U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

DEMec
DEPARTAMENTO
DE ENGENHARIA
MECÂNICA

AdFEUP
Adhesives Group
Grupo de Adesivos

AB2013
2nd International Conference
on Structural Adhesive Bonding

jointdesigner | DEVELOPMENT OF A WEB APPLICATION FOR THE DESIGN OF ADHESIVE JOINTS

DATE

4 JULY 2013

AUTHORS

MARCELO BRUNO SERRÃO FONTES PARENTE DA COSTA
LUCAS FILIPE MARTINS DA SILVA
RAUL DUARTE SALGUEIRAL GOMES CAMPILHO

Contents

Contents

Motivation

The prediction of an adhesive joint behaviour is complex and depends on various factors, which means that different analytical methods, whose complexity can require a simple calculator or a powerful computer for solving, can be used to predict said behaviour.

Contents

Objectives

- **Main objective: create an user interface where all types of analytical methods (simple and complex) can be easily used and evaluated.**

- **Analytical methods objectives:**
  - Implement analytical methods that can be used for various material properties;
  - Ability to use both elastic and plastic analytical methods;
  - Anisotropic adherends support.

- **Application objectives:**
  - Create an interface that can be used by all engineers, even those without experience in adhesives;
  - Visualize results as plots, e.g. peel and shear stress plots;
  - Print plots and export results (Excel, PDF, etc.) to use outside JointDesigner;
  - Database of materials (adhesives and adherends), with both general and private material options.

Contents

Elastic analysis

- **Volkersen [1938]**
  - Adhesive deforms only in shear;
  - Adherends deform in tension (elastic).

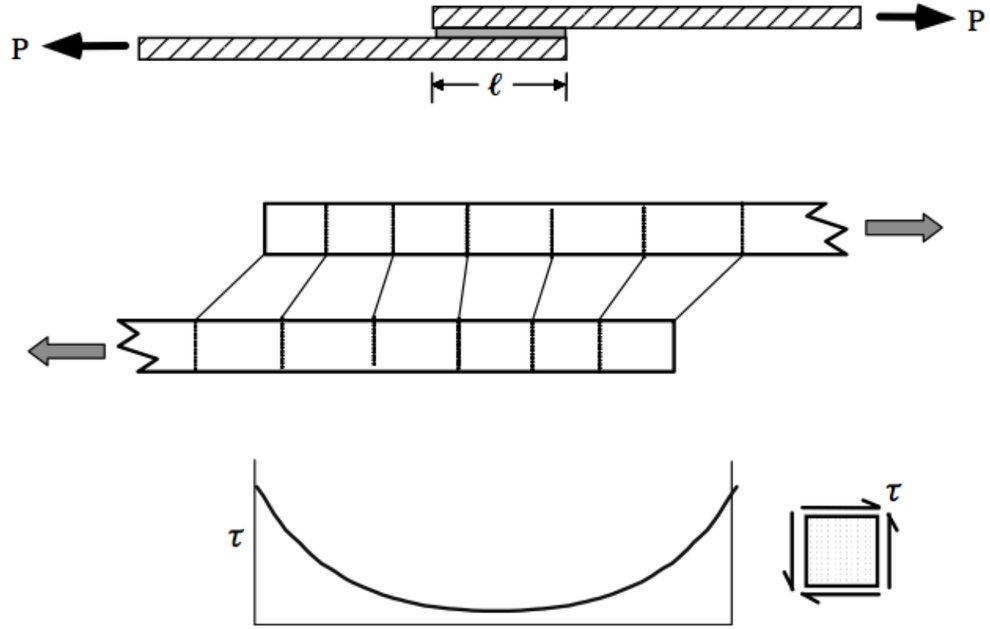
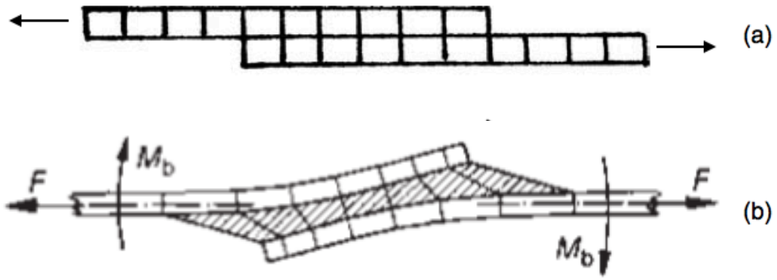


