UTILIZATION OF COMSOL MULTIPHYSICS JAVA API FOR THE INTEGRATION OF **COMPOSITE MATERIAL** MODULE WITH A **CUSTOMIZED USER INTERFACE**

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INTRODUCTION

Composite Materials

- Composites are made up of individual materials referred to as constituent materials
- Two main categories of constituent materials: Matrix and Fiber
- Some Advantages: Light Weight, High Strength, Durability, Strength Related to Weight, Corrosion Resistance and Design Flexibility

Need to integrate with COMSOL

- COMSOL Multiphysics is capable of modeling and simulation of any physics-based system
- Adding a user-friendly interface to integrate Composite Material properties will further enhance its capabilities
- Use of Composite Materials in various industries such as aircraft, automotive, etc is rapidly getting acceptance
- So, in the process of modeling and simulation, many a times user wants to use Composite Materials properties in the analysis

METHODOLOGY

- COMSOL API (Application Programming Interface) which is an interface based on Java, is used to develop custom application based on COMSOL
- An initial GUI is built based on a model of a simple 'Rectangular Block', having a point force acting on the edge
- Final GUI is built based on a model of 'Mechanical Part', having a combination of forces and moments acting on it
- Halpin-Tsai Model, a semi-empirical model chosen based on its accuracy and appropriateness, is used to develop algorithm to calculate Composite Material properties

HALPIN-TSAI MODEL

Halpin-Tsai equations are the handy forms of Hill's generalized self-consistent model results with engineering approximations to make them suitable for the designing of composite materials.

$$E_1 = E_f V_f + E_m V_m$$

$$\nu_{12} = \nu_f V_f + \nu_m V_m$$

$$\frac{M}{M_m} = \frac{1 + \varepsilon\eta V_f}{1 - \eta V_f}$$

$$\eta = \frac{\frac{M_f}{M_m} - 1}{\frac{M_f}{M_m} + \varepsilon}$$

where,

M = composite material modulus E_{22}, G_{12} or v_{23}

M_f = composite material modulus E_f, G_f or v_f

M_m = composite material modulus E_m, G_m, or v_m

PROGRAM ARCHITECTURE

```
import java.awt.BorderLayout;

class RectModelDemo implements ActionListener {
    private JFrame frame;
    private JFrame frame1
    private Model model;

    private JButton solveButton;
    private JButton calculateButton;

    private NumberFormat percentFormat;
    private JTextField editV;
    private JTextField editE1;
    private JTextField editE2;
```

Declaration of Class and Parameters

```
static String[] compProperty = new String[10];
public static void main(String[] args) {
    RectModelDemo demo = new RectModelDemo();
    demo.init();
    demo.start();
}
public void init() {
    ModelUtil.initStandalone(true);

}
public void start() {
    lookandfeel();
    frame= new JFrame("Model taken from COMSOL - GUI");
    frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
    frame.setSize(1200,900);
    GUIPanel mainPanel = new GUIPanel();
```

Basic methods: Main, init, start

PROGRAM ARCHITECTURE

```
    frame.setJMenuBar(menubar);
    frame.setVisible(true);
    }

public void solve(){
    model.physics("solid").feature("lemm1").set("Evector_mat", "userdef");
    model.physics("solid").feature("lemm1").set("rho_mat", "userdef");
    model.physics("solid").feature("lemm1")
         .set("nuvector", new String[][]{{compProp7}, {compProp8}, {compProp9}});
    model.physics("solid").feature("lemm1")
         .set("Gvector", new String[][]{{compProp4}, {compProp5}, {compProp6}});
    model.physics("solid").feature("lemm1").set("rho", compProp10);
    model.physics("solid").feature("lemm1")
         .set("Evector", new String[][]{{compProp1}, {compProp2}, {compProp3}});
    model.physics("solid").feature("lemm1").set("Gvector_mat", "userdef");
```

'Solve' method to run model

```
            model.result("pg1").set("window", "window1");
            model.result("pg1").run();
        }
    });
}

private JPanel leftPanel(){
    MigLayout layout= new MigLayout("wrap 2");
    JPanel panel = new JPanel(layout);
    JLabel label = new JLabel("Pre-Processing");
    panel.add(label,"span, wrap 15px");
    label.setFont(new Font("Serif", Font.PLAIN, 25));
    label = new JLabel("Fiber Property:");
```

'leftPanel 'method for defining fields in input side of GUI

PROGRAM ARCHITECTURE

```
            model.result("pg4").set("window", "window1");
            model.result("pg4").run();
        }
    });
    return panel;
}
}
private JButton solveButton(){
    solveButton = new JButton("Simulate");
    model= RectModel.run();
    solveButton.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        solve();
    }
    });
    return solveButton;
}

private void sPlot(){
    model.result().dataset("cpl1")
       .set("genpoints", new String[][]{{xs1Coord, ys1Coord, zs1Coord}, {xs2Coord, ys2Co
       model.result().dataset("cpl1").set("planetype", "general");
    model.result("pg6").set("window", "window1");
    model.result("pg6").run();
}

private JButton calculateButton(){
    calculateButton = new JButton("Calculate Composite Properties");
    calculateButton.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        String fiberPer = editFC.getText();
        double fibPercent = Double.parseDouble(fiberPer);
        String matrixPer = editMC.getText();
```

'Solve Button' which calls 'solve' method

'Calculate Button' method calculates composite properties

PROGRAM ARCHITECTURE

```
public static void fiberProp(){
        try {

            FileInputStream fiberProperty = new FileInputStream(new File("D:\\Ris
            HSSFWorkbook workbook = new HSSFWorkbook(fiberProperty);
            for(int i=0; i<13; i++){
                HSSFSheet fiber = workbook.getSheetAt(i);
                Iterator<Row> rowIterator = fiber.iterator();
                int row_index=0;
                while(rowIterator.hasNext()) {
                    Row row = rowIterator.next();
```

