A study on the wrinkling characteristics of NBR material

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1. INTRODUCTION & OBJECTIVE

Nitrile rubber is synthetic rubber consisting of phase of acrylonitrile andbutadine, hence popularly known as acrylonitrile-butadine rubber [1]. Traces of other metallic inclusions are generally used while compound of nitrile rubber is made. This includes Sulphur, Zinc-oxide, TDP oil etc. This type of material finds its uses in hydraulic hoses, seals, gaskets, tank liners, aircraft applications and more. One of the dominant application is in medical section. Doctors use to have nitrile gloves for surgical procedure. Such gloves are susceptible to wrinkling. Wrinkle is fold or bifurcation or generation of wavy surface due to inability of material to resist compressive loads. This class of problem has been tackled in literatures by two approaches. First being tension field theory, in which secondary principal stresses are treated as zero and analytical formulations are built [2-4]; but it is not easy to determine the wrinkling details such as wavelength and amplitude from this approach. Second approach is based on the bifurcation theory. This treats the problem as buckling of plates by reducing stiffness of plate to much lower value, reducing the geometry down to a membrane. This approach is cumbersome but wrinkling details can be obtained. However, robust numerical convergence schemes are required to solve the ensuing computational models [5,6].

This work details wrinkling of incompressible hyperelastic material (Nitrile rubber) with Ogden material model for plane stress conditions. The formulation accounts for wrinkling features by introducing a wrinkling tensor and modified stretches in the kinematics. Material constants are obtained from experiments with in-house developed test rig. Test prototype has been developed to take care of large deformations with large strains under uniaxial, biaxial as well as shear conditions. It also generates stress relaxation data. Wrinkling measurements are done by non-contact method with brand new technique using Arduino controller. Model and experimental results show good agreement.

Keyword: Cauchy's stress, Ogden model, wrinkling, hyperelastic material

2.RESULT& HIGHLIGHT OF IMPORTANT POINTS

Typical wrinkling configuration and parameters involved in the model are highlighted in Fig. 1(a). Two parameters and three parameters Ogden model captured material response for both cases of with and without wrinkling. On the onset of wrinkling, when secondary principal stress is approaching zero, the maximum principal stress determined are shown in Fig.1 (b). Second Piola Kirchhoff's stress is used as stress measure. In-compressibility condition is accommodated

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by imposing constraints. The associated multiplying parameter is obtained as situation results in plane stress problem. Prior to this, experimentally, wrinkling depth, orientation and associated loads were captured.

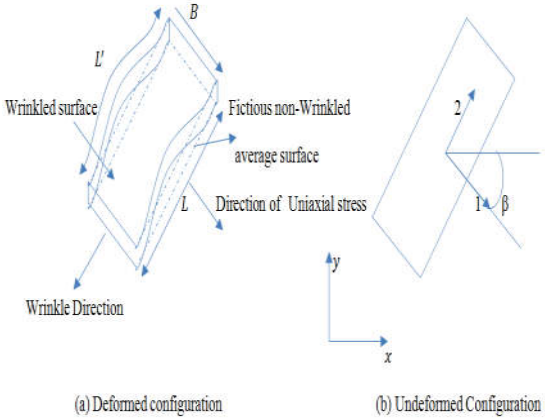

Fig.1(a)

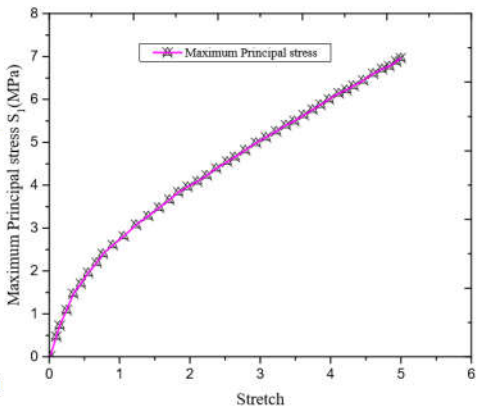

Fig.1(b)

Fig.1: (a) Wrinkling configuration details; (b) Maximum principal stress obtained through Ogden material model at the onset of wrinkling

Other details are not mentioned here due to brevity but will be highlighted in the paper. This paper willdetail in- depth experimental performance of NBR with developed test rig over wide range of stretches (uniaxial case), unequal and equal stretches (bi-axial case), and large shear with lateral displacement. Quasi-static as well as explicit behavior will alsobe highlighted.Stress relaxation data of material is retrieved to have better of material aspects.Wrinkling orientation will be detailed. This also will feature simulations based upon outcomes of analytical treatment. The schemes for analyses will be highlighted and the description of that thing will be given. Material behavior over wrinkling parameter range will be critically analyzed further. Formulation comprises tangent stiffness terms for plain stress case and their derivations with focus on wrinkling along with corresponding stress measures. Merits and comments over all cases will be reported. As this behavior involves material and geometric nonlinearity such as wavy nature of surface, its modeling requires user material. Stress relaxation determined previously will be calibrated and thus viscoelastic nature will be captured.Finally, data obtained through developed test prototype will be compared with tested results of NBR using standards and those existing in the literature.

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