A STUDY ON THE PROPERTIES ESTIMATION OF HYPERELASTIC MATERIAL UNDER LOW TEMPERATURE CONDITIONS

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1. Introduction

Hyperelastic materials are used in various fields such as machinery, civil engineering and marine & offshore plants industries due to excellent vibration damping ability, energy absorption capacity and low noise characteristics. The behavior of the hyperelastic material is described using the strain energy density function and there are various nonlinear material models to express it. In general, for the analysis of hyperelastic materials, the material properties test is required to derive the coefficients of the nonlinear material model. In particular, the properties of hyperelastic materials is changed according to temperature, unlike ordinary steels. Therefore, in order to consider various temperature conditions, it is necessary to carry out the same number of tests as the number of conditions. In this study, tensile test was performed for four temperature conditions to analyse the behavior of hyperelastic material under low temperature condition. An algorithm for estimating properties of hyperelastic materials at specific temperatures was developed and verified.

2. Tensile test of hyperelastic material under low temperature conditions

The physical properties of the hyperelastic material under low temperature conditions were tested under hysteresis conditions in consideration of Mullin's effect. The specimens are made of natural rubber and the temperature conditions are -40℃, -20℃, 0℃, 23℃. The stress-strain curve of the tensile test result and nonlinear material models are shown in Fig.1. The material models considered are Ogden, Yeoh, and Mooney-Rivlin models, and are expressed as equation (1) - (3), respectively.[1][2]

(1) $$W = \sum_{i=1}^{N} \frac{u_i}{\alpha_i}\left(\bar{\lambda}_1^{\alpha_i} + \bar{\lambda}_2^{\alpha_i} + \bar{\lambda}_3^{\alpha_i} - 3\right) + \sum_{k=1}^{N} \frac{1}{d_k}(J-1)^{2k} \quad \text{– Ogden Model}$$

(2) $$W = \sum_{i=1}^{N} C_{i0}\,(\bar{I}_1 - 3)^i + \sum_{k=1}^{N} \frac{1}{d_k}(J-1)^{2k} \quad \text{– Yeoh Model}$$

(3) $$W = C_{10}(\bar{I}_1 - 3) + C_{01}(\bar{I}_2 - 3) + \frac{1}{d}(J-1)^2 \quad \text{– Mooney-Rivlin Model}$$

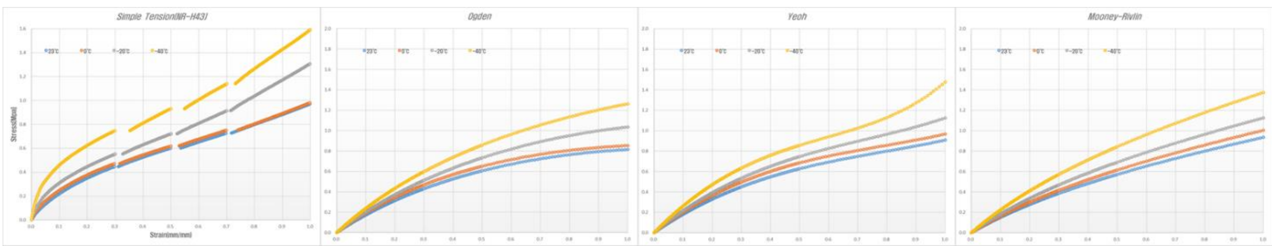

Figure 1 : Tensile test result and nonlinear material models under the low temperature condition

3. Estimation of mechanical properties of hyperelastic materials in low temperature condition

The algorithm for estimating the mechanical properties of the hyperelastic material at a specific temperature is formulated as shown in Equation (4) and the procedure is as follows:

(4) $$stress_{temp.} = nU + \sum_{a}^{n-1} ay$$

Where, *n : range of temperature(between to max. temperature and min. temperature)*
U : unit change value(change value per 1℃ between 0℃ and 23℃)
y : Change with temperature
a : Weight factor of temperature

Phase 1 : Draw the S-S curves of the nonlinear material model at 23 ° C, 0 ° C, and -40 ° C.
Phase 2 : Separate the S-S curve equally according to the strain
Phase 3 : Derive the stress value for the strain at the specific temperature through the formalized model.
Phase 4 : Draw the S-S curve and derive the material model coefficients

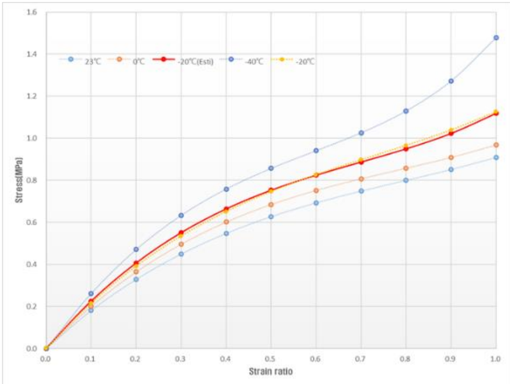

Figure 2 : Estimation of hyperelastic material properity at -20℃

Figure 2 show the estimation results at -20 ° C temperature condition. Yeoh model was used for this estimation. The results show up to about 5% error with the experimental results and it can be seen that the developed algorithm is well estimated

4. Conclusion

In this study, the behavior of hyperelastic material in low temperature condition was analyzed and an algorithm for estimating mechanical properties of hyperelastic material at specific temperature was developed.
1) The stiffness of hyperelastic material increases with decreasing temperature and the amount of change in stiffness are initially increases and then decreases
2) An algorithm for estimating properties of hyperelastic materials at specific temperature was developed and verified for applicability. This study is meaningful to confirm that it is possible to estimate properties of hyperelastic material which is a representative nonlinear material. This study is meaningful to confirm that it is possible to estimate properties of hyperelastic material which is a representative nonlinear material.
Further research will be carried out on generalization study of algorithms developed for various hyperelastic materials.

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