An application to calculate the factors which are used to determine the tensile rupture load of a lug under axial, transverse or oblique loading

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Abstract: *This work describes a computer application to calculate the values of the factors which are used to determine the tensile rupture load of a lug under axial, transverse or oblique loading. It can be used as a procedure for identifying potential failure modes. Lugs are connector-type elements widely used as structural supports for pin connections in aerospace industry. Failure modes in lugs are functions of lug geometry and material mechanical properties. For a lug under axial load three modes of lug failure are considered: tension, shear and bearing. Under transverse load the load to cause rupture or unacceptable permanent deformation of the lug is given. Tension mode failure usually occurs in materials of low ductility. In materials with high ductility, the failure mode of a lug can be either tensile or shear tear-out, depending on the lug geometry. The application has a graphical interface that allows the user to use them with much ease and view immediately the results and provides a flexible ad-hoc print reports and diagrams that allow to present analysis information. It includes Microsoft Excel Object Library as reference to the Excel material properties file.*

Key Words: *lug failure analysis, material properties, computer program, graphical user interface*

1. INTRODUCTION

To develop "An application to calculate the values of the factors which are used to determine the tensile rupture load of a lug under axial, transverse or oblique loading" was chosen Visual Basic (VB) from Microsoft Visual Studio was chosen as the Integrated Development Environment (IDE) on Windows platform.

It provides comprehensive facilities to maximize programmer productivity for software development from design to deployment. The user communicates with the application through a graphical interface.

VB provides source code editor, builder, and various tools to ease and simplify the construction of a Graphical User Interface (GUI) such as controls and, in addition, enables to integrate the external component or references. Controls are added to the application interface from the VB Toolbox.

Each control has a set of properties, and a set of event- associated procedures associated with it. An event procedure is a piece of code that responds to events that can occur for that object. Most of the events are generated by the user, enabling them to dictate the order of execution or to create various scenarios.

The application interface (VB form) is divided in frames whose visibility is function or event-driven functions generated by one of the following controls: CommandButton, CheckBox, OptionButton or ComboBox. The Frame control is used for group controls and provides a means of visually sub-dividing the Form Controls should be drawn within the Frame in order to be associated with the Frame and, in this case, moving the Frame also moves all of the associated controls.

When Option Buttons are used, only one may be selected on the Frame from a control array of Option Buttons. The Checkbox control is used to give the user a choice of yes/no multiple choice options.

The PictureBox is used to display images (such as geometry lugs) or act as a container to other controls. Pictures are loaded into the PictureBox using the LoadPicture function. The main event for a PictureBox is the Click event.

The TextBox is used to display text that may be edited directly by the user or as container to capture the application result.

In many cases, the text must be converted according to the particular meaning of (integer or floating). The CommandButton is used by the user to invoke some action. The default event for a CommandButton is "Click".

The application integrates two special controls as external components: CommonDialog and MSChart.

The common dialog control provides an interface between Visual Basic and the procedures in the Microsoft Windows dynamic-link library Commdlg.dll to display the desired dialog when, at run time, the application use one of the methods: ShowOpen or ShowSave. MSChart is a chart that graphically displays data and it was integrated by setting as component Microsoft Chart Control 6.0.

To integrate MSChart, IDE use the Object Linking and Embedding Microsoft technology (OLE). OLE allows accessing data from one application and includes them to another. Data from Lugs application are used by MSChart itself. Graphical interfaces both are easy both for operation and testing applications because the user communicates with them in real time to run them according to numerous scenarios.

Also, the application includes Microsoft Excel Object Library as reference to the Excel material properties file.

2. THE CALCULATION FORMULA

Lugs are connector-type elements widely used as structural supports for pin connections in aerospace industry. Fig.1 shows the lug under loading.

