using Finite element software ANSYS. Raghvendra Vijaywargiya, Itzhak Green [4] presented total energy loss due to sliding under an elastic plastic deformation as a function of the sliding distances. Some cases, spring back causes geometrical inaccuracies of bent parts in bending operations. To restrain

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these spring back, bending parameter need to be considered. Akinlabi et al., [5] reported the effects of spring back on mechanically formed steel plates. Topology optimization of both geometrically and materially nonlinear structure is studied using a general displacement functional as the objective function by Daeyoon Jung, Hae Chang Gea [6] using numerical techniques.
Chiroux et al., [7] achieved displacement and stress results analytically and compared these to experimental results for soil and wheel repsone of the structures using nonlinear approach with the support of finite element method. A numerical study using the finite element method was developed by Antunes et al.,[8] to understand the limited response of the component and to study the effect of changing material and geometry under electrical application. The deformation of a composite made up of a random and homogeneous dispersion of elastic spheres in an elasto-plastic matrix was simulated by the finite element analysis of three dimensional multi particle cubic cells with periodic boundary conditions by Gonzalez et al., [9]. large deformation elasto-plasticity problems including unilateral contact and friction is presented together with an extension of the friction law for large deformation analysis by Jung-ho Cheng and Noboru kikuchi [10].

MODEL DESCRIPTION

A three-dimensional finite element model was constructed using the ANSYS finite element program. Material nonlinear effect is studied by selecting bush and plate model. the square shaped high stiffed plate is modeled and used to compress the bush which is made with very low stiffened material. The analysis is carried out for the behavior of linear and nonlinear response of the bush and plate model. the geometrical details of the plate and bush are taken as given below.

- Inner diameter of bush (D_i) = 27.5 mm; Outer diameter of bush (D_o) = 36 mm; Length of bush (L)=26.5mm; Side of the square plate= 50 mm; thickness of plate = 8 mm. The geometrical details are provided in Fig.1 and all the dimensions are in mm.