'fiberProp' method for defining fiber properties

```
public static void matrixProp(){
    try {

        FileInputStream matrixProperty = new FileInputStream(new File("D:\\Rishabh
        HSSFWorkbook workbook = new HSSFWorkbook(matrixProperty);
        for(int i=0; i<13; i++){
            HSSFSheet matrix= workbook.getSheetAt(i);
            Iterator<Row> rowIterator = matrix.iterator();
            int mat_index=0;
            while(rowIterator.hasNext()) {
                Row row = rowIterator.next();
```

'matrixProp' method for defining matrix properties

PROGRAM ARCHITECTURE

```
private JPanel rightPanel() {
    MigLayout layout = new MigLayout("wrap 6");
    final JPanel panell = new JPanel(layout);
    JLabel label = new JLabel("Post-Processing");
    panell.add(label,"span, wrap 15px");
    label.setFont(new Font("Serif", Font.PLAIN, 25));
    label = new JLabel("Contour Plot:");
    panell.add(label,"span, wrap 10px");
    label.setFont(new Font("Serif", Font.PLAIN, 17));
    String[] contourType = {"Select Contour Type", "Lines", "Filled"};
```

'rightPanel' method for defining fields in output side of GUI

```
private JButton linePlot(){
    JButton linePlot = new JButton("Line Plot");
    linePlot.addActionListener(new ActionListener() {
        public void actionPerformed(ActionEvent e) {
            x1Coord = editX1.getText();
            y1Coord = editY1.getText();
            z1Coord = editZ1.getText();
            x2Coord = editX2.getText();
            y2Coord = editY2.getText();
            z2Coord = editZ2.getText();
```

'linePlot' method for plotting Line Plot

PROGRAM ARCHITECTURE

```
private void plot(){
            model.result().dataset("cln1")
            .set("genpoints", new String[][]{{x1Coord, y1Coord, z1Coord},
                    {x2Coord, y2Coord, z2Coord}});
            model.result("pg2").set("window", "window1");
            model.result("pg2").run();
}

private JButton surfacePlot(){

    JButton surfacePlot = new JButton("Surface Plot");
    surfacePlot.addActionListener(new ActionListener() {
        public void actionPerformed(ActionEvent e) {
            xs1Coord = editXs1.getText();
```

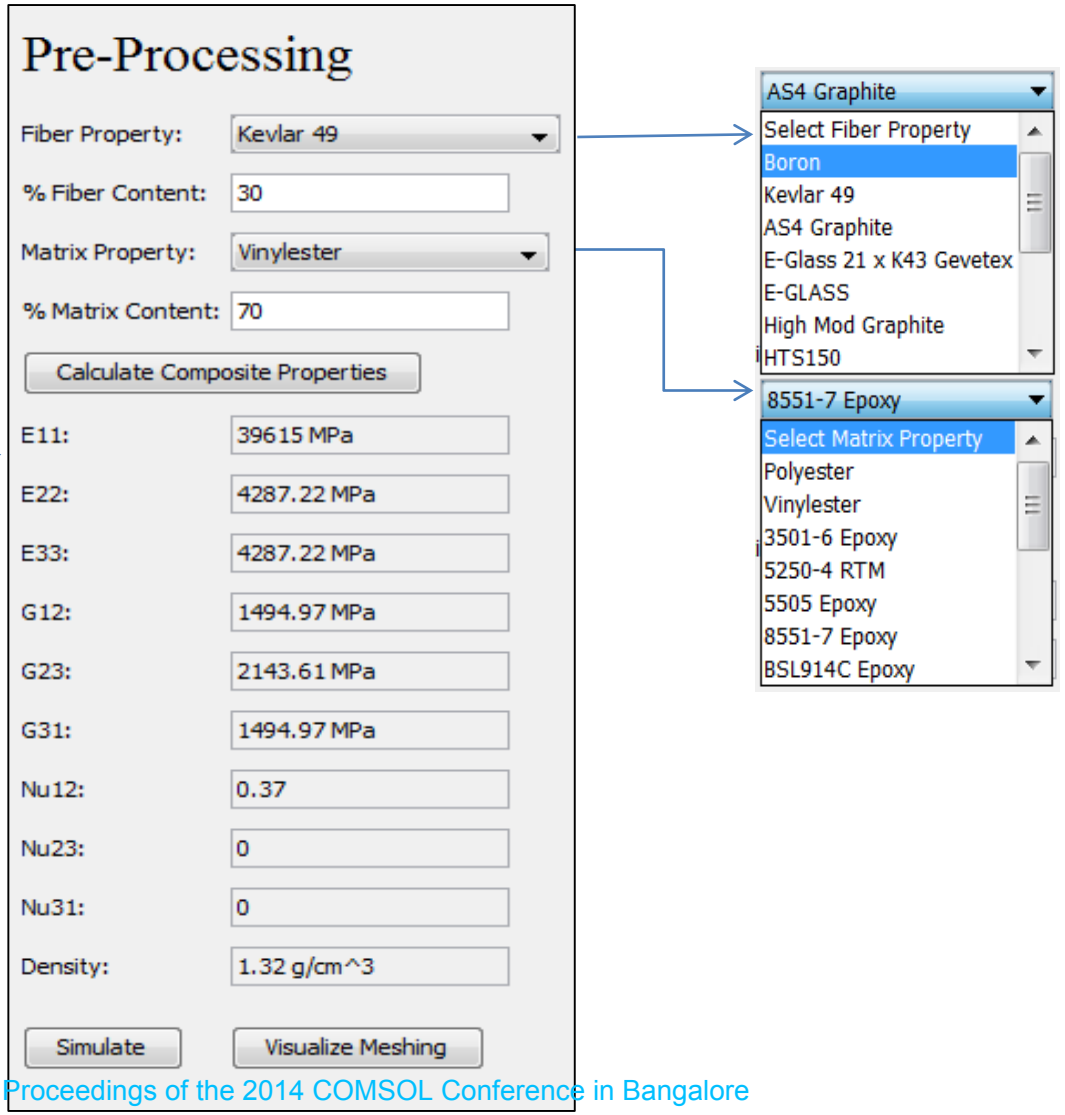
'plot' method and 'surfacePlot' method for plotting surface Plot

```
private JMenuBar menu() {
      JMenuBar menubar = new JMenuBar();
      JMenu menu = new JMenu("File");
      menubar.add(menu);
      JMenuItem item = new JMenuItem("Open");
      menu.add(item);
      item = new JMenuItem("Exit");
      item.setActionCommand("exit");
```