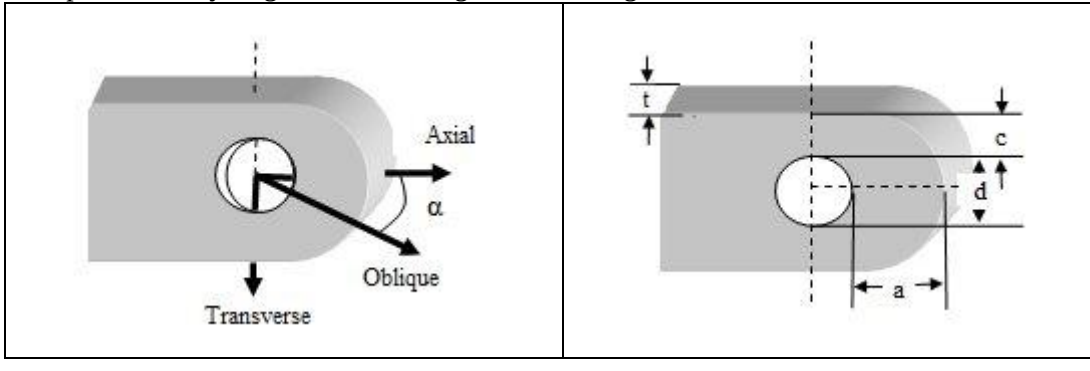


Fig. 1 - Lug under loading

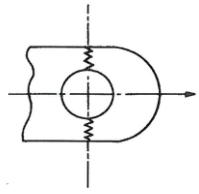
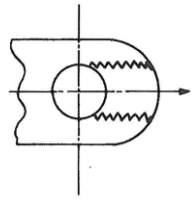
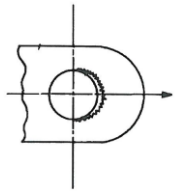
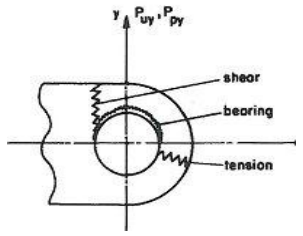
Modes of lug failure under axial loading			Modes of lug failure under transverse loading
			
Tension	Shear	Bearing	

Fig. 2 The modes of lug failures under axial or transverse loading

The application implements the formulas from Ref. BAC STRUCTURAL DESIGN DATA, Vol 2 1965, Data Sheet No. 15.1.1 through BAC Data Sheet No. 15.7.8. The coefficients are determined by interpolation using the data sheets diagrams.

The Reserve Factors for ultimate tensile and shear stresses should be determined as follows:

Ultimate tension $RF = \dfrac{0.9 \,.\, 2 \,.\, c \,.\, t \,.\, f_{tu}}{P_u}$;

Ultimate shear $RF = \dfrac{0.46 \,.\, 2 \,.\, a \,.\, t \,.\, K \,.\, f_{tu}}{P_u}$ where f_{tu} is the minimum longitudinal ultimate static tensile strength of the material and K is given as $K = f(2a/d)$ from diagram named “Correction factor for shear lugs” in Data Sheet No. 15.5.1.

The Reserve Factors for proof bearing, tensile and shear stresses should be determined as follows:

Proof bearing $RF = \dfrac{1.45 \,.\, d \,.\, t \,.\, t_1}{P_y}$;

Proof tension $RF = \dfrac{0.9 \,.\, 2 \,.\, c \,.\, t \,.\, t_1}{P_y}$;

Proof shear $RF = \dfrac{0.43 \,.\, 2 \,.\, a \,.\, t \,.\, K \,.\, t_1}{P_y}$, where t_1 is the minimum longitudinal proof static tensile strength of the material and K is the same as above.

Transversely loaded lugs are checked in the same general manner as axially loaded lugs.

The allowable ultimate transverse load of the lug is defines as: $P'_{tru} = k_{tru} \;\; A_b \,.\, f_{tux}$ where $k_{tru} = f(A_{av}/A_b)$ is the efficiency factor for transverse ultimate load, and $A_b = d \,.\, t$ the projected bearing area $A_{av} = \dfrac{6}{\dfrac{3}{A_1} + \dfrac{1}{A_2} + \dfrac{1}{A_3} + \dfrac{1}{A_4}}$, and A_i are from Fig.3.

The allowable yield transverse load of the lug is defines as: $P'_{try} = k_{try} \; A_b \cdot f_{t2x}$ where $k_{try} = f\left(A_{av} / A_b\right)$ is the efficiency factor for transverse yield load, and f_{t2x} is the yield stress in tension of lug material across grain. The coefficients k_{tru} **and** k_{try} **are obtained from Diagrams from Data Sheet No. 15.7.7 and** Data Sheet No. 15.7.8, respectively.

The failure load of a lug under oblique loading at angle α to the x-direction may be estimated from the rupture loads of the lug under axial loading and transverse loading by using the following interaction formula

$$RF = \frac{1}{\left(R_a^{1.6} + R_{tr}^{1.6}\right)^{0.625}} \quad , \quad \text{where} \quad R_a = \frac{axial \;\; component \; of \; applied \;\; ultimate \;\; load}{\min\left(\lambda_S.2.a.t.f_{tu} \quad , \quad \lambda_T.2.c.t.f_{tu}\right)} \quad ,$$

and $R_{tr} = \dfrac{transverse \; componentof \;\; applied \; ultimate \; load}{P'_{tru}}$; with $\lambda_S = f(R_{tu})$, $\lambda_T = f(R_{tu})$ obtained from Diagrams from Data Sheet No. 15.5.3 and Data Sheet No. 15.5.2, respectively.