FIG. 1 *- Volkersen analysis, with resulting shear stress plot (bottom) for elastic adherends.*

Contents

Elastic analysis

- **Goland & Reissner [1944]**
  - Due to the eccentric load path of a SLJ, a bending moment occurs, which causes the joint to rotate;
  - In addition to the shear stress, peel stress is also present.



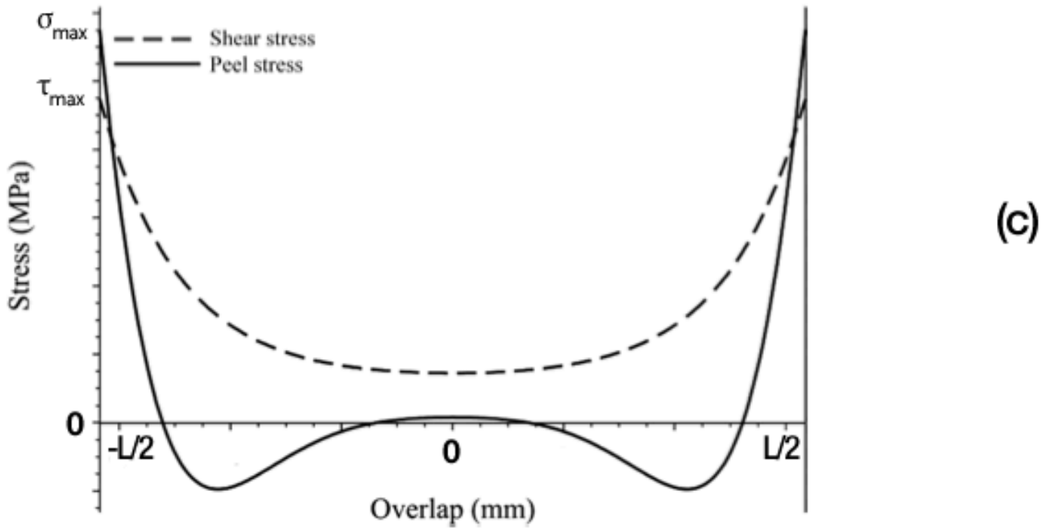


FIG. 2 *- Goland & Reissner analysis: (a) joint configuration, (b) deformed joint with applied force and resulting bending moment, and (c) example shear and peel plots [da Silva et al., 2009].*

Contents

Elastic analysis

- **Ojalvo & Eidinoff [1978]**
  - Detected a deficiency in the work published by Goland & Reissner:
    - Incomplete shear-strain/displacement equation for the adhesive;

