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Report 7

Extensions to GLUEMAKER a Finite Element Modelling Tool For Adhesive Joints to Include Material Models for Flexible Adhesives

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CONTENTS

1 INTRODUCTION

TWI has developed a software program, GLUEMAKER, for the simplified finite element analysis of adhesive joints. This program is very useful in aiding the inexperienced FEA user to investigate the sensitivity of the material parameters of joint and identify a suitable design of experimental specimens. GLUEMAKER sits on top of the FEA preprocessor-solver-post processor (FAM) system and provides a user friendly interface to create meshed and loaded adhesive joints. The GLUEMAKER system is based around the FAM pre and post-processor supplied by FEGS Ltd. and the solver is ABAQUS Standard supplied by HKS. Currently the user can investigate five joint geometries:

i) Simple lap joint
ii) Tapered lap joint
iii) Stepped lap joint
iv) Double lap joint
v) Scarf joint

and four types of model; 2D plane strain, 2D axisymmetric, 3D flat plate and 3D tubular. Currently the 3D option only covers geometry and mesh generation and assignment of material properties. It does not as yet apply loads or boundary conditions.

This report is intended as a supplement to the GLUEMAKER User Guide (1) and details the additions made to GLUEMAKER which resolves some coding errors, increases the mesh density in the adhesive layer in the joint and adds a new analysis model, Hyperelastic, for the modeling of 'rubbery type' materials. The reader is referred to the user guide published by TWI (1) for a general description of the GLUEMAKER program and to a subsequent report (2) on the validation of the program. The FAM User Guides (3) and the ABAQUS User Manuals (4) are also recommended for queries on problems relating to the graphical interface and the solver.

2 NEW MATERIAL MODEL FOR GLUEMAKER, HYPERELASTIC ANALYSIS

(a) Original Gluemaker:
Material Models: Linear elastic or Elastic-plastic

(b) Revised Gluemaker:
Material Models: Linear elastic, Elastic-plastic or Hyperelastic

Load box 1 of GLUEMAKER, Figure 1, has been modified to allow the user to select an additional material model, *HYPERELASTIC (4). This model is isotropic and nonlinear. It is valid for materials that exhibit instantaneous elastic response up to large strains i.e. rubber etc. For details of the type of tests required to generate the input data for the analysis the reader is referred to a report by Charalambides and Olusanya (5).

The data input can also be in the form of the coefficients of a mathematical fit to the model using all or some of the test data options. It is important to note that in the adhesive selection stage in Material box 1 any adhesive can be selected as this only acts as dummy input data and is overwritten by the user file. This occurs after the translation of the FAM format file to ABAQUS by the use of the FAM to ABAQUS program using an internal GLUEMAKER nawk program which combines the load case information from the GLUEMAKER controls file into the solver input file, *user*.inp.

When a hyperelastic analysis is selected, Load box 4, Figure 2, is modified so that the user file which holds the test data or coefficients can be selected. Three new 'hyperelastic' boxes, Figures 3-5, which give examples of the format of the input file have been defined as on-line help for the user. The Finish box which displays or prints the model summary has also been updated to reflect these changes.

3 INCREASED MESH DENSITY IN THE ADHESIVE LAYER

The number of elements used to describe the adhesive layer has been increased by 250% from 96 elements (24 x 4) to 240 elements (24 x 10) for quadratic elements. Table 1 details the change in the resolution of the mesh control for Gluemaker. Figure 6 compares the FE mesh with the Mesh Box slider bar set at 5. This increase in the density of the mesh in the adhesive section alloys greater resolution of the adhesive behavior during finite element modeling.

It should be noted that models generated by GLUEMAKER can be used in ABAQUS Explicit, for example an joint impact test simulation, if this is the case then linear elements must be selected as the Explicit code does not accept quadratic elements.