'menu' method for menu bar at the top of GUI

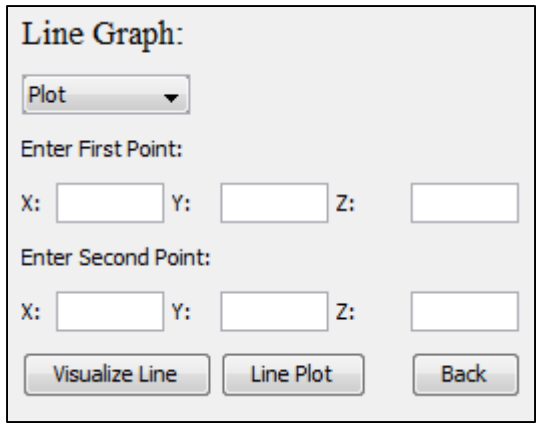
USER INTERFACE…

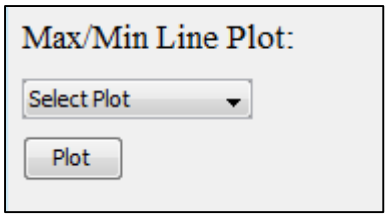
INPUT INTERFACE

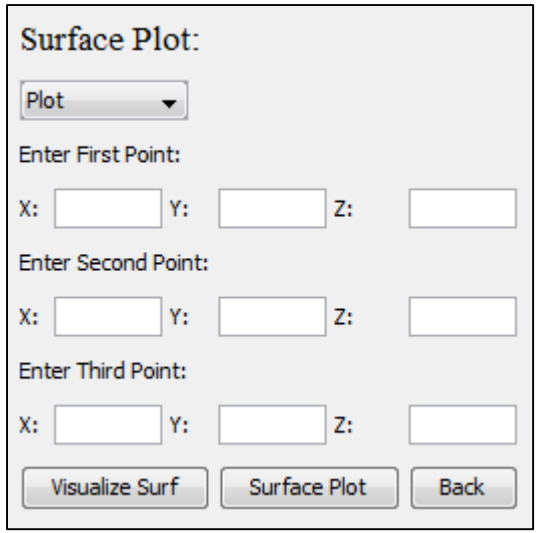


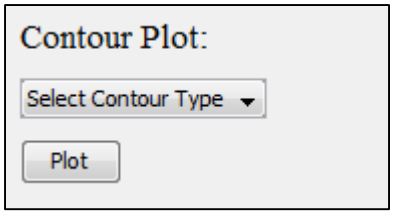
...User Interface

Interface for Post-Processing of Results

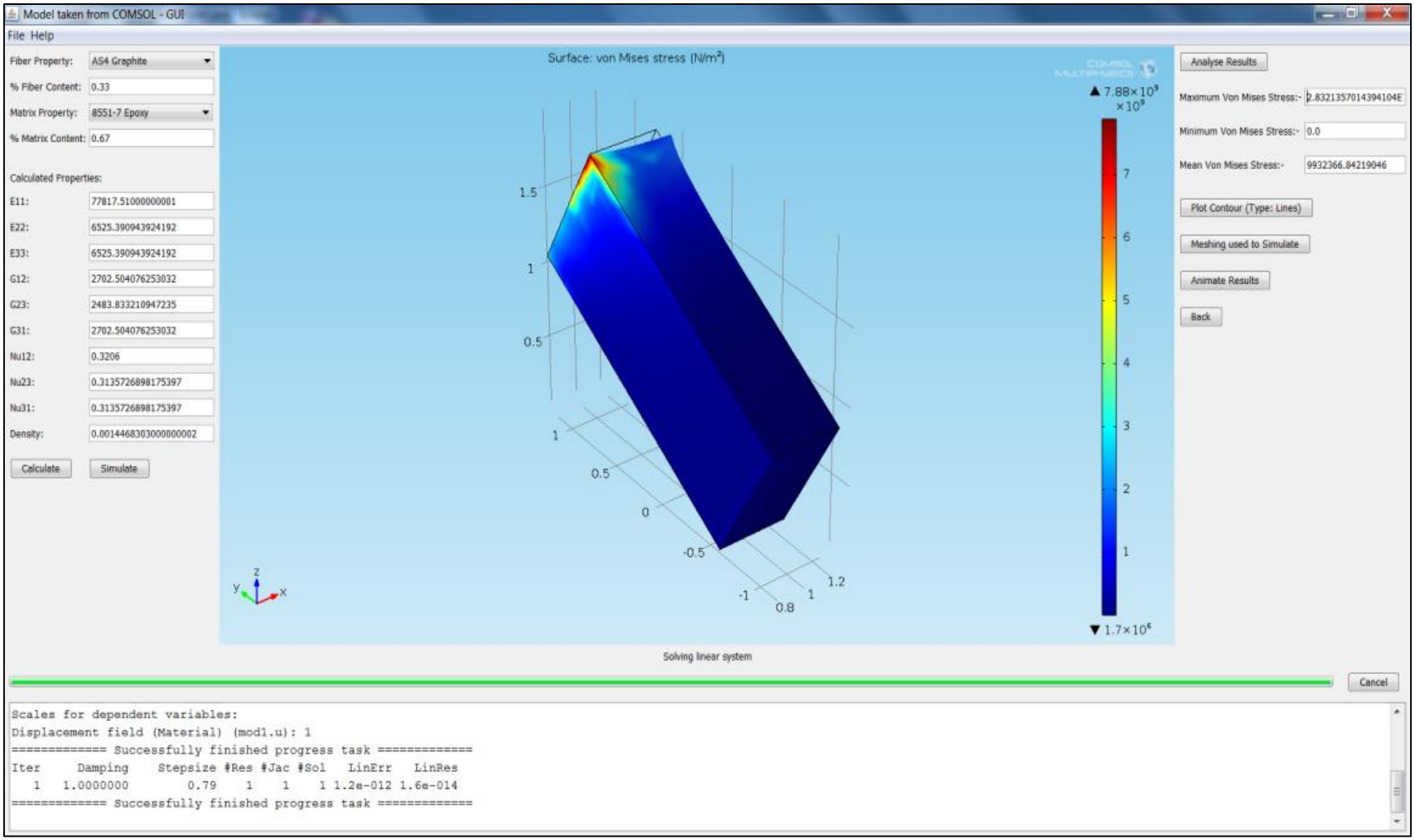




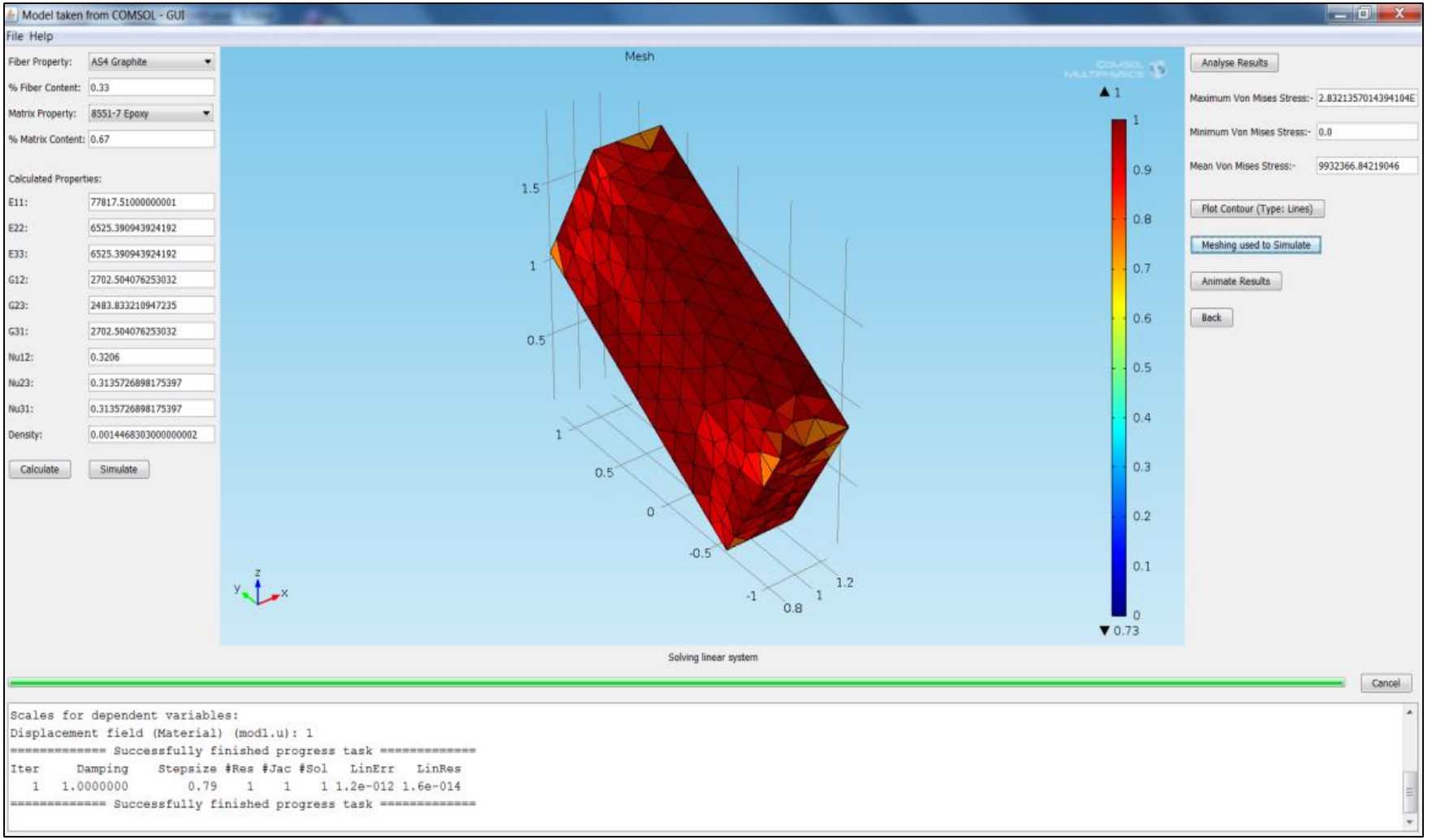




RESULTS


Model taken from COMSOL - GUI
File Help
Fiber Property: AS4 Graphite
% Fiber Content: 0.33
Matrix Property: 8551-7 Epoxy
% Matrix Content: 0.67
Calculated Properties:
E11: 77817.51000000001
E22: 6525.390943924192
E33: 6525.390943924192
G12: 2702.504076253032
G23: 2483.833210947235
G31: 2702.504076253032
Nu12: 0.3206
Nu23: 0.3135726898175397
Nu31: 0.3135726898175397
Density: 0.0014468303000000002
Calculate
Simulate
Surface: von Mises stress (N/m²)
▲ 7.88×10⁹
×10⁹
▼ 1.7×10⁶
Analyse Results
Maximum Von Mises Stress:- 2.8321357014394104E
Minimum Von Mises Stress:- 0.0
Mean Von Mises Stress:- 9932366.84219046
Plot Contour (Type: Lines)
Meshing used to Simulate
Animate Results
Back
Solving linear system
Cancel
Scales for dependent variables:
Displacement field (Material) (mod1.u): 1
============= Successfully finished progress task =============
Iter Damping Stepsize #Res #Jac #Sol LinErr LinRes
1 1.0000000 0.79 1 1 1 1.2e-012 1.6e-014
============= Successfully finished progress task =============