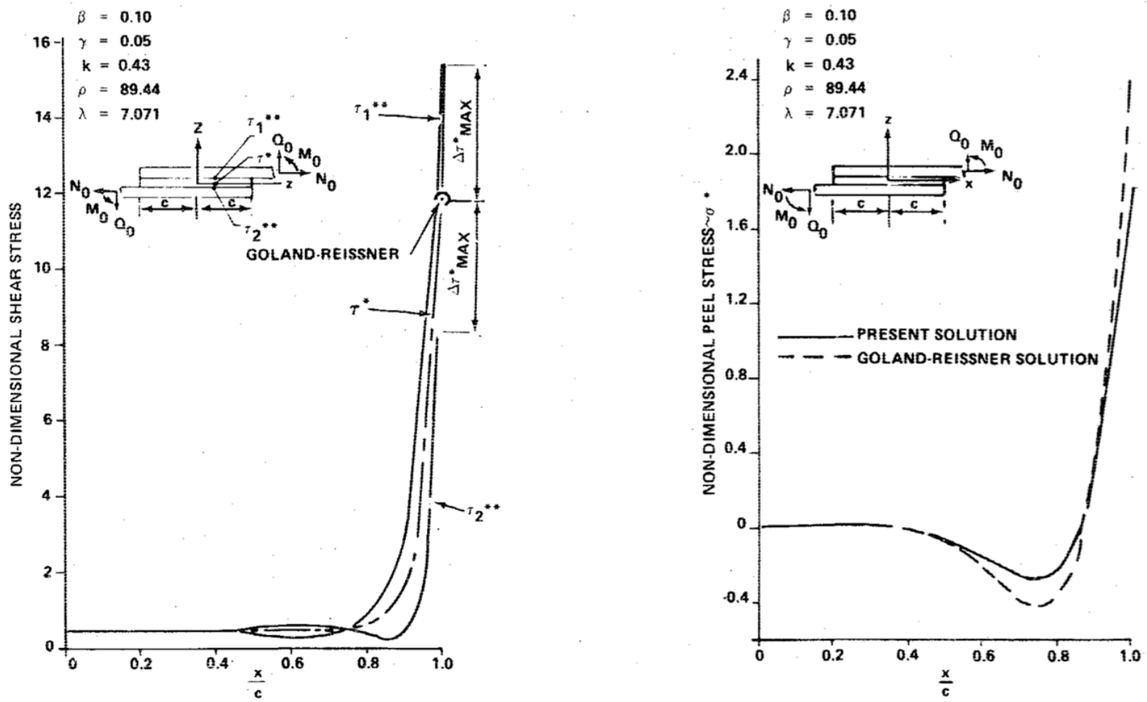


FIG. 3 *- Comparison between Ojalvo & Eidinoff and Goland & Reissner's results: (left) shear stress distribution, and (right) peel stress distribution [Ojalvo et al., 1978].*

Contents

Plastic analysis

- **Hart Smith [1973]**
  - Considers the plastic deformation of an adhesive in addition to the elastic response.