	Original Version		New Version	
Mesh Control Parameter	Linear Elements	Quadratic Elements	Linear Elements	Quadratic Elements
1	2	2	6	4
2	2	2	8	4
3	4	2	10	6
4	4	2	12	6
5	4	2	14	8
6	4	2	14	8
7	6	4	16	8
8	6	4	16	8
9	6	4	18	10
10	6	4	18	10

Table 1: Comparison of mesh densities in the through thickness adhesive layer for the original and the modified GLUEMAKER package

4 CORRECTION TO THE LABELLING OF THE INCREMENT NUMBER

The GLUEMAKER reference manual indicates that 35 increments can be used per load case, this is not achievable as the naming system for each result definition, RDEF, is a single, case insensitive alphanumeric code. In practice, a maximum of 16 increments are available as the GLUEMAKER program inadvertently creates a FAM system "reserved word" which is for the operation of the post-processing system thus causing an error in the program. In this modified version of GLUEMAKER the increment labeling is rearranged to ignore the label leading to this error. In this revision more than 34 increments can be read in for post-processing, however, the program accepts data from the initial 33 increments and then overwrites all subsequent increments except the final increment data set.

The modifications made to GLUEMAKER for this software release are detailed in Table 2.

REFERENCES

1 GLUEMAKER - A program for simplified finite element analysis of adhesive joints, User's Guide,
A P Dyer, TWI report 8180/15/95, September 1995.

2 Finite element analysis of adhesive joints, Final report,
A P Dyer, TWI report 8180/17/95, October 1995.

3 FAM build fundamentals. Version 2.0 release 1.1 1990. FEGS Ltd, Oakington Cambridge.

4 ABAQUS/Standard, Version 5.7, User's Manual Volume III, HKS Inc, 1997.

5 DTI Adhesives Programme: The Performance of Adhesive Joints. Project PAJ1, Failure Criteria and their Application to Viscoelastic/Viscoplastic Materials.
Report 3: The Constitutive Models Suitable for Adhesives in some Finite Element Codes and Suggested Methods of Generating the Appropriate Materials Data.
M N Charalambides, A Olusanya. NPL Report CMMT(B)131, April 1997.

LIST OF FIGURES

ACKNOWLEDGEMENTS

This work was funded by Project PAJ1 of the DTI, Performance of Adhesive Joints Programme.

Table 2 List of Changes to GLUEMAKER

Date & author	Procedure	File	Description
18.12.97 - FH		lapjoint_geom.tcl	Increase the element number of the adhesive layer. Divisions of lines B5, B6, B13 & B23 are increased from 2 to 6.
08.02.98 - FH		loadbox1.tcl	Increase available options to include hyperelastic analysis along with Linear Elastic and Nonlinear Elastic/Plastic Analysis.
08.02.98 - FH		loadbox3.tcl	Minor changes for hyperelastic analysis.
08.02.98 - FH		loadbox4.tcl	Add a frame for hyperelastic material data input when doing hyperelastic analysis. A temporary file named as "ABAQUS.hyperelastic" is generated to store hyperelastic data.
08.02.98 - FH		finishbox.tcl	Minor changes for hyperelastic analysis.
08.02.98 - FH		nawkfile	Correction to ABAQUS input file are done for hyperelastic analysis. Element types of adhesive layer are changed to corresponding hybrid elements, such as CPE4 to CPE4RH. Hyperelastic materials properties are written into input file from temporary file "ABAQUS.hyperelastic" for adhesive. Elastic and plastic properties are commented out.
11.02.98 - FH		runFEbox2-aba.tcl	The temporary file "ABAQUS.hyperelastic" holding the data for hyperelastic analysis is deleted after the FE analysis.