Lug yield

$$RF = \frac{1}{\left(R_a^{1.6} + R_{tr}^{1.6}\right)^{0.625}} \; , \; \text{where} \; R_a = \frac{axial \;\; component \; of \;\; applied \;\; yield \;\; load}{allowable \;\; proof \;\; load \;\; for \;\; axialy \;\; loaded \;\; lug} \; ,$$

and $R_{tr} = \dfrac{transverse \;\; component \; of \;\; applied \;\; yield \;\; load}{P'_{try}}$.

3. THE APPLICATION STRUCTURE

The application includes several frames. The main is at the top. His controls run the application.

The CommandButton control from the main frame “Lug_Geometry” is utilized to shows a picture of the lug and to assimilate the name of the editing TextBox data in the Lug_Geometry frame.

The Proc_method frame contains two Option Buttons to set one of type of material processing: castings or wrought.

The Material frame chooses one material from steel or aluminum. The user must fill all of the properties in the Material_Data frame using a data sheet or data file.

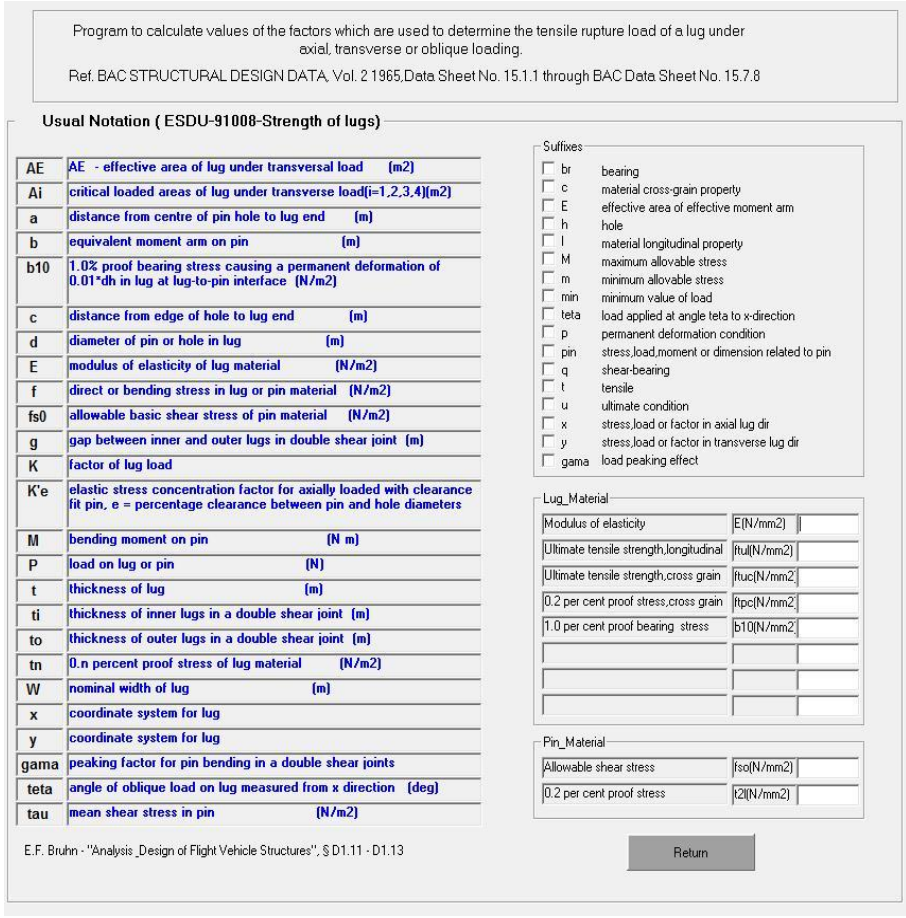
The Material Properties Button allows the user to read the material properties from an Excel or txt file saved anywhere or to select an Excel file from the application’s folder.

The next three CommandButton: Axial, Transverse and Oblique loading launches sequential computing for reserve factors which are used to determine the tensile rupture load of a lug under axial, transversee or oblique loading.

The values of these factors are obtained in the corresponding frames. Finally, by pressing Show Graphic button, the user chooses one parameter from the ComboList one parameter to see his behaviour.

The application is accompanied by a user’s manual.

First user interface is for lug analysis nomenclature.



Using the following interface, starts the lug analysis.