RESULTS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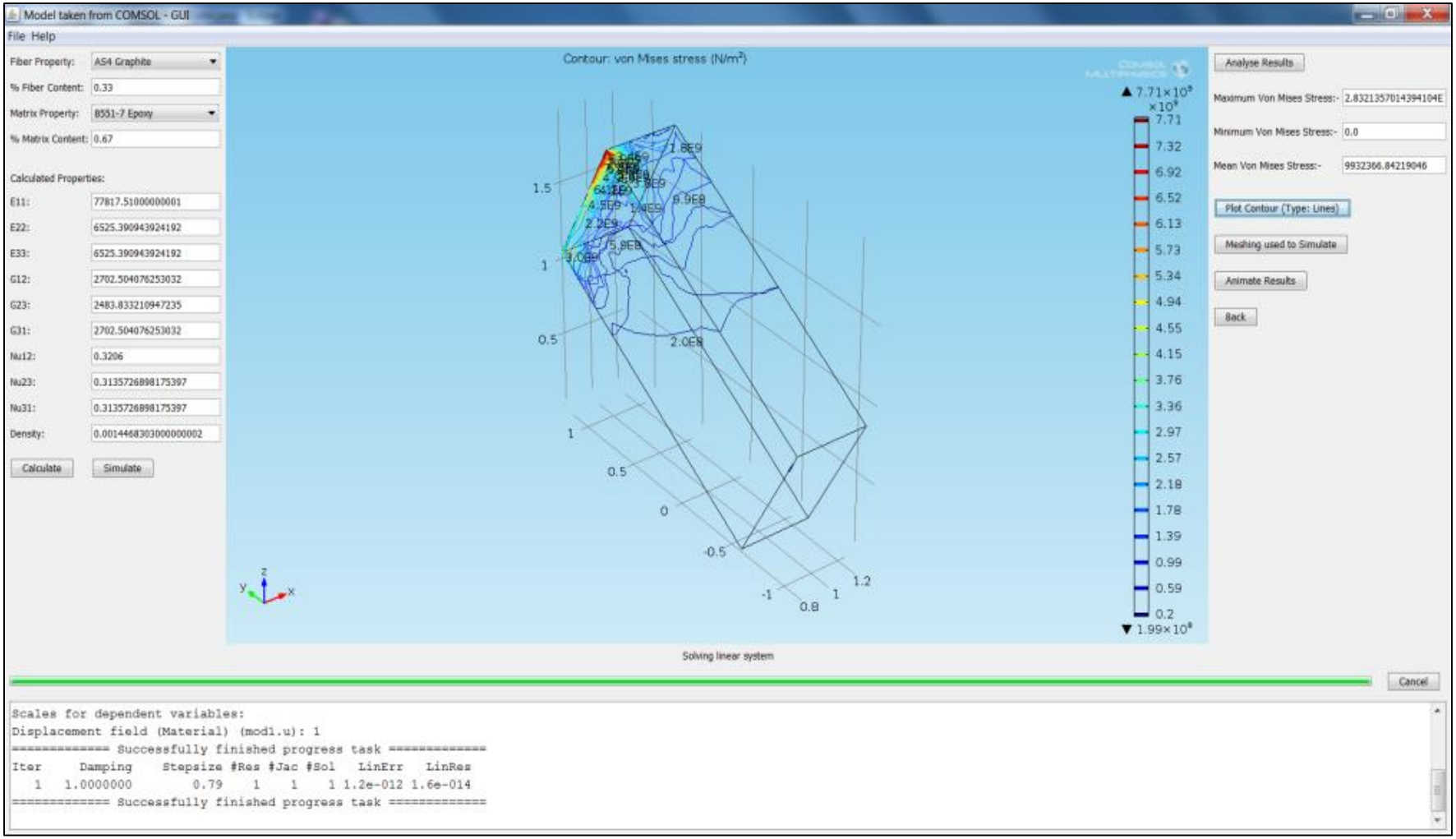
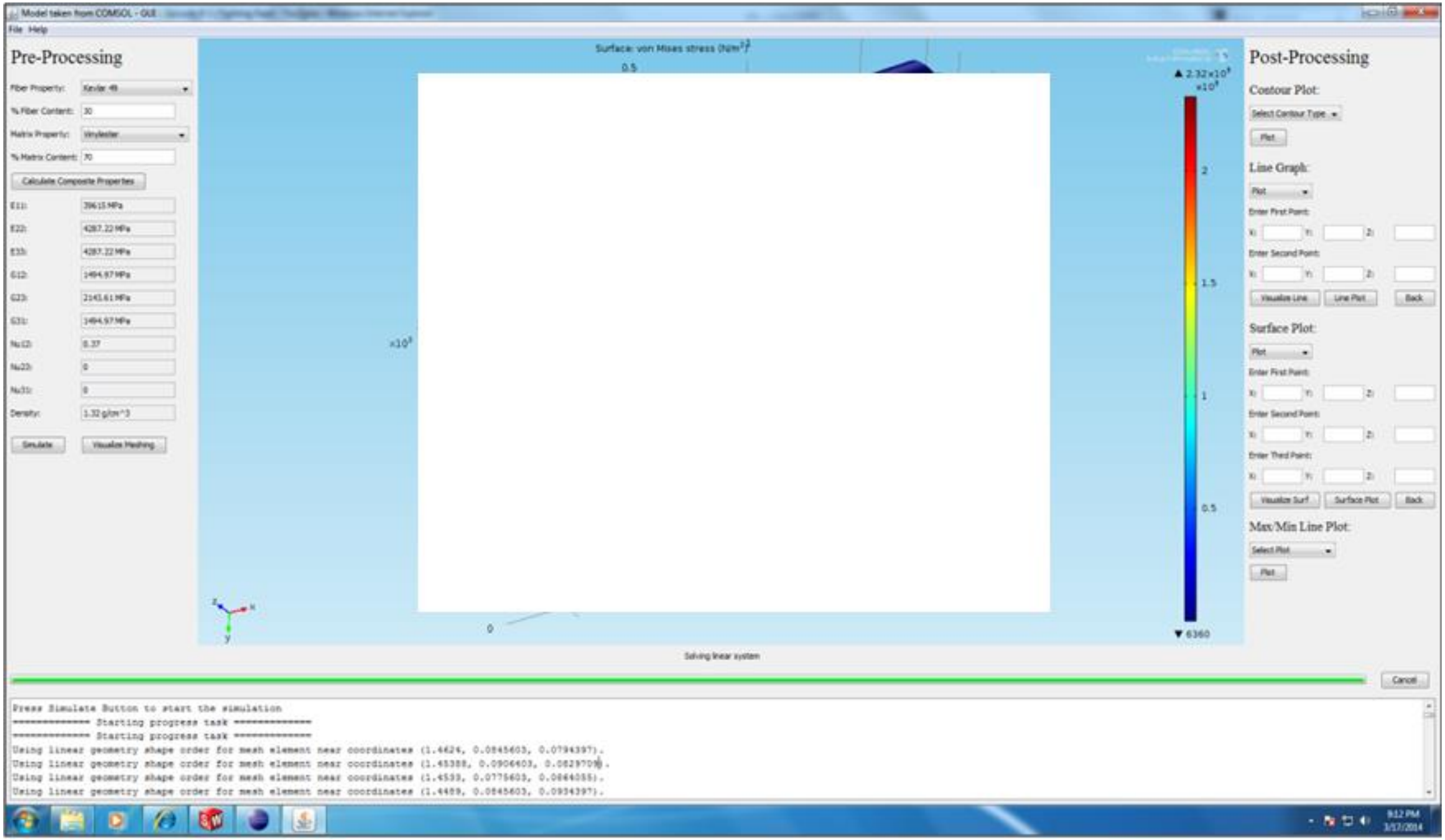
G23: 2483.833210947235
G31: 2702.504076253032
Nu12: 0.3206
Nu23: 0.3135726898175397
Nu31: 0.3135726898175397
Density: 0.0014468303000000002
Calculate
Simulate
Mesh
Analyse Results
Maximum Von Mises Stress:- 2.83213570143941046
Minimum Von Mises Stress:- 0.0
Mean Von Mises Stress:- 9932366.84219046
Plot Contour (Type: Lines)
Meshing used to Simulate
Animate Results
Back
Solving linear system
Cancel
Scales for dependent variables:
Displacement field (Material) (mod1.u): 1
========== Successfully finished progress task ==========
Iter Damping Stepsize #Res #Jac #Sol LinErr LinRes
1 1.0000000 0.79 1 1 1 1.2e-012 1.6e-014
========== Successfully finished progress task ==========