18.03.98 - FH		loadbox1.tcl	Three lines are added for displaying description of hyperelastic material data file.
			if {$anatype == "Hyperelastic" } then {
			mkhyperbox1 $w
			}

18.03.98 - FH		hyperbox1.tcl	A new file created in directory /GLUEMAKER/p8180/fhu_dev by FH containing procedure mkhyperbox1 to display an example of a hyperelastic material data file.
18.03.98 - FH		hyperbox2.tcl	A new file created by FH contains procedure mkhyperbox2 to show another example of a hyperelastic material data file.
18.03.98 - FH		hyperbox3.tcl	A new file created by FH contains procedure mkhyperbox3 to show a further example of a hyperelastic material data file.
18.03.98 - FH		tclIndex	Add three lines for automatic set command execution of above three new files. i.e. set auto_index(mkhyperbox1) "source $dir/loadboxes/hyperbox1.tcl" set auto_index(mkhyperbox2) "source $dir/loadboxes/hyperbox2.tcl" set auto_index(mkhyperbox3) "source $dir/loadboxes/hyperbox3.tcl"
12.06.98 - AO		setrdefs-aba.tcl	Problem in sub routine set_inc_code solved by checking and accepting FAM result database then regenerating the mesh connectivity and reapplying loads. Use FAM commands CHEC, ACCE, GENC, LOAD ALL. Increments larger than 35 can be achieved, however only the last increment is retained all increments above 34 are overwritten

