Approach of Mooney-Rivlin material Model in Air Intake System

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***Abstract*— Behavior of hyper elastic material is to express the large elastic deformation under the small applied force. This behavior is applicable for all rubber components. The bellows of air intake system which consists amount of suction pressure due to which collapse and expand of bellow occur due to their flexibility in accommodating assembly mismatches. Sometimes there is a tendency of negative pressure being formed this negative pressure can destabilize the rubber component, and create a condition where it may collapse under the local vacuum generated. Performing a finite element analysis (FEA) on a hyper elastic material is difficult due to nonlinearity, large deformation, and material instability as it is an hyper elastic phenomenon and will require usage of various hyper elastic material models like yeoh, ogden, neo-hookean, mooney-rivlin etc. In various hyper elastic material model in Mooney-Rivlin material model is apply to the bellow of air intake system. This paper undergoes the uniaxial test in ANSYS, curve feeting is achieved. Hyper elastic curve fitting it is a tool for estimating the material constants 3, 5 & 9 Parameter by inputting experimental stress-strain data and comparing it to the experiential results and find out the beast fit hyper elastic material models for the air intake system.**

***Index Terms*— Air Intake System, FEA, Hyper elasticity, Mooney-Rivlin, Rubber**

I. Introduction

Aim of air intake system in engine is to provide the cool and dust free air to the combustion chamber. When designing such type of intake aim for the internal flow is to ensure that the engine can provide as great an increase of static pressure as the engine face the as possible. Most of intake system consisting of rubber parts which behavior under the various tedious conditions. During this operating condition rubber parts (bellow) get expand and collapse under suction pressure as well as operating condition. This collapse turns towards the negative pressure it can be destabilized the rubber component. FEA of the rubber component is complex due to its hyperelastic phenomenon it requires usage of various hyper elastic material models such as yeoh, ogden, neo-hookean, mooney-rivlin etc. Many researches are goes under the hyperelastic material.

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- Air intake system (AIS)

The air intake system used in internal combustion engine to provide the clean and dust free air to the combustion chamber, fresh air has a major effect on the engine performance and also on emissions. A well designed air intake system provides cool, clean air for combustion which is the necessary ingredients for the engine combustion process. The intake manifold is an important part of the air intake system where enough air should be guided to the cylinder. Design of Air Intake system is comfortable with different models, such air intake system consisting various accessories such as clean side, clean hose turbo, dirty side, air filter unit, below etc. Due to their feasibility rubber component are used in the air intake system. Bellow of intake system consisting to the hyperelastic material. In which beast fit material model is found out.

- Hyperelastic Material

A hyperelastic material is an elastic material, which returns to its original shape after the forces have been removed. Hyperelastic material also is Cauchy-elastic, which means that the stress is determined by the current state of deformation, and not the path or history of deformation. For many materials linear elastic models do not accurately describe the observed material behavior. Rubber is most common example of this kind of material whose stress strain relationship can be defined as non-linearly elastic, isotropic, incompressible and generally independent of strain rate.

II. Literature Review

Number of researchers currently working on hyperelastic material, some of the data from previous research work is reviewed.

Arun U Nair, Hubert Lobo and Anita M Bestelmeyer, perform review on the experimental procedures for characterizing the mechanical behavior of hyperelastic materials with an emphasis on the equivalency between different tests and estimation of tear strength [1]. Kurt Miller, Ann Arbo, they perform on the stress-strain relationship in a material under all loading conditions experimental data needs to be created such that a reasonable material model may be selected to define material behavior pertinent to the application of interest[2]. The Cambridge Polymer Group CPG perform the elastic response of rubber-like materials is often based on the Mooney-Rivlin model, which describes

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the material's stress-strain relationship as a function of two empirically determined constants C1 and C2[3]. Xiao-Yan Gong and Riyad Moe are found that the finite element analysis (FEA) on a hyperelastic material is difficult due to nonlinearity, large deformation, and material instability. This paper provides a brief review of the hyperelastic theory and discusses several important issues that should be addressed when using ANSYS [4].

In Hyper elastic material here we take the Mooney Rivlin Material Model in which three, five and nine parameter material model are available. From these beast fit material model are formed out on the bases of experimental and simulation method. Experimental test are carried out on the LME Test bed.