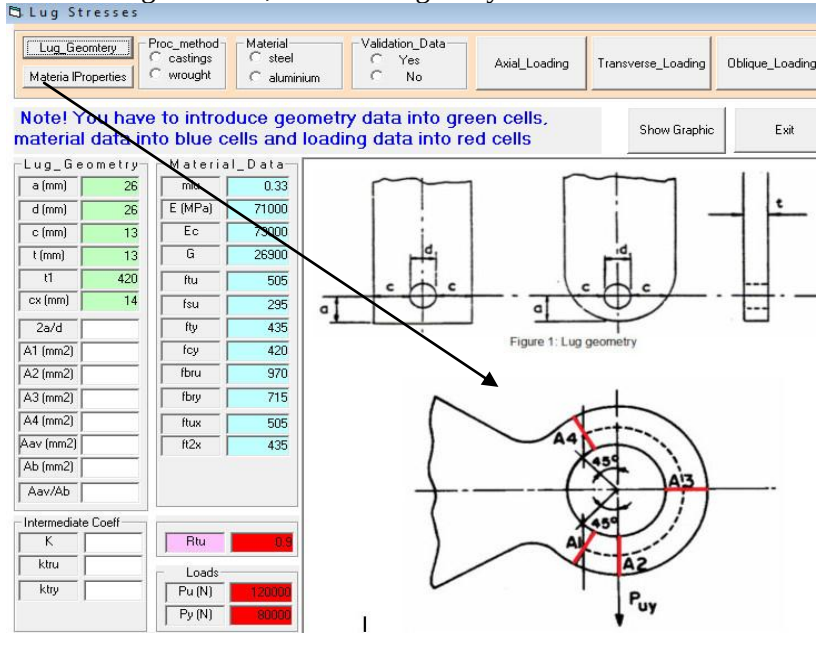
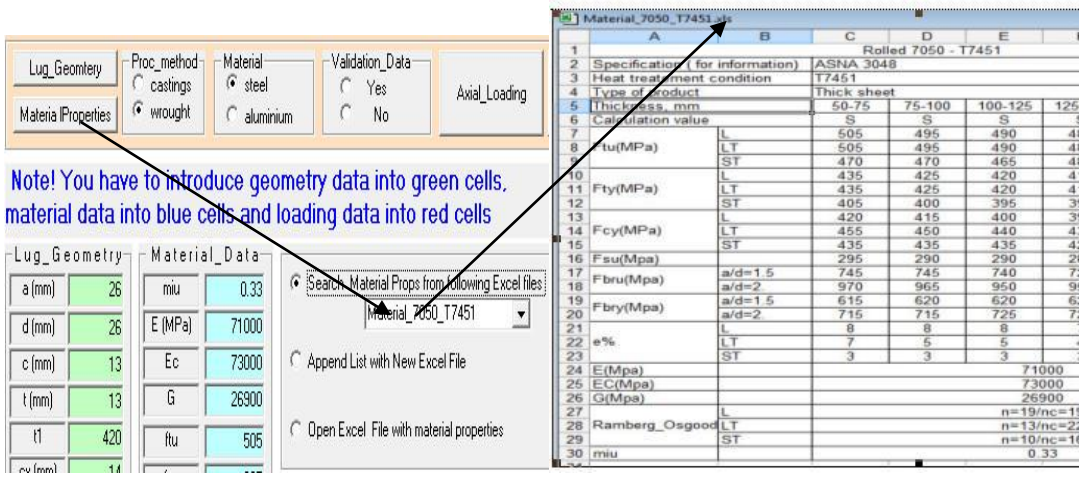