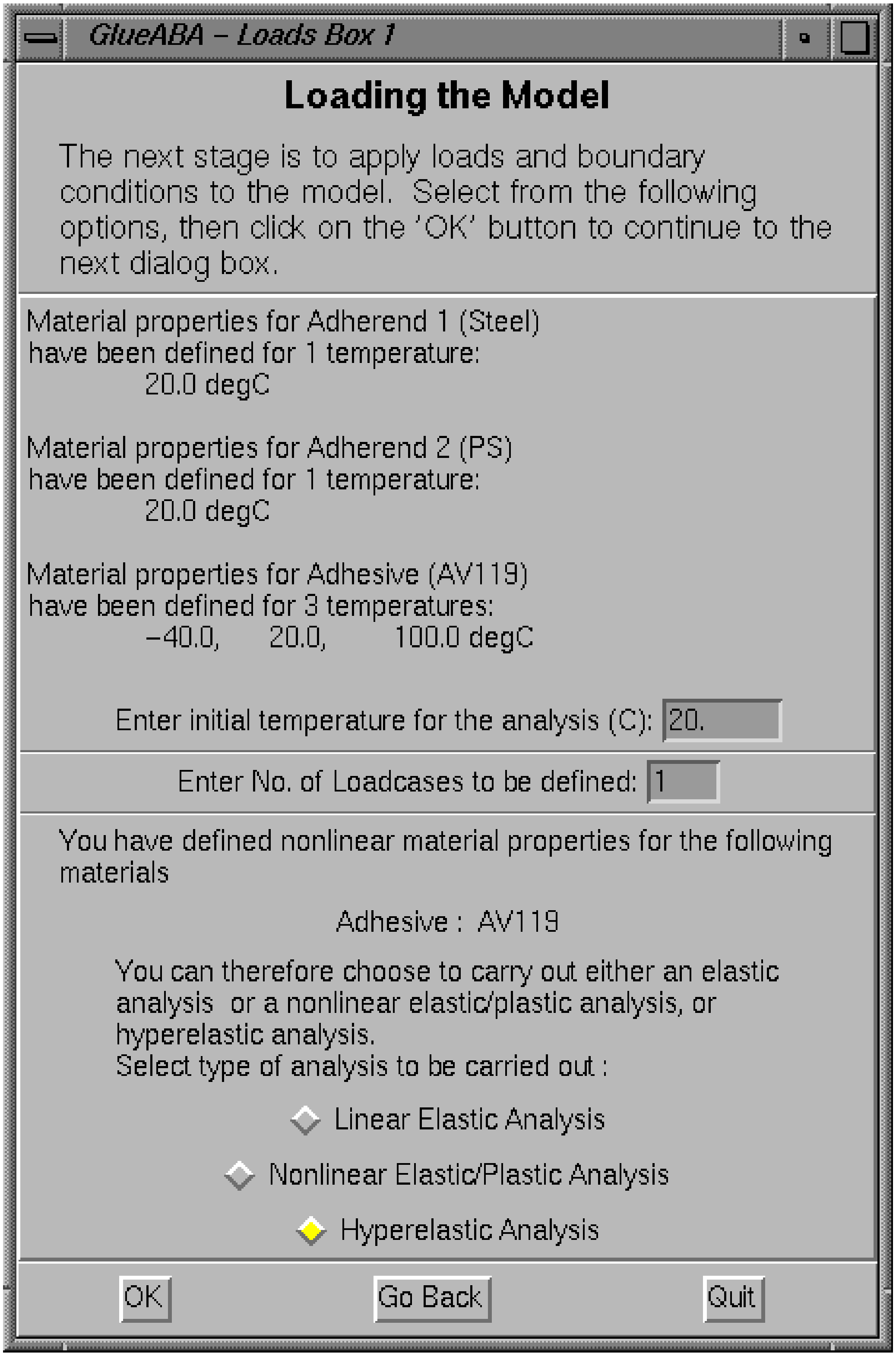


Figure 1 – Load box 1 (revised)