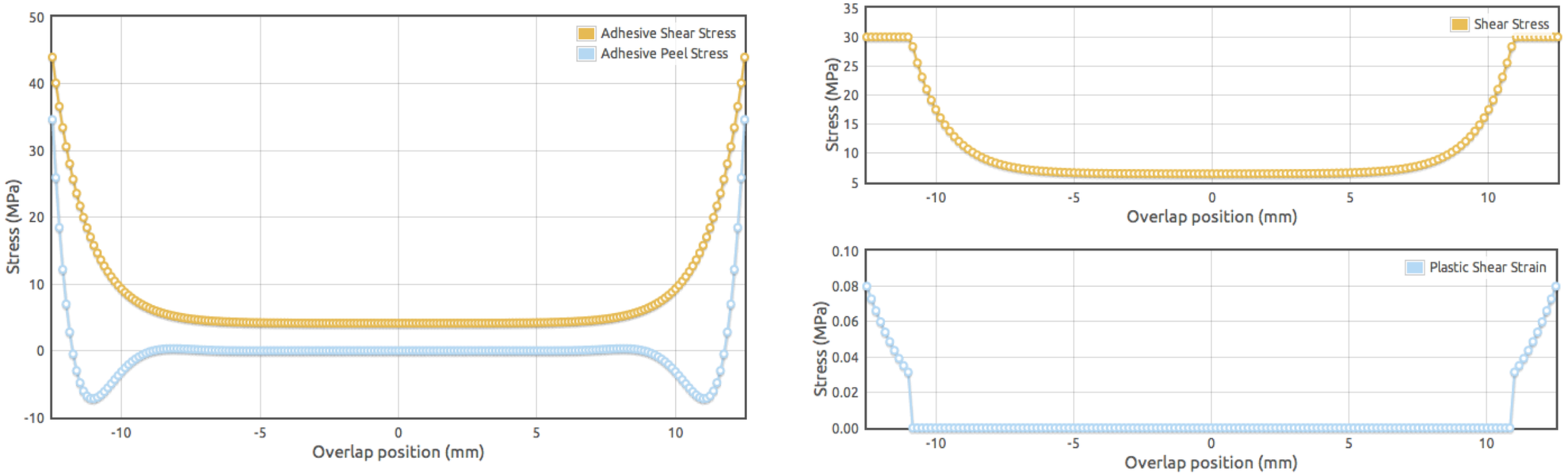
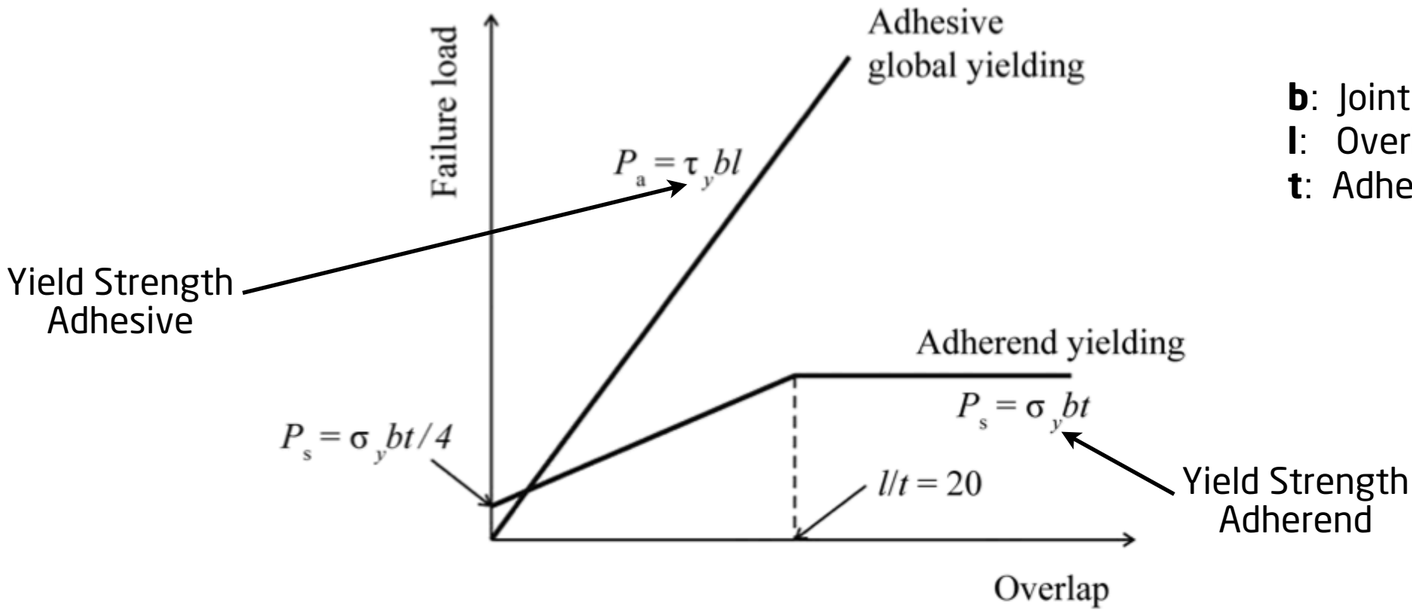


FIG. 4 *- Results for an arbitrary joint: (left) adhesive shear and peel stress, (top right) shear stress and (bottom right) plastic shear strain.*

Contents

Plastic analysis

- **Adams [1997]**
  - Simple predictive model that gives the adhesive global yielding and the adherend yielding;
  - Predicts load for total plastic deformation of both adhesive and adherends.



b: Joint Width
l: Overlap Length
t: Adherend Thickness

FIG. 5 *- Simple design methodology of single lap joints based on the adherend yielding according to Adams et al* [*Karachalios et al., 2013*].

Summary of analytical methods implemented

Adhesive behaviour	Adherends			Results	Methods
	Behaviour	Material	Similarity		
Elastic	Elastic	Isotropic	Dissimilar	Stresses	Volkersen
			Similar		Goland & Reissner
			Dissimilar		Ojalvo & Eidinoff
Plastic			Similar		Hart Smith
	Plastic			Failure load	Adams

TAB. 1 *- List of implemented analytical methods as function of various parameters* [*da Silva et al., 2009*].

Contents

Advantages of the web application

- **Advantages** compared to a desktop application:
  - Independent of operating system;
  - Independent of place of usage;
  - Easier to apply updates;
  - Easier to investigate problems;
  - Reuse of existing technology (plotting, printing, etc.) to speed up development;
  - Avoid the distribution problems we would have with MATLAB.