Fig. 3



The interface with the final results

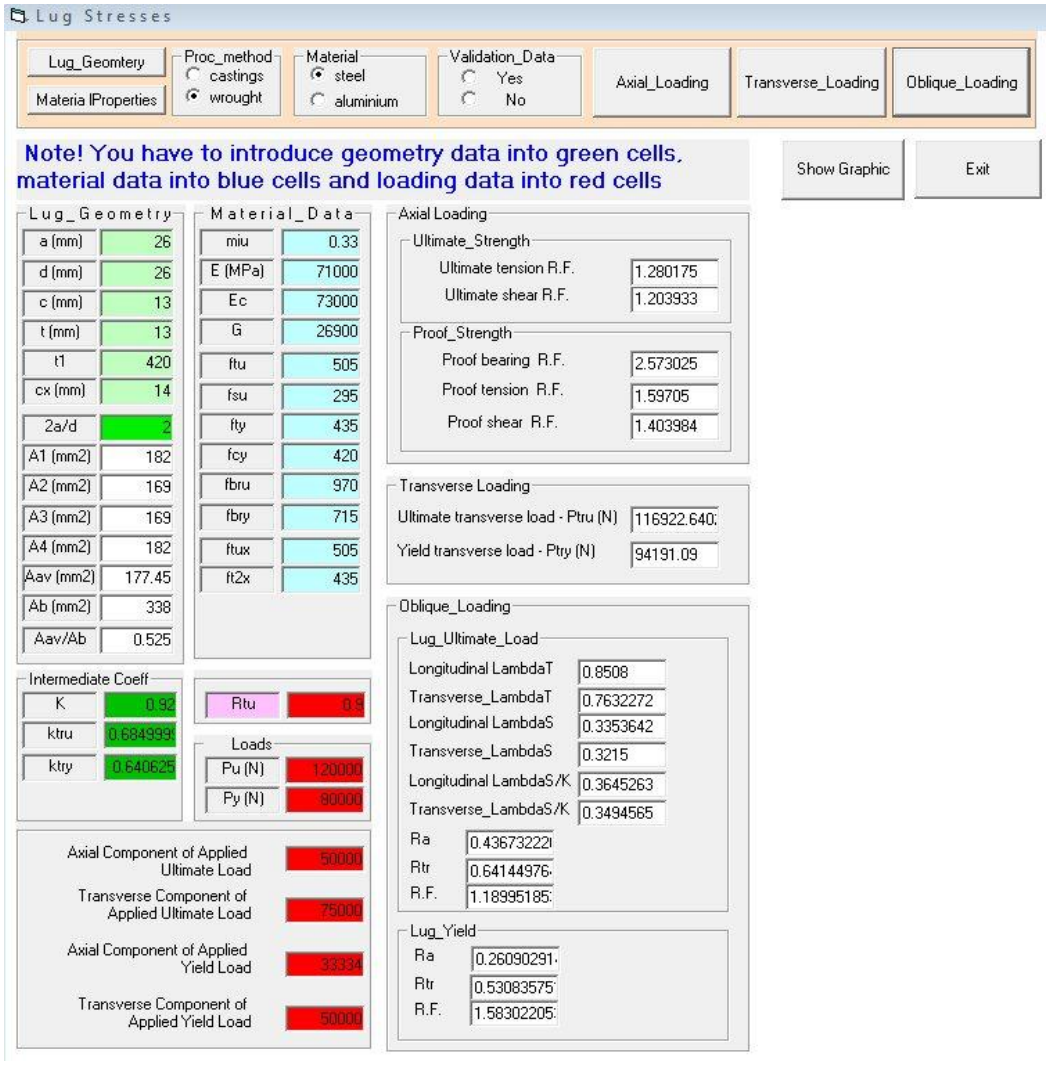