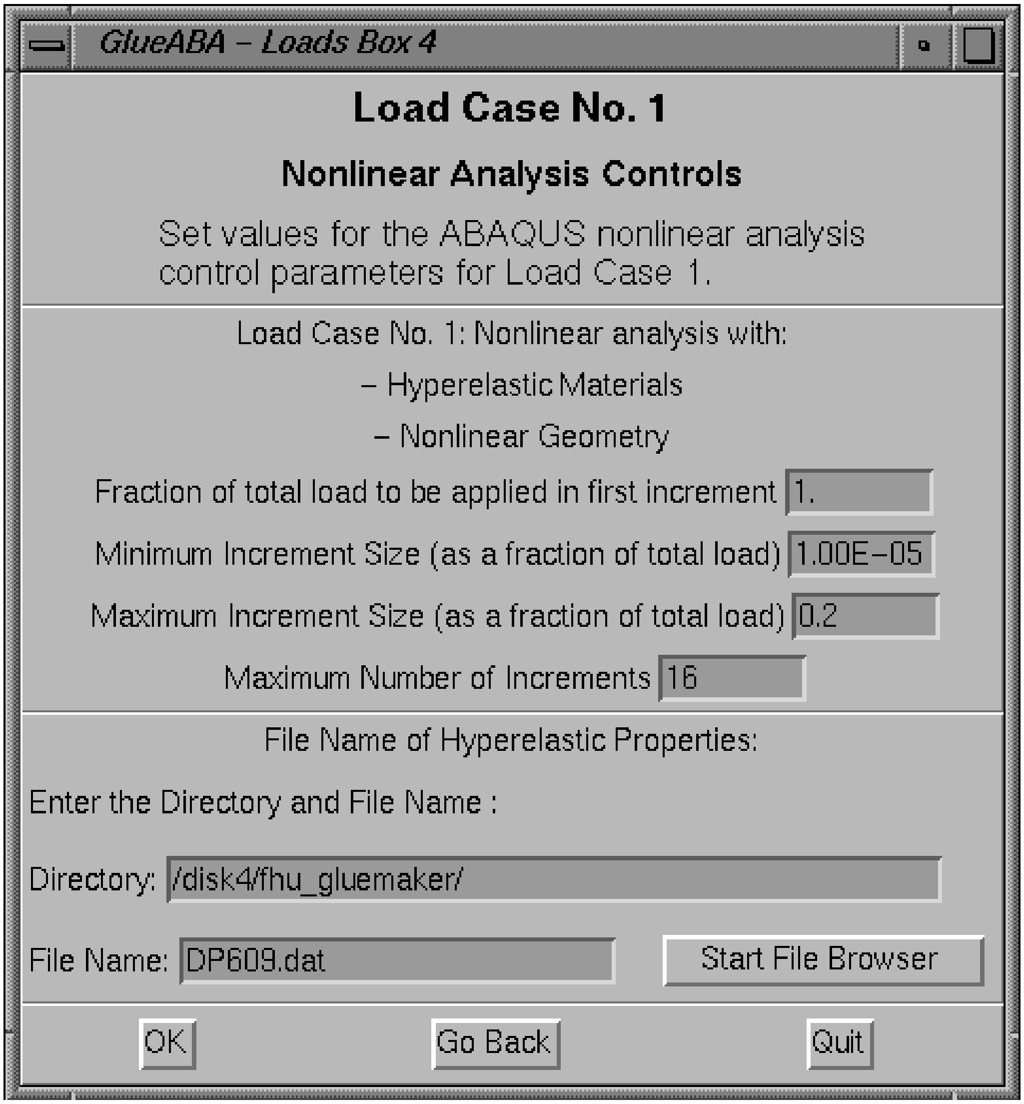


Figure 2 – Load box 4 (revised)

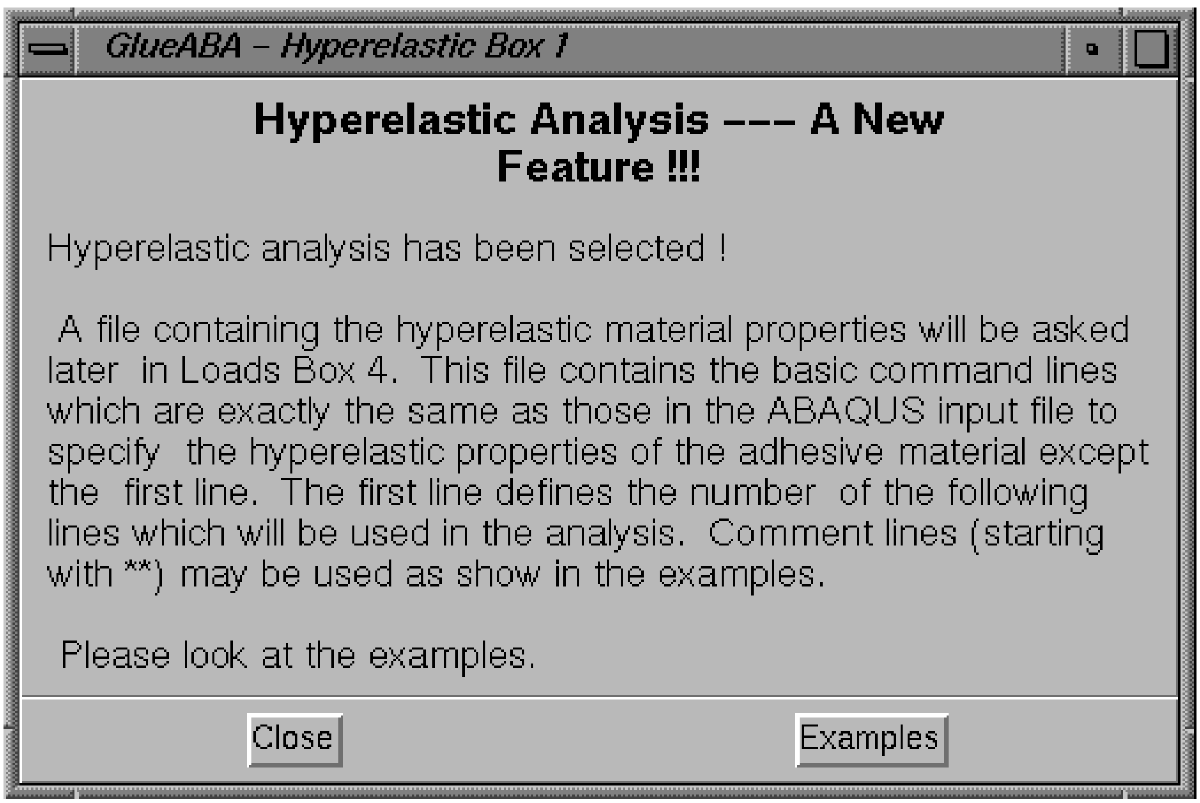


Figure 3 – Hyperelastic box 1 (new)