III. FE Analysis of Air intake system

Finite Element Analysis of rubber component is getting difficult due to their nonlinear effect. Non-linearity of rubber component getting advantages in to the air intake system due to their flexibility and assembly mismatch, experimental stress-strain data are use for the defining the Mooney-Rivlin Constants. These data are as follows;

TABLE-1
Engineering Strain–Stress Data

Sr. No.	*Engineering-strain*	*Engineering-stress*
1	*0.819139E-01*	*0.82788577E+00*
2	*0.166709E+00*	*0.15437247E+01*
3	*0.253960E+00*	*0.21686152E+01*
4	*0.343267E+00*	*0.27201819E+01*
5	*0.434257E+00*	*0.32129833E+01*
6	*0.526586E+00*	*0.36589498E+01*
7	*0.619941E+00*	*0.40677999E+01*
8	*0.714042E+00*	*0.44474142E+01*
9	*0.808640E+00*	*0.48041608E+01*
10	*0.903519E+00*	*0.51431720E+01*
11	*0.998495E+00*	*0.54685772E+01*
12	*0.109341E+01*	*0.57836943E+01*

By assigns the engineering strain-stress data in the ANSYS workbench for this problem, the fitted constitutive parameters for the three-parameter Mooney-Rivlin model by curve fit, Solving the Experimental stress strain data by uniaxial test Using all of experimental data to fit the three, five, and nine-parameter Mooney-Rivlin models results in the following material constant parameters, fit to the entire range of experimental data.

TABLE-2
Material Constants

Constant	Three-Parameter	Five-Parameter	Nine-Parameter
C_{10}	1.33885599	1.47269949	1.45922139
C_{01}	0.52362135	0.37721376	0.39133722
C_{20}		0.03588767	0.88504453
C_{11}	-0.01648363	-0.09775501	-1.8376038
C_{02}		-0.01683696	0.88971789
C_{30}			0.00432526
C_{21}			-0.0309937
C_{12}			-0.1378222
C_{03}			0.04959877

Material constant of three, five and nine parameters are applied to the rubber component (Bellow) of AIS. Intake system consist the suction pressure at the engine operating condition which affect on the bellow expand and collapse. On the basis of trial and error, limiting value of suction pressure is taken as $1e^{-5}$ bar.

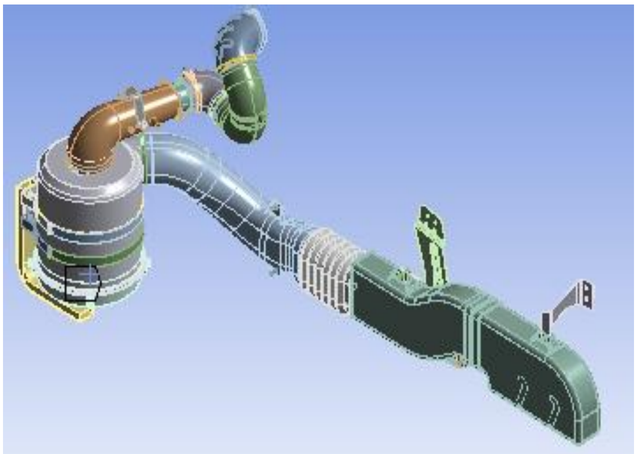

Fig. 1 Air Intake System

IV. Fea Results

Three-parameter material models are applied to the bellow for checking the expansion and collapse. As shown in fig 2 total deformation is 9.50mm max. This is at the limiting condition at maximum pressure to the bellow.

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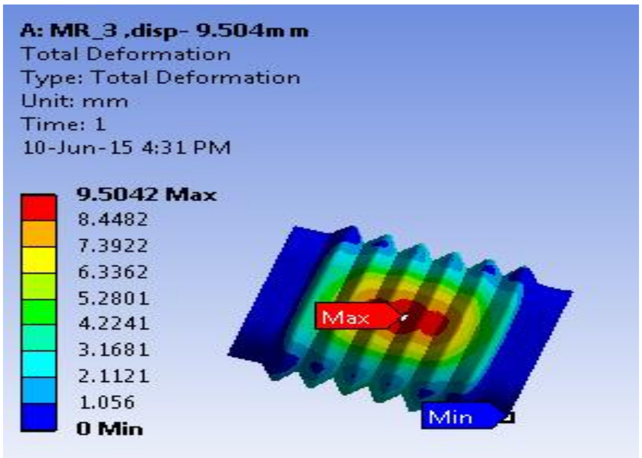

Fig. 2 MR-3 Material Model

At five-parameter material model as shown in fig. 3 deformation of bellow is 9.41mm max. This is at the limiting condition at maximum pressure to the bellow.