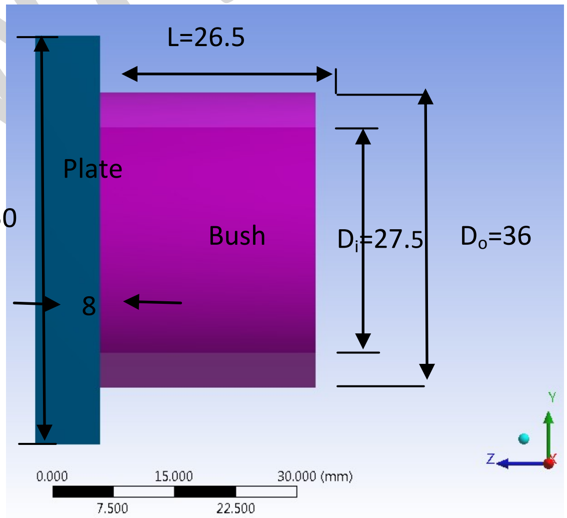

Fig.1. Geometry of bush and plate model

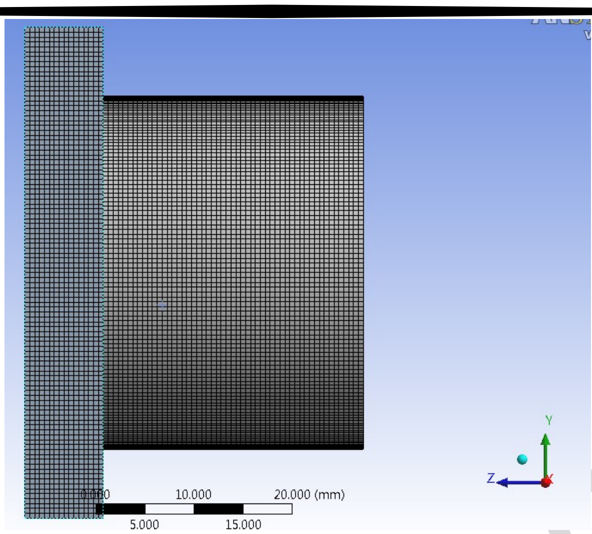

Fig.2. Finite Element mesh on bush and plate model

MATERIAL PROPERTIES

In order to predict spring back effect or nonlinearity effect, the bush is attributed with polythene and the plate is assigned high stiffened material of structural steel with Young's modulus of 2e9MPa. The high stiffened plate is used to compresses low stiffness bush. For better understanding the material nonlinearity effect, the linear analysis is also performed by selecting default polythene material properties available in ANSYS workbench. And for material nonlinearity effect, the multilinear isotropic hardening parameters are considered. Default polythene properties are sufficient to perform the linear analysis but in the nonlinear analysis, the plastic strain corresponding to the stresses is required. Table.1 shows the variation of plastic strain corresponding to the stress which is provided in plasticity multilinear isotropic option in workbench. The young's modulus of plate is taken as E=2e9MPa, Poisson's ratio=0.3

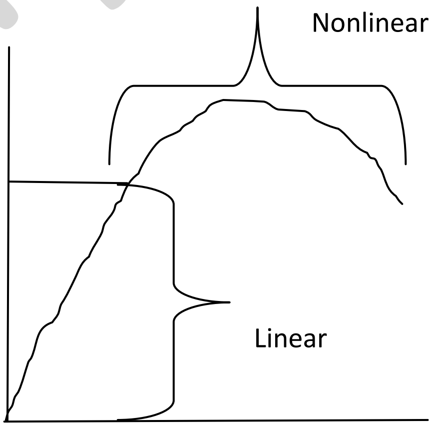

Fig.3. Stress Strain curve for general materials

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Table.1. Material Properties for nonlinear analysis

Plastic strain MM^-2	Stress (MPa)
0	18
1e-5	38
2e-5	39
3e-5	40
4e-5	41

LOADING AND BOUNDARY CONDITIONS

The high stiffness plate is used to displace the bush for 5mm and the plate will be regained to its original position after the displacement. The bush after taking compressive displacement from plate, it will not regain its previous size, shape due to the behavior of non-linearity. One end of the bush is fixed in all aspects and the plate is displaced for 5 mm. the finite element mesh is shown in the Fig.2.

SOLUTION CONTROLS FOR LINEAR ANALYSIS

In the linear analysis, compressive deformation is applied in 3 steps. In the first step no deformation is applied and in the second load step the compressive deformation of 5mm is applied and in the last load step the deformation is moved back to 0mm.