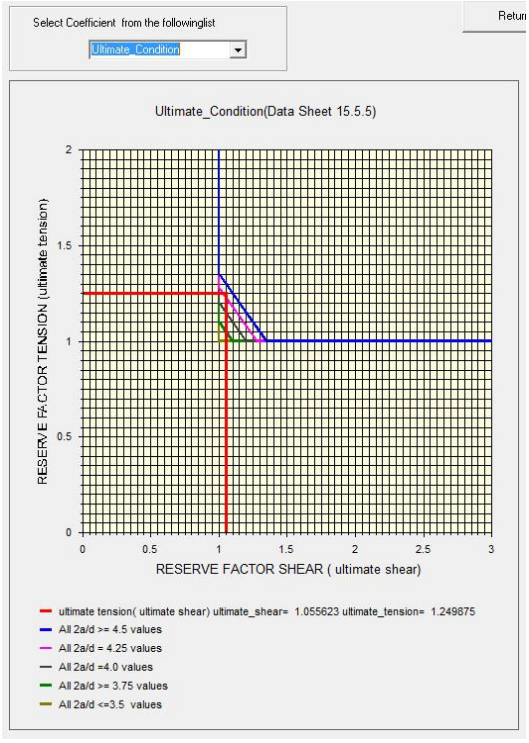
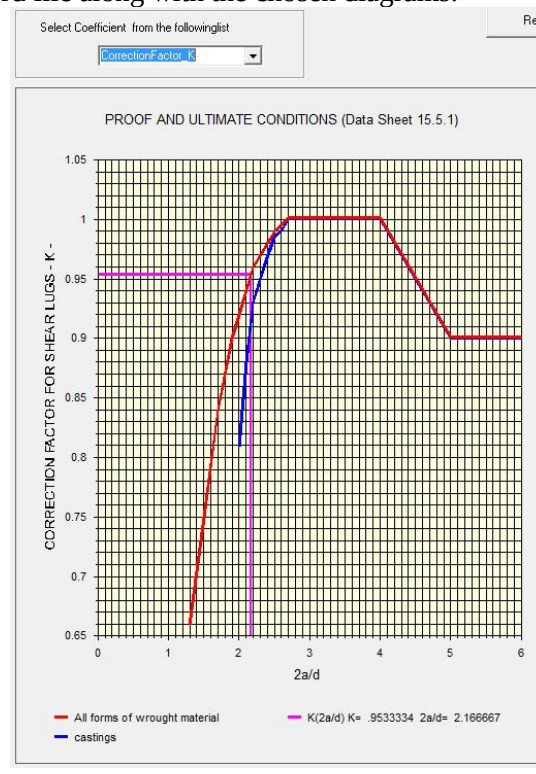
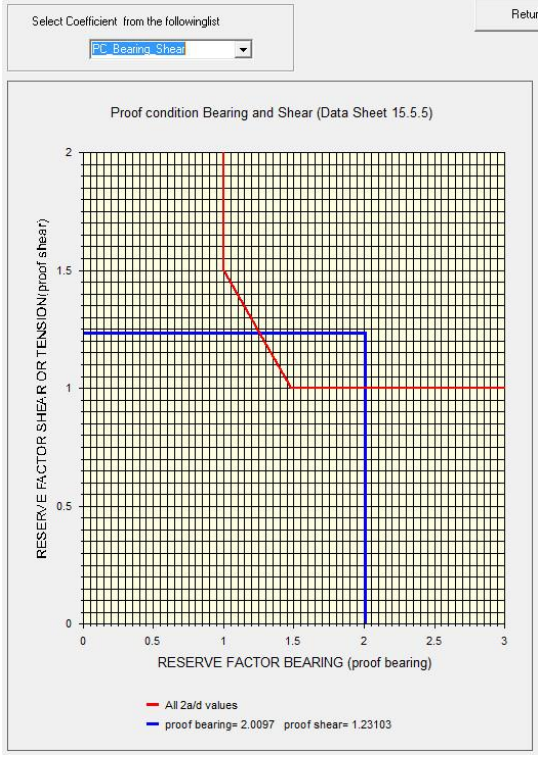