- **Disadvantages** to a desktop application:
  - Needs a server to run (extra costs):
    - At the moment it runs on our server at FEUP - free.
  - Weak algebraic and mathematical power:
    - We use a dedicated CAS system to solve this problem.

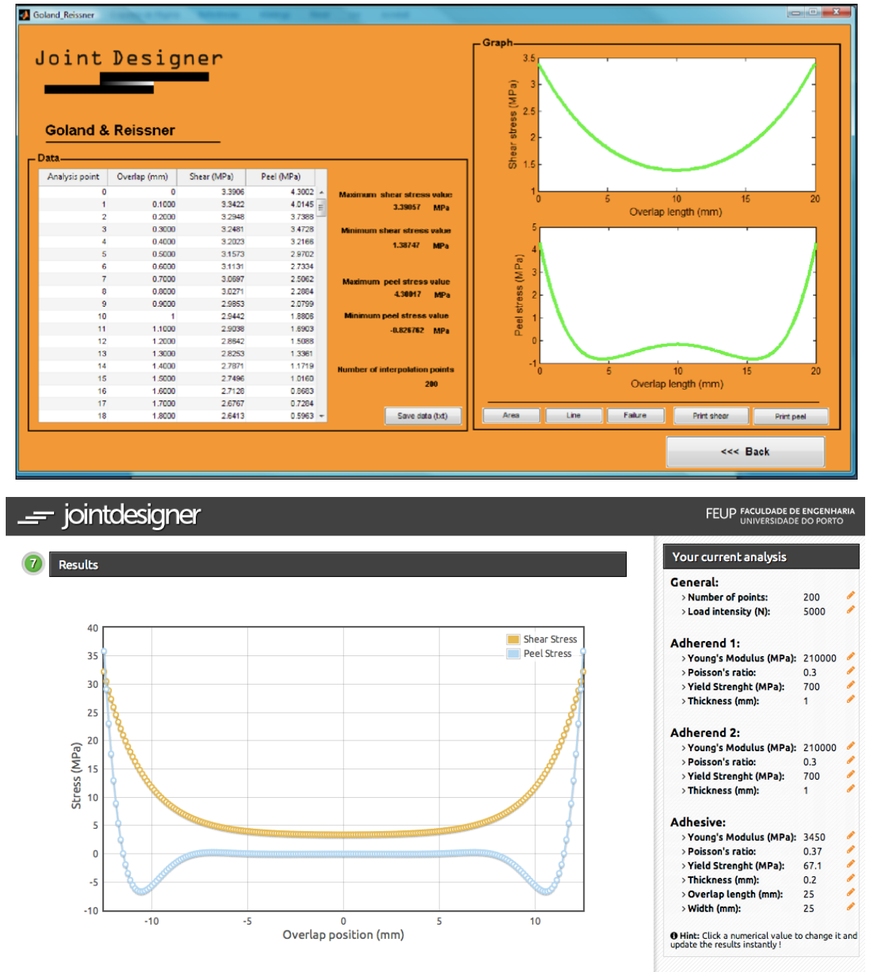


FIG. 6 *- JointDesigner as: (top) a desktop application in 2009, and (bottom) a web application.*