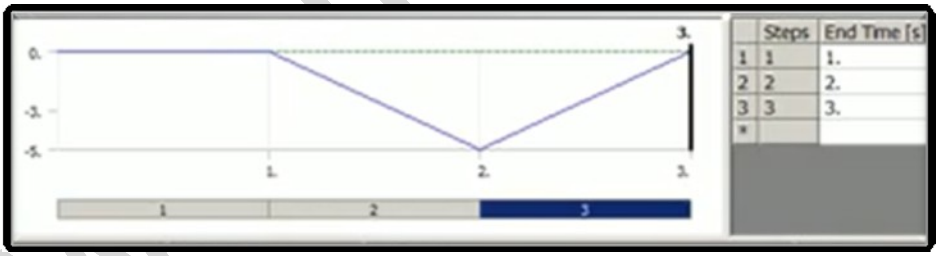

Fig. 3. Details of deformation applied in three load steps for analysis

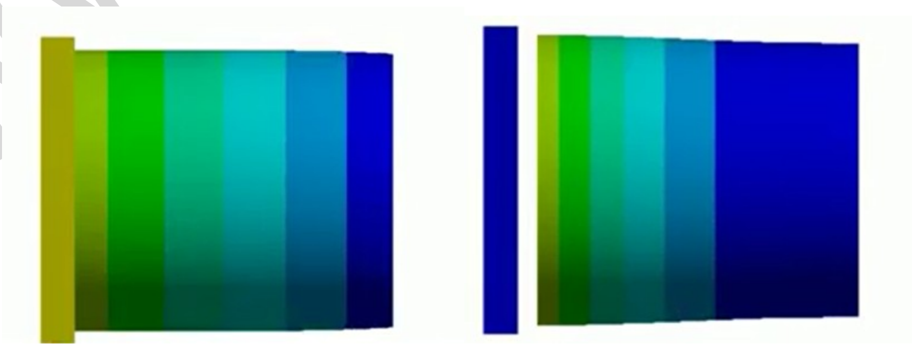

Fig.4. Displacement contours for linear and nonlinear analysis

RESULTS

The primary objective of the present study is to understand the difference between the linear and nonlinear analysis in terms of force displacement relations, strain energy and stresses. From the Fig.5 it is observed that the reaction forces in bush are increasing with increasing the deformation and at the same time decreasing the reaction forces decrease the deformation. The response of the bush is same in loading and unloading, which indicates the strain associated in the material due to compressive load completely disappeared when the load is removed. This is also indicated that there is no nonlinear effect or spring back effect or plasticity effect under the provided conditions.

A different behavior is observed from Fig.6. The effect of geometrical nonlinearity is clearly observed from the Fig.6. unlike linear response, (Fig.5) the variation of force with respect to displacement is not same during loading and unloading stages. That is due to the plasticity response of the bush under compressive deformation which cannot be regained its shape completely. Considerable amount of strains is locked in the material as a result the shape and size of the bush are changed.

Fig.7 shows the variation strain energy with respect to the deformation. In the linear analysis, the variation of strain energy is increases with increase in the displacement. But in the nonlinear analysis, (Fig.8) the strain energy is maximum upto certain displacement, later sudden decline in the property is observed in the property with respect to the displacement due to nonlinear plasticity.

Fig.9-10 shows the variation of normal stresses under the assumption of linear and nonlinear methodology. As the name indicates, the variation of normal stress is increasing with increasing the displacement on the bush whereas the path followed by during loading and unloading is same. Unlike the linear analysis, different situation is arised in nonlinear response as shown in the Fig.10.