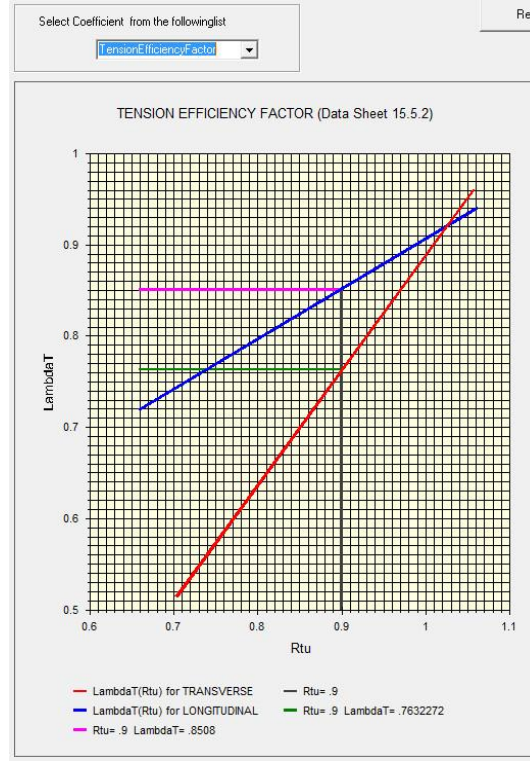
Fig. 4

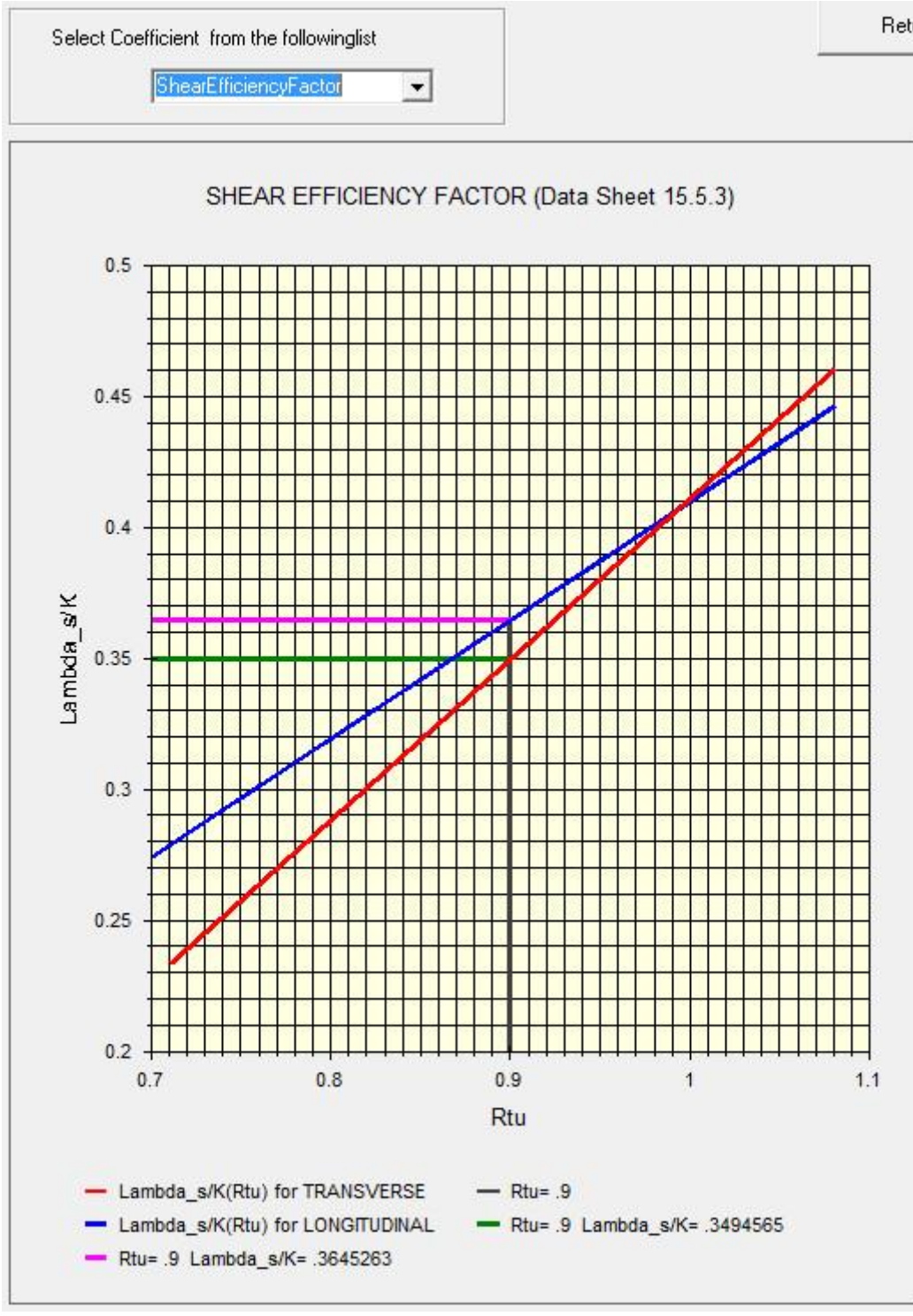
The final results are recorded in a MSWord file along with the chosen diagrams.