Contents

Internal diagram

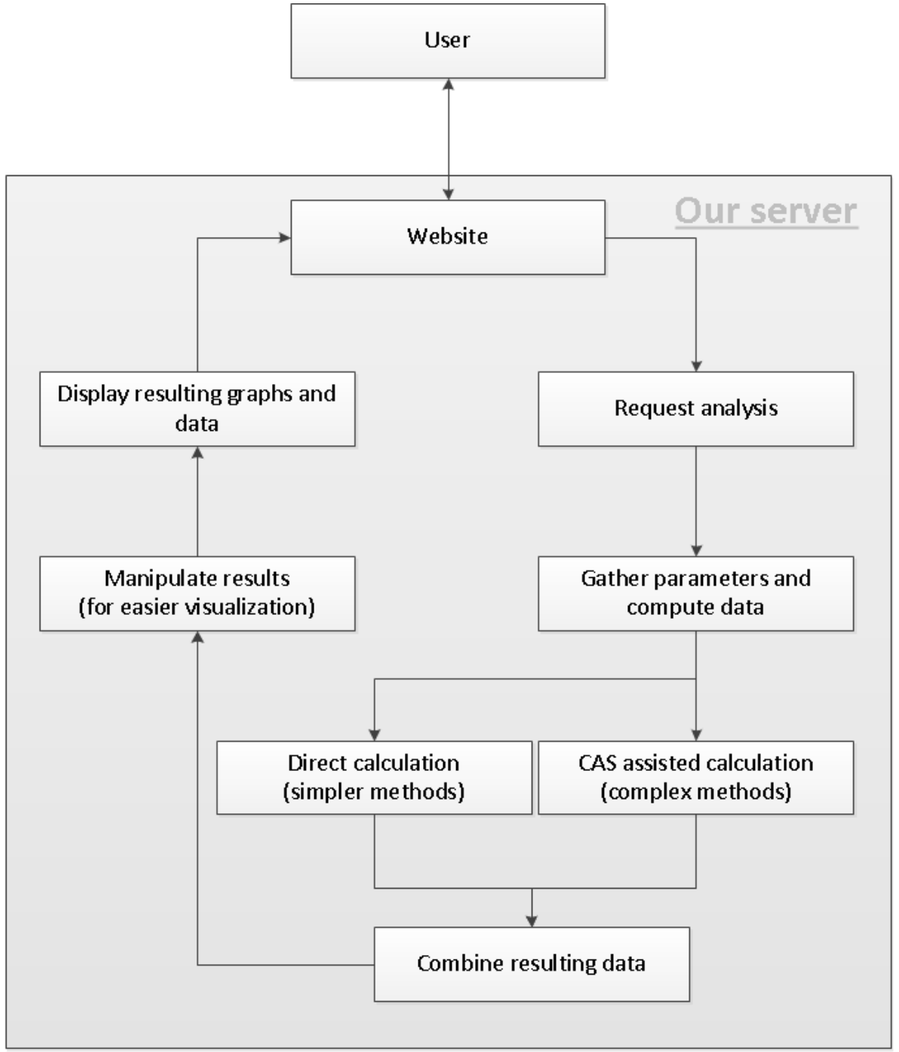


FIG. 7 *- Diagram representing the backend of JointDesigner.*

Contents

Choosing a CAS * (Computer Algebra System)

- **Necessary because JointDesigner needs to:**
  - Solve systems of equations;
  - Evaluate differential equations:
  - Complex equations are preferably handled by software created for that purpose.
- **Open-source CAS selected based on capabilities and speed:**
  - Singular - very fast and highly efficient algorithms;
  - Maxima - fast, stronger and wider support of mathematical and algebra concepts;
  - SAGE - open-source alternative to MATLAB/Maple, and incorporates Maxima as well.

$$\frac{P}{l\tau_p}(\lambda' l) = 2\lambda'\left(\frac{l-d}{2}\right) + (1-K)(\lambda' d) + K\tanh(\lambda' d)$$

$$\frac{P}{\tau_p}\lambda^2\left[1+3k(1-\nu^2)\left(1+\frac{t_a}{t}\right)\right] = 2\left(\frac{\gamma_p}{\gamma_e}\right) + K\left[2\lambda'\left(\frac{l-d}{2}\right)\right]^2$$

$$2\left(\frac{\gamma_p}{\gamma_e}\right) = K\left\{\left[2\lambda'\left(\frac{l-d}{2}\right) + \tanh(\lambda' d)\right]^2 - \tanh(\lambda' d)\right\}$$

