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**Robert Lowe <rlowe1@udayton.edu>**

**Putting you to work !**

*Wed,* Aug 4, 2021 at 3:10 PM

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C:Second! Material cont

Chen,

Below are some Mooney-Rivlin parameters for four different soft, stretchable, photo-curable materials we have examined. I believe c1 and c2 correspond to A and B in the M-R strain energy function, per the SolidWorks user's manual. All parameters have units of MPa.

M-R

Material | AFRL Elastomer SUV Elastomer ) SilOHflex | ELAST-BLK 10 Parameter Values c = 0.0083 C1 = 0.2767

G=0095

*C*i = 0.7757 = 2.35€ - 14 = 0.0308 b = 5.75€ - 07 C2 = 2.25148 - 07 NRMSEL 0.01789 | 0.12661

0,06681

0.29564

**Of these four materials, the only one currently printable at UDRI IS ELAST-BLK 10, a commercially available material from 3D Systems. Frankly, it is a lousy material and has effectively been phased out. The other three are from literature. W**e (Braeden and Joseph) are trying to get a similar material to the "AFRL elastomer" up and running on the Figure 4 printers at UDRI, but we don't have formal test data or calibrated models ... yet. For Poisson's ratio, it is generally recommended to use a value of 0.49 to 0.499 so that the material is weakly compressible. This **preserv**es the mathematical structure of the governing equations and keeps the numerical method happy, while preserving near-incompressibility characteristic of most rubbery and elastomeric materials.

Ogden parameters are shown below. mu\_i are in MPa, alpha\_i are dimensionless. **I do not recommend using this model.** As it is "higher-order," It typically does not predict other deformation modes (e.g., compression, biaxial tension, shear, torsion) well in FEA analyses when only calibrated to uniaxial tension data.

Material

-Ogan

Parameter Values

AFRL Elastomer SUV Elastoiner | SilOHflex | ELAST-BLK 10 *H*i = -0.0111 Hi = 2.1198m Hi = 0.2671 *H*i= 0.0562

a = 1.4292 Q] = 0.8211 0 1= 0.2671 a = 3.7848 *1*12 = 6.03€ - 06 *H*O = 0.0117 l *H2* = 8.050 - 05 *H2* = 0.0047

22 = 5.8233 02 = 3.5776 Q2 = 6.8677 02 = 9,0703 *113* = 0.02911

*H3* = 0.4076 *13* = -0.0066

*143* = 0.4093 *4*3 = 16.8615 03 = 21.9032 a3 = 343.4955 03 = 10,6912

0.00035

0.00751

0.00230

0.04109

CS

NRMSE

Blatz-Ko is a compressible hyper-elastic model. As such, it is most appropriate for compressible materials like foams or porous elastomers. We do not have a calibrated version of this model.

Hope that helps. If I can assist further, please don't hesitate to reach out.

Best Regards, Bob

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*Y* = C, (11-3) + Cz (I*2-3)*

CM-R

1189

Hyperelastic models for rubber-like materials

1189

*3.1.1 Uniaxial tension (UT)*

In uniaxial tension, the specimen is elongated in only one direction, for example, 11 = 1. From incompress ibility, that is, *1*3 = 27,5 = 1, and the assumption of isotropy, the complementary principal stretches follow as à2 = 13 = 1-1/2. Thus, the corresponding deformation gradient and the invariants, cf. Eq. (11), are

Ta 0 0 1 *FU*T = 0 2-1*/*2 T. L*U*T = 22-1 +12*, LUT* = 2-2 +22.

(18) 0 0 2-1*/*2 Since the contraction is unhindered in the transversal directions, both PUT are zero and only *pu*ta) has to be determined. By setting Eq. (17) to zero, for example, for *i =* 2, and calculating the derivatives a*l 12/8*2*2* from Eq. (11), the resultant pressure is determined as

2 av

11 ay PUT=

22] a*12*

(19) Inserting this into Eq. (1*7*) for i = 1, we obtain the analytical formulation for the first principal stress:

ray law .

(20) -Lari 2012 ][ 12]: *3.1.2 Equibiaxial tension (ET)*

+

2

*PUT* = 2 24

P= axial stress

C2

1=1+ES

- axial strain

The specimen is equally stretched in two orthogonal directions, that is, a = 12 = 1. Again due to incom pressibility, the remaining principal stretch reads 13 = 1-2, and the corresponding deformation gradient and invariants follow as

Tio 07 *p*ET = 00 , LET = 2-4 +222, LET = 22-2 +24.

(21) 001-2 The stresses in load directions are equal, while the third direction is stress-free due to unhindered contraction, that is*, PET = PE*T and *P*ET = 0, respectively. The pressure is determined by setting Eq. (17) to zero for *i =* 3:

2 ay 4 ay

ÞET = af ati + 12 ala

*(22)*

and by reinserting this into (17) for i = 1, we obtain the first and second principal stresses:

(23)

*3.1.3 Pure shear (PS)*

The pure shear set-up of Treloar (52) utilises rectangular sheets having a much larger width than length to rea lise a zero deformation perpendicular to the loading direction 1 = 1, that is, 22 = 1 holds almost everywhere except for the vicinity of the free edges. From incompressibility, the third principal stretch n3 = 2-1 and the corresponding deformation gradient and the invariants read

Tao 07 *p*PS = 010. *PS = IPS = 1,98* = 22 +2-2 + 1.

(24) 001-1 From unhindered contraction in the third direction, the pressure follows from setting (17) to zero for *i* = 3:

. 2 av

11 ay -2|1+ a2a1,

(25)

Insertion of (25) into (17) yields the principal stresses in load direction and perpendicular to this:

*p*

*=* 2a +

(26)