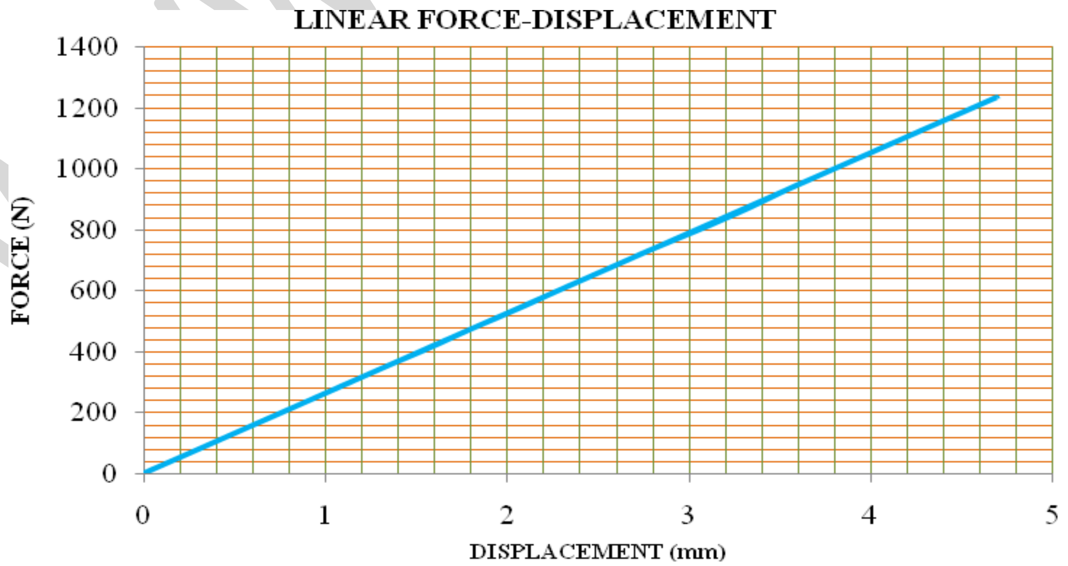

Fig.5. Variation force and displacement for linear analysis

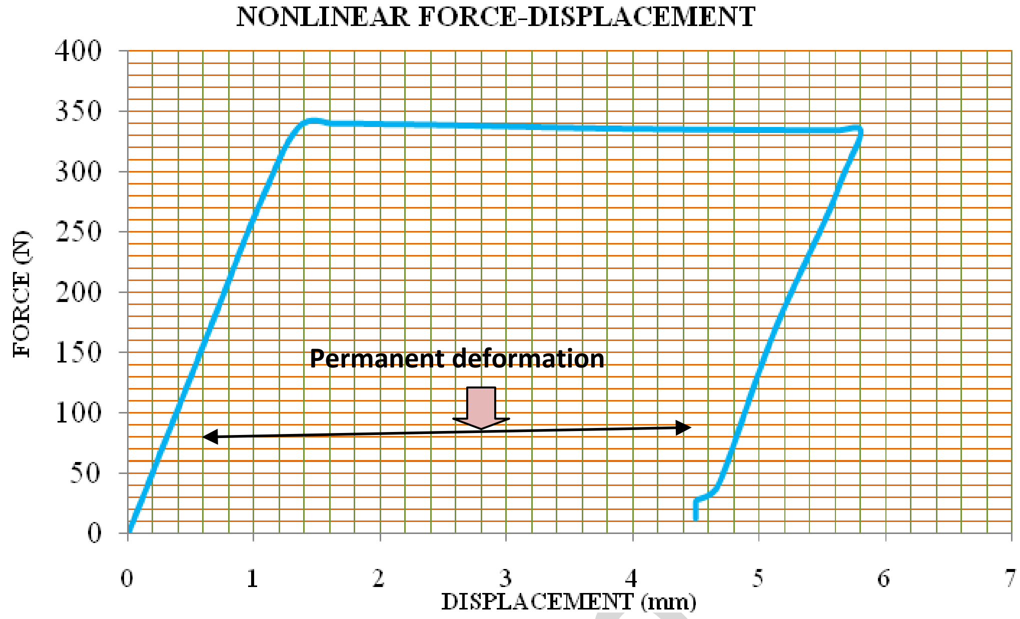

Fig.6. Variation force and displacement for nonlinear analysis

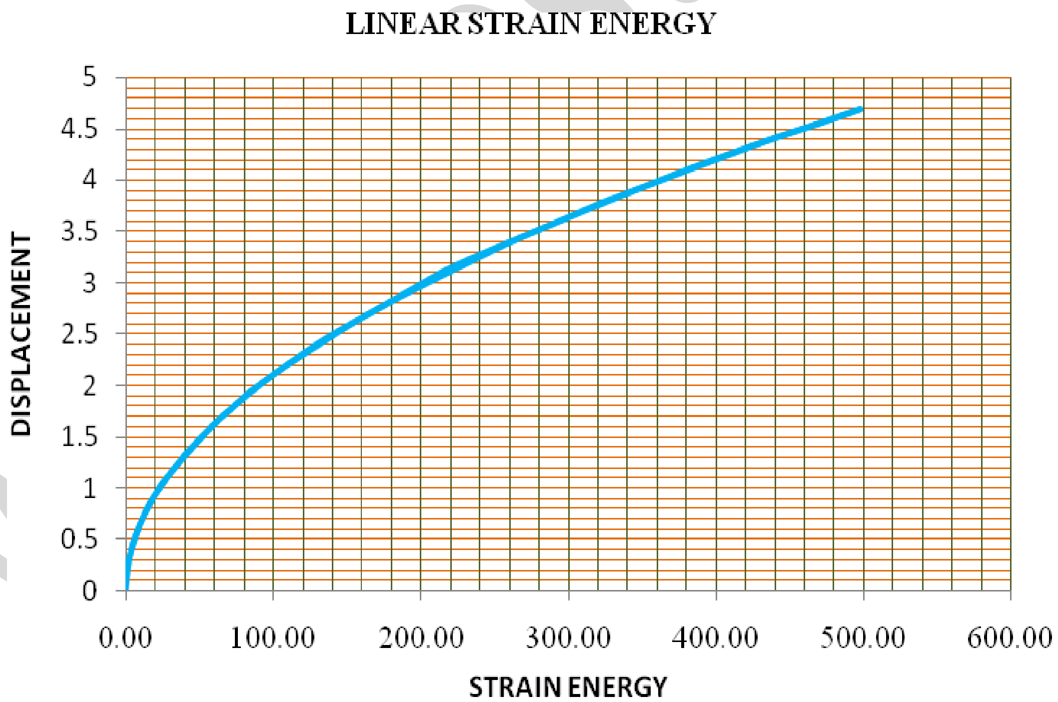

Fig.7. variation of strain energy for linear analysis

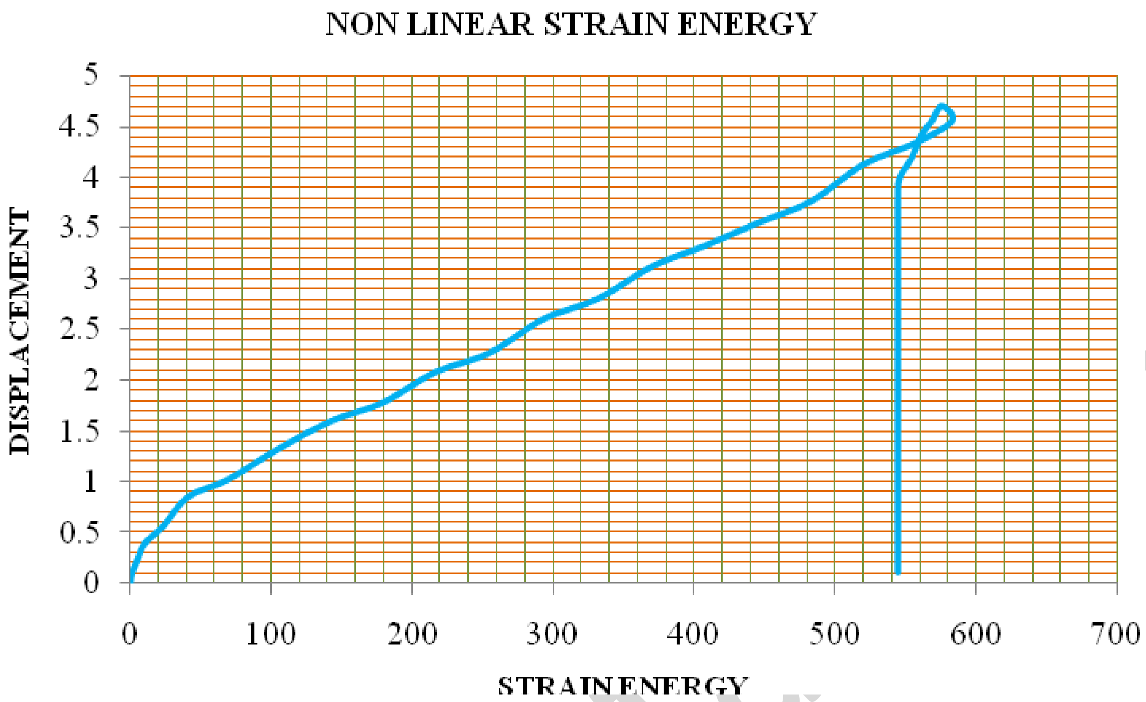

Fig.8. variation of strain energy for nonlinear analysis

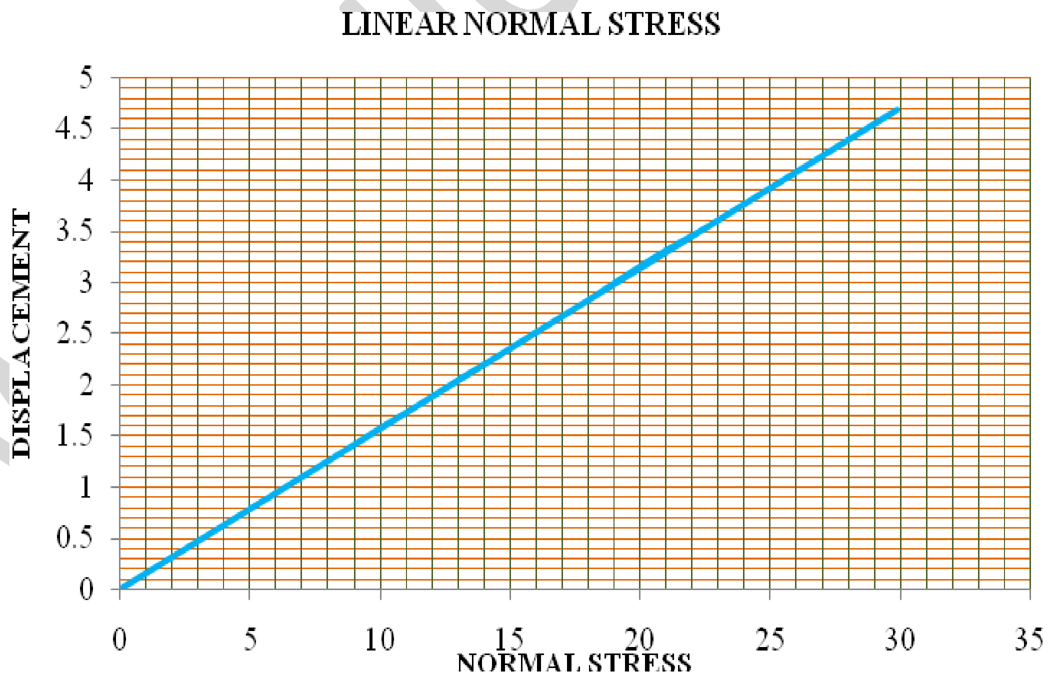

Fig.9. Variation of normal stresses for linear analysis