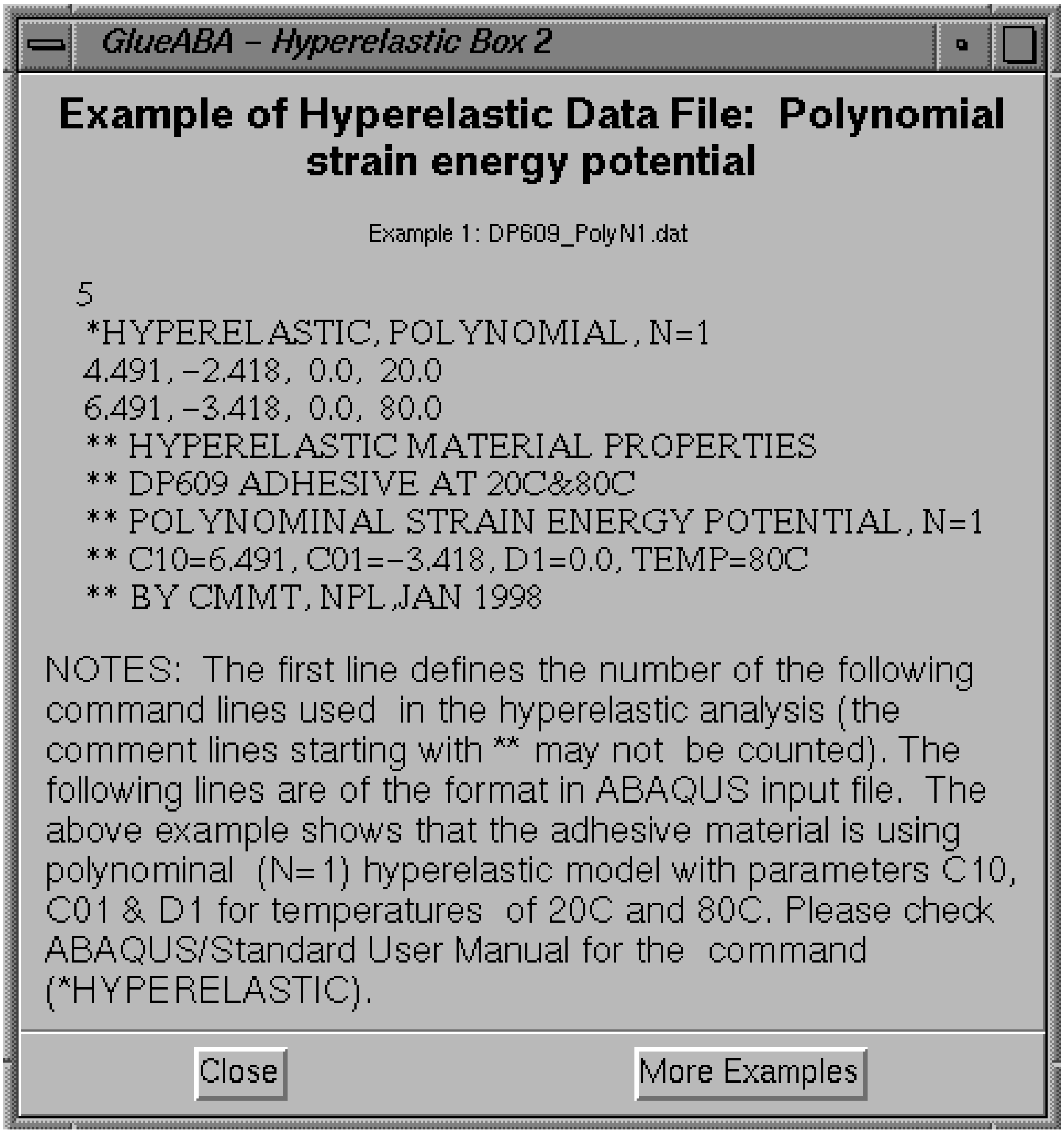


Figure 4 – Hyperelastic box 2 (new)