RESULTS



CONTOUR PLOT

RESULTS



SIMULATION ON A MORE COMPLEX MODEL

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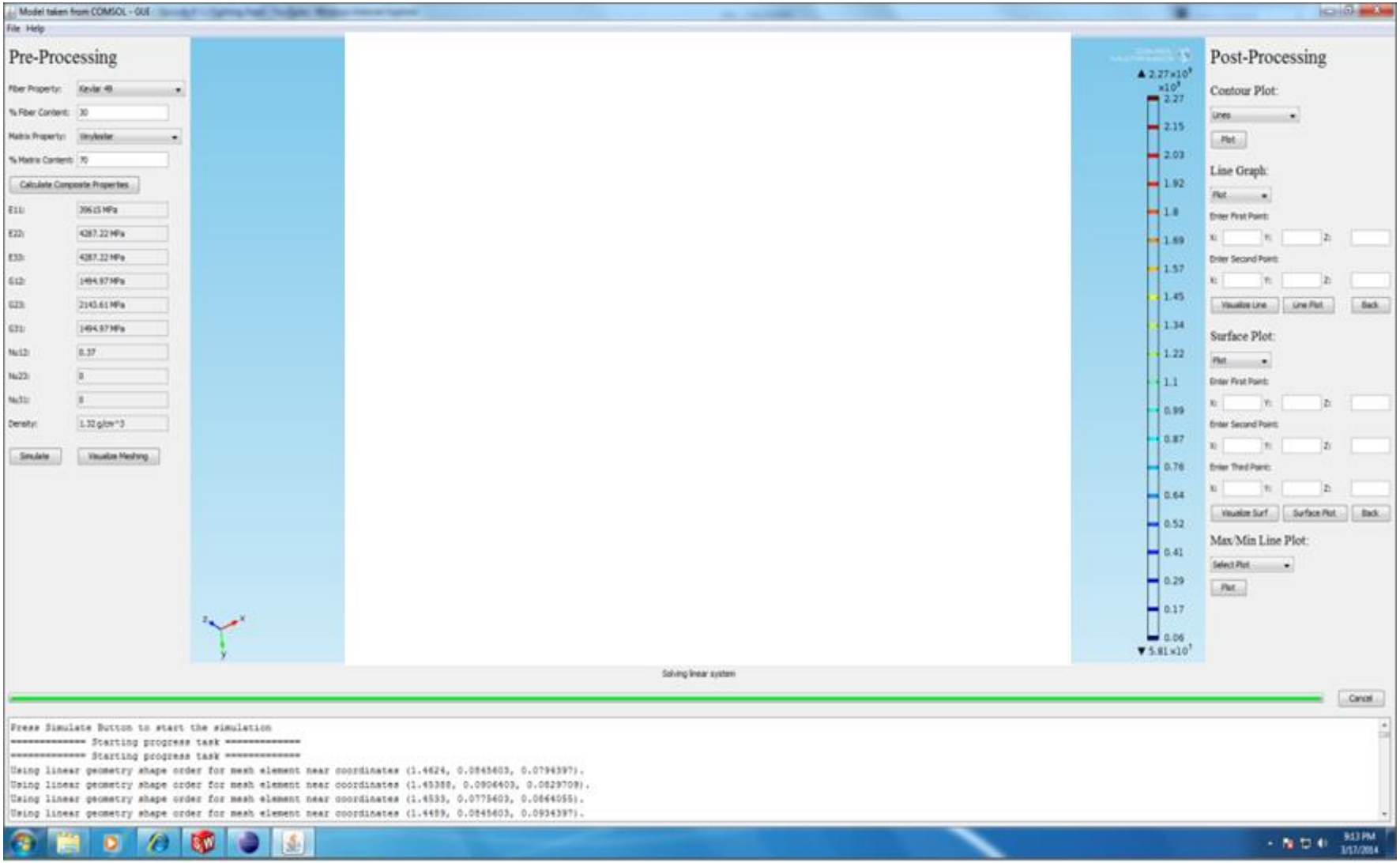
RESULTS