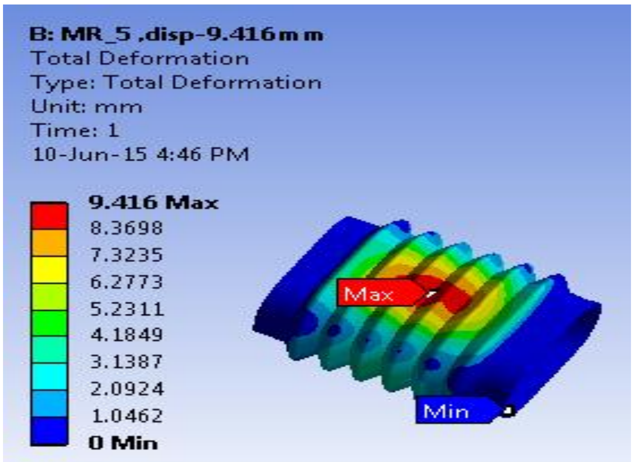

Fig. 3 MR-5 Material Model

Last of the nine-parameter material model deformation of bellow gets the scratched. Applied limiting air pressure goes exceeded these pressure can't sustain the bellow and assembly of bellow get disturbed and scratch. These deformations are shown in fig 4.

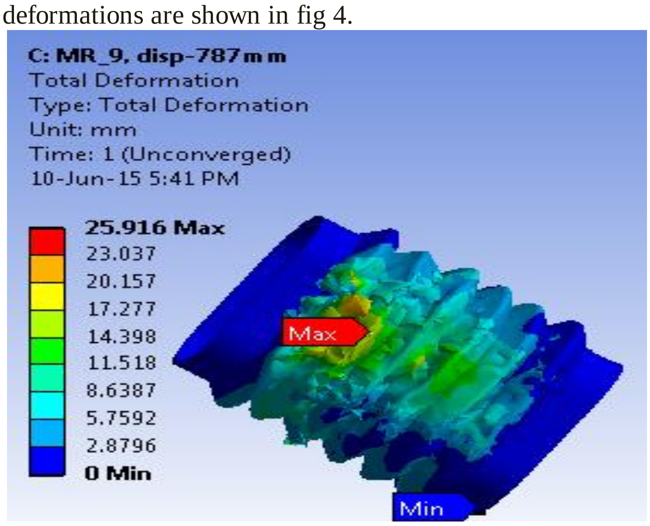

Fig. 4 MR-9 Material Model

V. Experimental Results

Experimental test on the bellow conduct on the LME Test shown in fig 5 in which deformation test taken by INSTRON 5924, SITRANS P500 type sensor are used which have reference accuracy ≤0.03 %, Suction test is conducted on the bellow at 1e-5 bar.

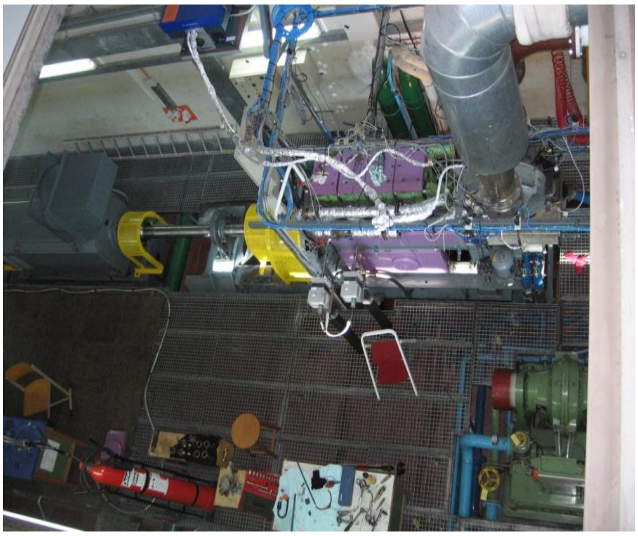

Fig. 5 LME Test Bed

An experimental testing show the limiting value of the deformation at which bellow sustains pressure at certain limit, all above average deformation is 9.33mm.

TABLE 3
DEFORMETION RESULTS

Sr. No.	Deformation
1	9.36mm
2	9.32mm
3	9.33mm

VI. Conclusion

FE Analysis of below at the three and five parameter shows the appropriate deformation which is 9.50mm & 9.41mm for three and five parameters respectively, at the nine parameter model it got disturbed and creates the irregular shape. From the experimental test result average deformation of bellow is 9.33mm which is near about to five parameter material model, from these five parameter mooney-rivlin material model is the beast fit material for the Bellow of Air Intake System.

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