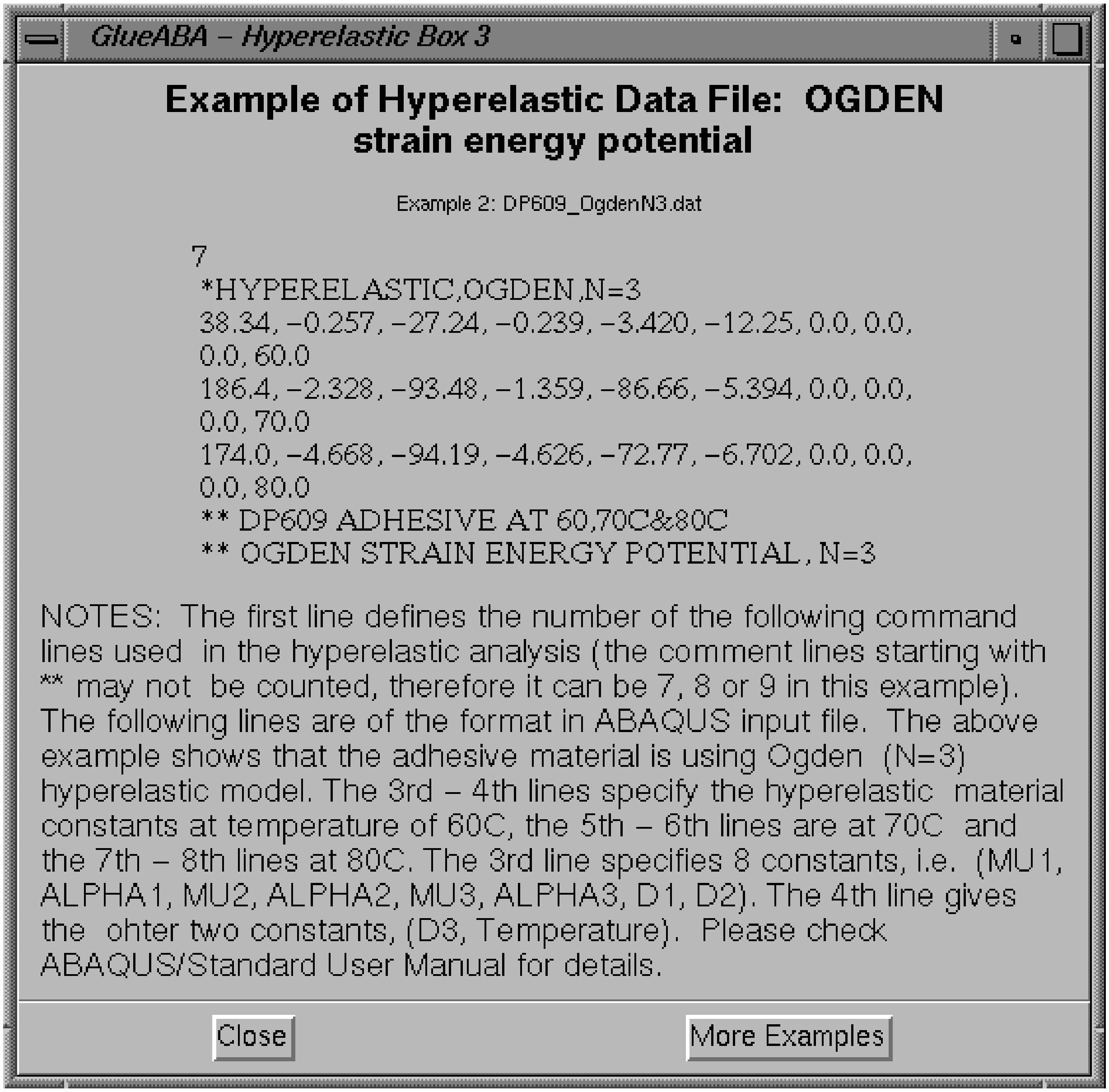
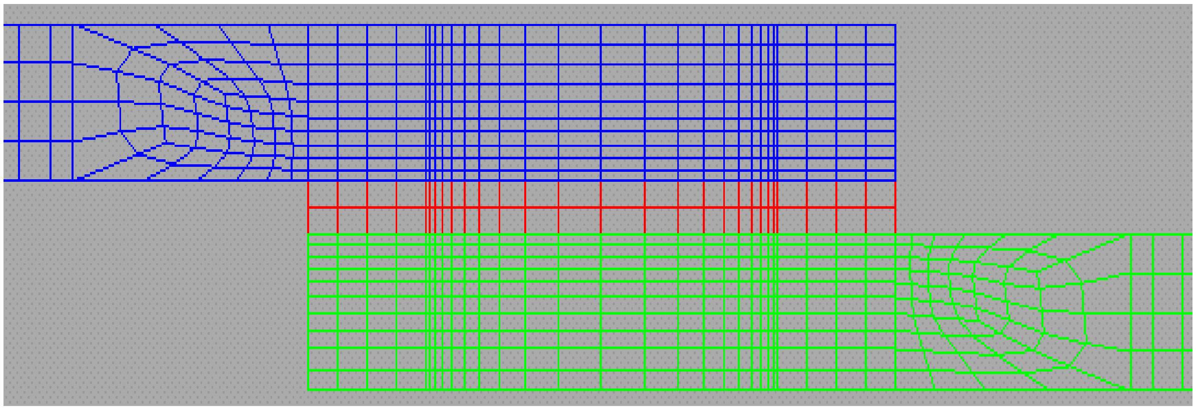
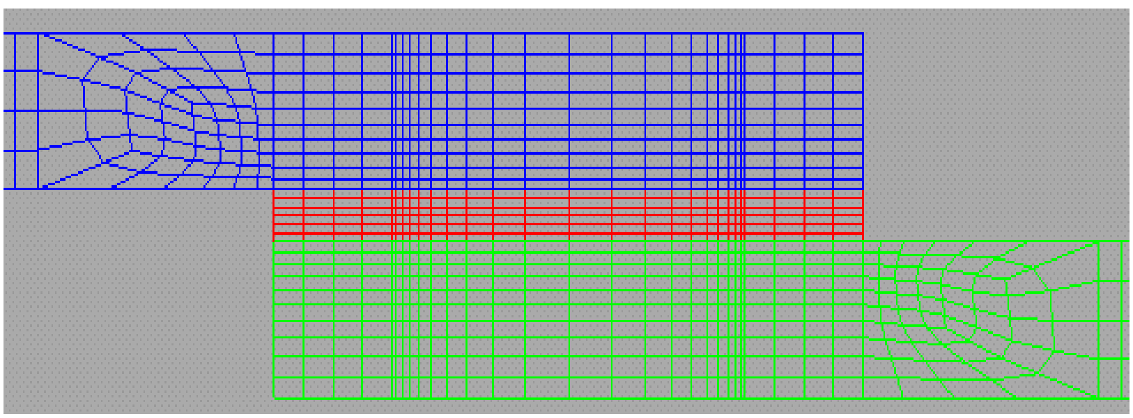


Figure 5 – Hyperelastic box 3 (new)



(a) A typical mesh generated by unrevised version



(b) A typical mesh generated by the revised gluemaker, more elements in adhesive layer

Figure 6 – More elements used in the adhesive layer in the revised gluemaker.