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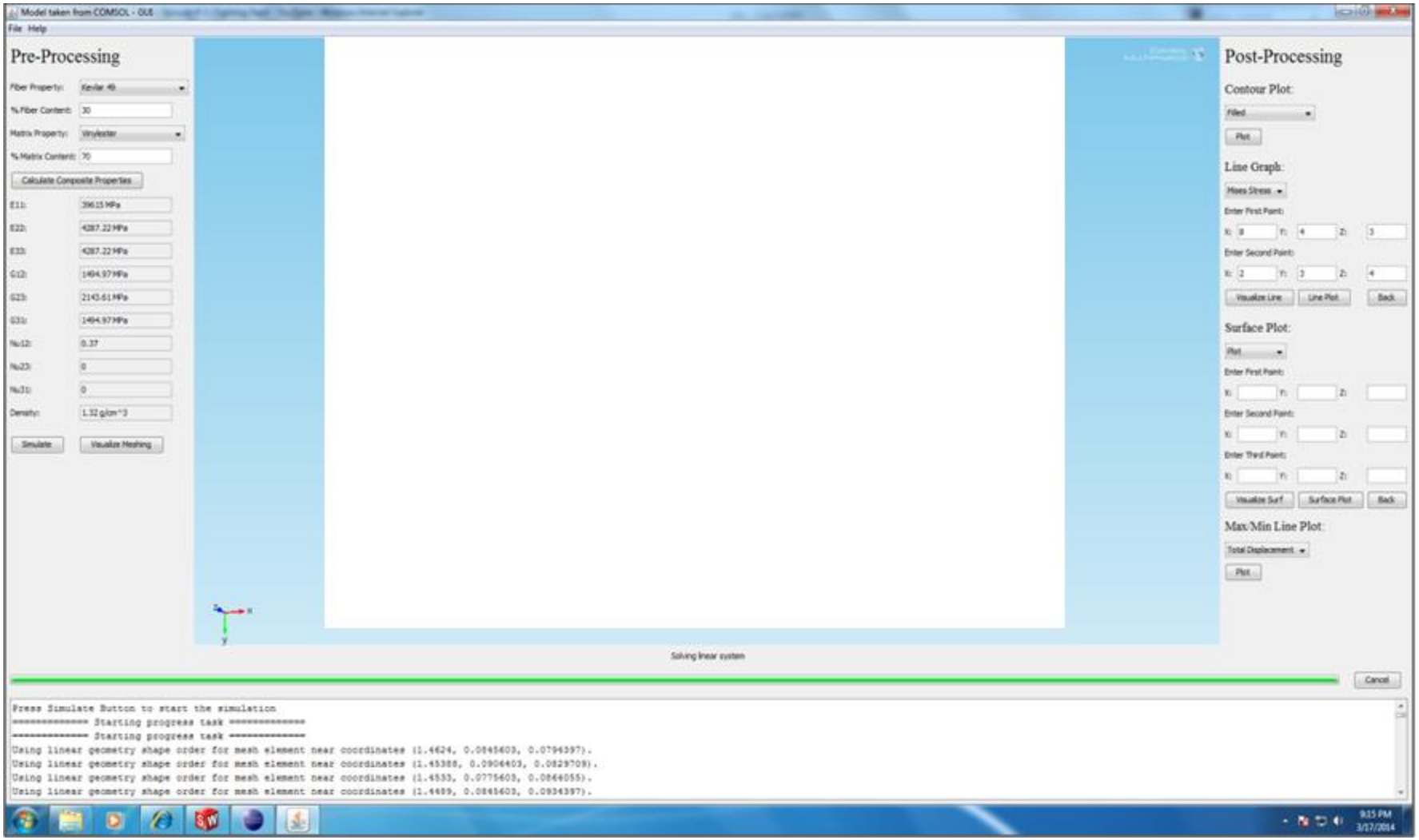
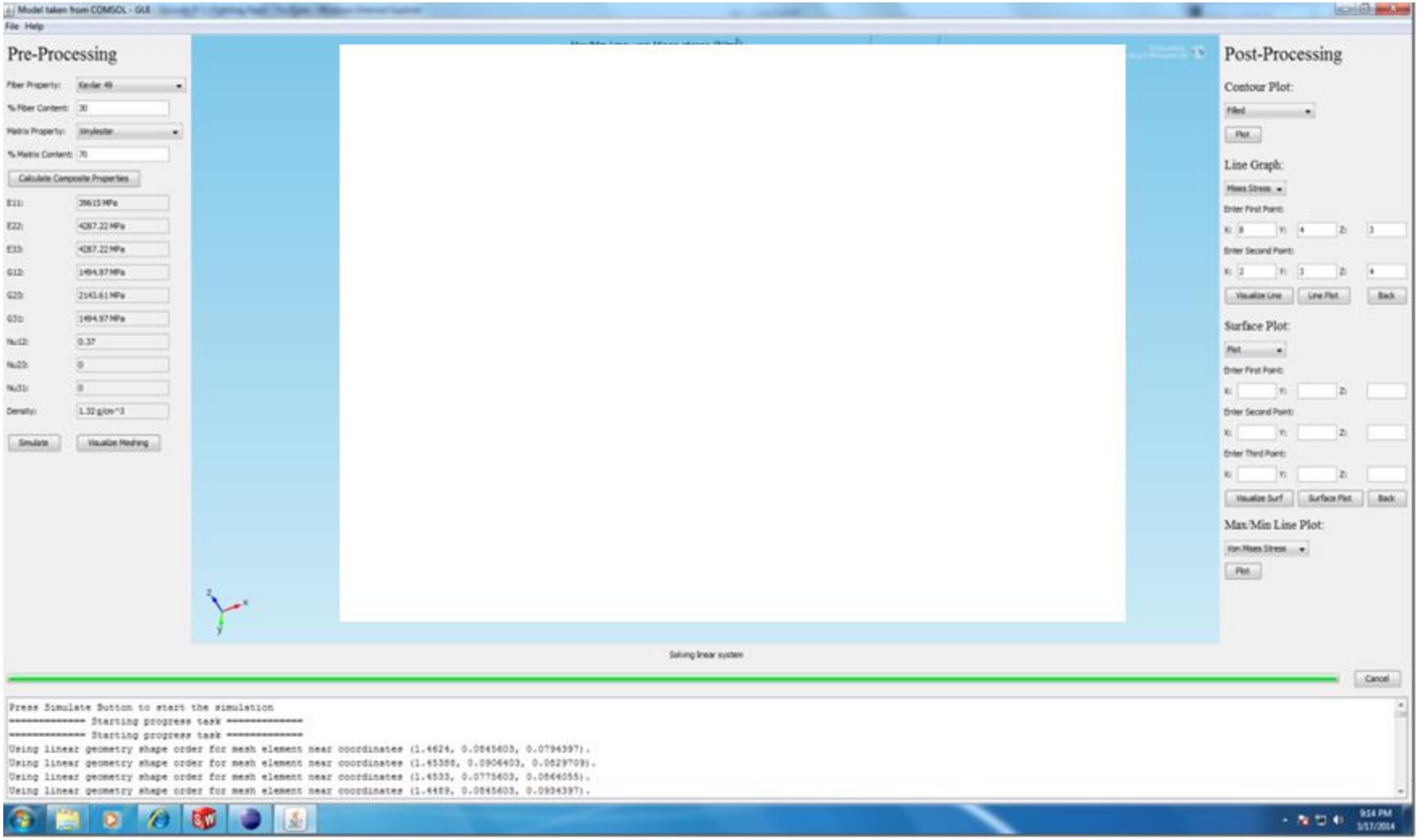
CONTOUR PLOT

RESULTS



LINE GRAPH

RESULTS



MAX/MIN LINE PLOT

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LIMITATIONS AND CHALLENGES

- Integrating failure criteria's for composite materials is not possible in an user interface
- Selecting points in the 3-D model is not possible by using mouse events on graphics panel
- Meshing of an complex model is difficult to perform in an user interface

CONCLUSION

- Composite Material properties were successfully integrated with COMSOL Multiphysics in a user-friendly interface
- GUI created is compatible to be used for any model for the purpose of performing simulation with Composite Material properties
- GUI can also be used to perform some of the important Post-Processing which can be cumbersome to do in COMSOL Multiphysics GUI for an inexperienced user

THANKS FOR YOUR ATTENTION