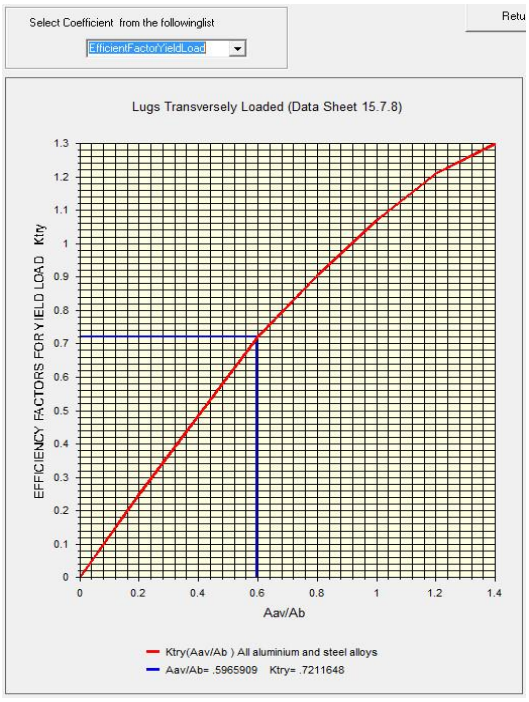


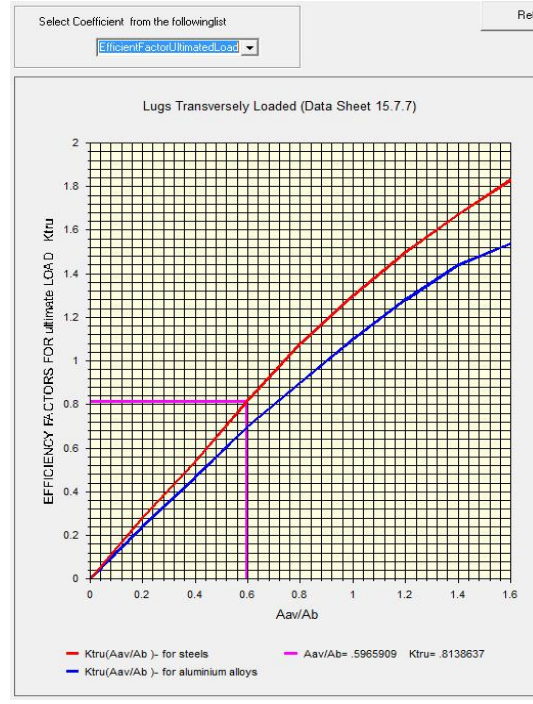


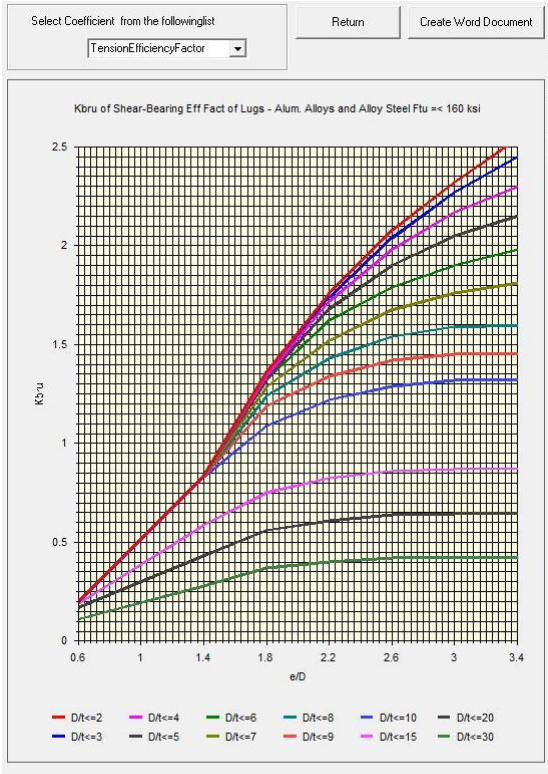





Select Coefficient from the followinglist
ShearEfficiencyFactor
Retu
SHEAR EFFICIENCY FACTOR (Data Sheet 15.5.3)
Lambda_s/K
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.7
0.8
0.9
1
1.1
Rtu
Lambda_s/K(Rtu) for TRANSVERSE
Lambda_s/K(Rtu) for LONGITUDINAL
Rtu= .9 Lambda_s/K= .3645263
Rtu= .9
Rtu= .9 Lambda_s/K= .3494565


Select Coefficient from the followinglist
EfficientFactorYieldLoad
Retu
Lugs Transversely Loaded (Data Sheet 15.7.8)
EFFICIENCY FACTORS FOR YIELD LOAD Ktry
Aav/Ab
Ktry(Aav/Ab) All aluminium and steel alloys
Aav/Ab= .5965909 Ktry= .7211648


Select Coefficient from the followinglist
EfficientFactorUltimatedLoad
Retur
Lugs Transversely Loaded (Data Sheet 15.7.7)
EFFICIENCY FACTORS FOR ultimate LOAD Ktru
Aav/Ab
Ktru(Aav/Ab)- for steels
Aav/Ab= .5965909 Ktru= .8138637
Ktru(Aav/Ab)- for aluminium alloys


Select Coefficient from the followinglist
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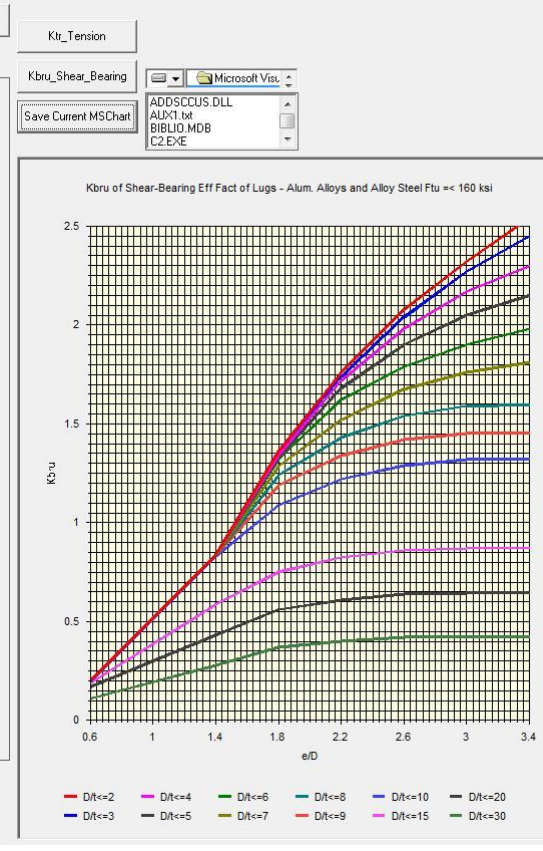
D/t<=30


Ktr_Tension
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D/t<=30

4. CONCLUSION

This application helps us to determine the minimum load cause failure by rupture or unacceptable permanent deformation of lugs under in-plane axial, transverse or combined loading. It can be used routinely in the predimensioning details phase of aeronautical structure.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the help provided by Radu Bisca whose advice has been a great help in testing and in establishing the application limits of the method.

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