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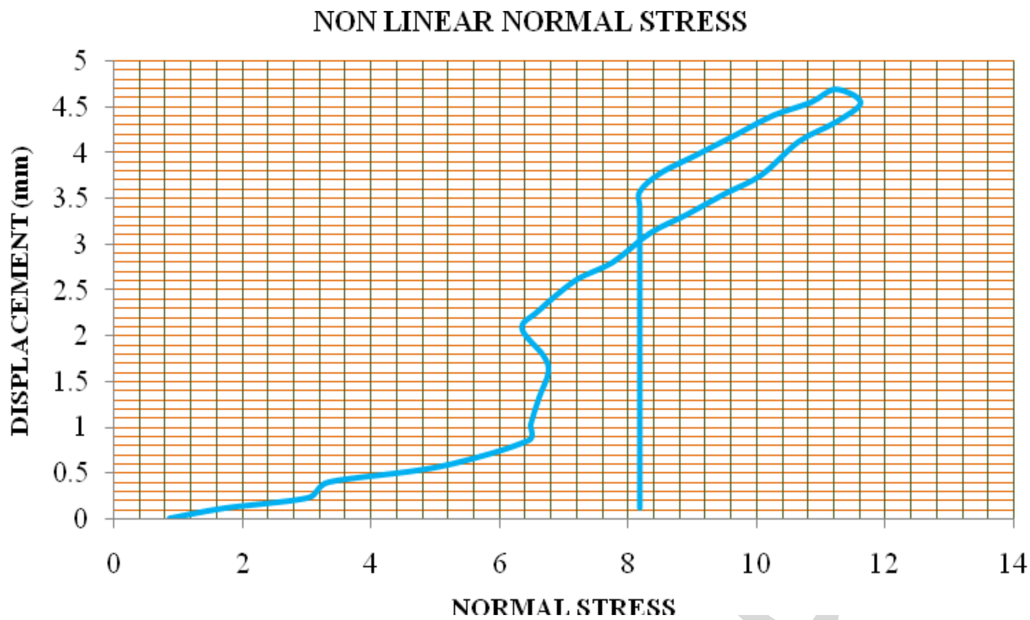

Fig.10. Variation of normal stresses for nonlinear analysis

CONCLUSIONS

The following conclusions are obtained in the perspective of material nonlinear effect. The three dimensional finite element method is very appropriate methodology in order to unfold the differences between the linear and nonlinear effect by considering plasticity properties. The deformation, shape and size of the polyethylene bush is changed due to nonlinear approach when compared linear analysis, the same bush is unchanged during loading and unloading stages. The response of stresses and strain energy is very much deviated due to nonlinear effect compared to linear analysis. In order to understand complete behavior of material under different designed and existing conditions, nonlinear analysis will provide good results when compared to linear analysis.

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