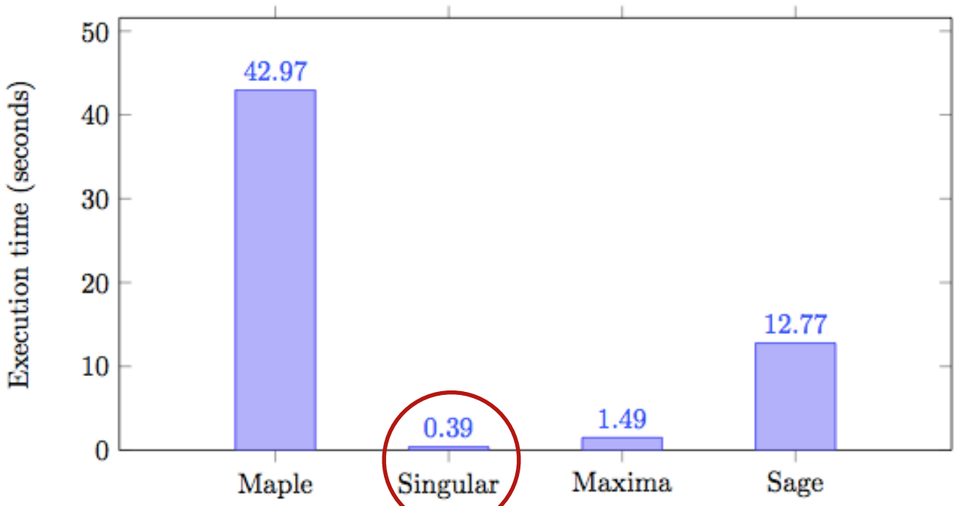


FIG. 8 *- System of equations used to test the CAS software (left), and resulting execution time for each (right).*

Contents

Key functionality

- **Analytical methods:**
  - Wide support of methods for each type of problem;
  - Each method is a module of the site, making it easy to develop and implement more methods;
  - Thanks to the use of a CAS system, virtually no limits on complexity of methods.
- **Front end of the web application:**
  - Ability to view stress values in each point of the joint;
  - Export results to various formats, and print directly from results page;
  - Save analysis online, so they can be accessed later;
  - Database of adhesives and adherends stores common materials:
    - Properties are automatically inserted.

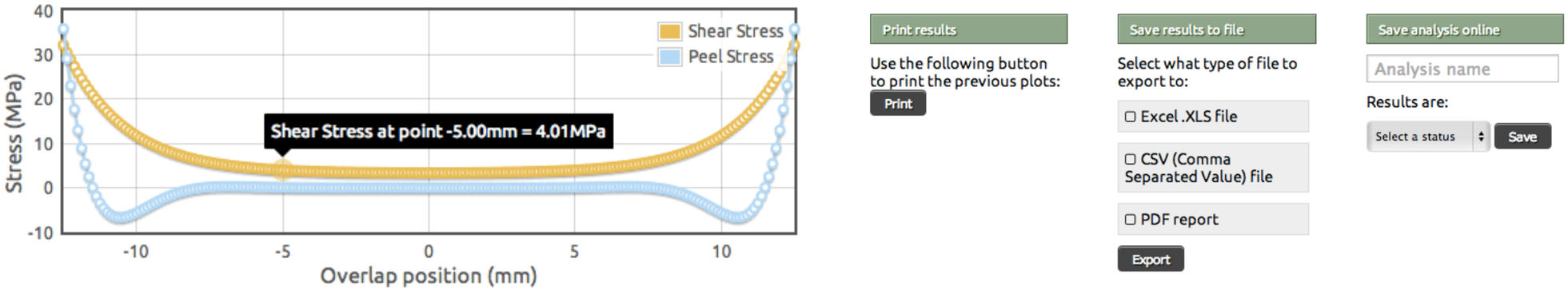


FIG. 9 *- Resulting plot ability to view stress at each point (left), and print/export/save features (right).*

Contents

Demonstration

Contents

Conclusions

- **Resulting application considered to be a success:**
  - Easy to use;
  - Various features and analytical methods;
  - Use of advantages available due to being a web product:
    - Sharing of data with other co-workers/accounts.

- **Main objectives accomplished:**
  - Reduction of the time an engineer needs to predict the behaviour of an adhesive joint
    - Possible to compute an analysis through JointDesigner in minutes;
  - Ability to export results to Excel and other software.

- **Created a valuable product to any engineer that designs adhesive joints.**

- **Possibility to extend and add new functionality to the web application, increasing its value over time.**