WingDesign: Manual for the Graphics-based User Interface for Use on Sun Workstations

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R.P.G. Zoontjes

WingDesignTool Release 2.0

Skin thickness [mm]: 2.50
U t [mm]: 1.60
P h [mm]: 30.00
P b [mm]: 20.00
E c [mm]: 30.00
R Non std

Stringer pitch [mm]: 100.00
WingDesign: Manual for the Graphics-based User Interface for Use on Sun Workstations

R.P.G. Zoontjes
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PREFACE

The program WingDesigntool is a graphics-based user interface for the program WingDesign - a program for the structural design of a wing cross-section. It makes use of the SunView system, which supports interactive graphics-based applications using windows. Therefore it runs only on Sun workstations on which SunView is implemented. WingDesigntool is intended to be used in conjunction with the CAD system MEDUSA. A part of the input data is obtained directly from a MEDUSA drawing sheet by the interface program WingDesignmedusa, which runs within MEDUSA.

Reference 1 is an explanation of the task of WingDesign. The present memorandum is the user’s guide for WingDesigntool and WingDesignmedusa. It is divided into two parts. The first is an introduction to both programs, in which a short description of their tasks is presented. The second part is a step-by-step tutorial. On the basis of an example all options will be reviewed. The three phases in the use of the program - defining the shape of the cross-section in a MEDUSA drawing sheet, designing and optimizing the structure, and making a drawing of the result - are clearly distinguished. The user is assumed to have some knowledge of working with MEDUSA (Ref. 2).
1. INTRODUCTION

WingDesign is a program for the structural design and optimization of a wing cross-section. The parameters defining the 'status' of the design are divided into five groups:

- geometric data defining the shape of the cross-section
- geometric data defining the dimensions of the structure
- material properties
- design requirements (i.e. loading cases and stiffness criterion)
- results of the structural analysis (i.e. stress distribution, strength, torsional stiffness and weight of the structure).

1.1 Program WingDesign tool

WingDesign tool offers a convenient means of manipulating the design in order to come to a satisfactory result. Figure 1 shows the WingDesign tool window. The geometric data defining the dimensions of the structure and results of the structural analysis are directly displayed on the screen, together with all options offered by the program. To specify the material properties and design requirements, two additional windows can be displayed (Figs. 2 and 3). The user interface is graphics-based, implying that changes to the design can be very simply made by editing the display, and that program options can be selected using the mouse.

![WingDesign tool window](image)

*Figure 1: The WingDesign tool window.*
Material properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Upper skin</th>
<th>Lower skin</th>
<th>Front spar</th>
<th>Rear spar</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL7075-T6</td>
<td>AL2824-T3</td>
<td>AL2824-T3</td>
<td>AL2824-T3</td>
<td>AL2824-T3</td>
</tr>
<tr>
<td>Maximum tensile stress (MPa)</td>
<td>540.00</td>
<td>440.00</td>
<td>440.00</td>
<td>440.00</td>
</tr>
<tr>
<td>0.25% proof stress (MPa)</td>
<td>480.00</td>
<td>260.00</td>
<td>260.00</td>
<td>260.00</td>
</tr>
<tr>
<td>Maximum shear stress (MPa)</td>
<td>310.00</td>
<td>250.00</td>
<td>250.00</td>
<td>250.00</td>
</tr>
<tr>
<td>Young's modulus (MPa)</td>
<td>71000.00</td>
<td>72000.00</td>
<td>72000.00</td>
<td>72000.00</td>
</tr>
<tr>
<td>Poisson's ratio</td>
<td>3.00e-01</td>
<td>3.00e-01</td>
<td>3.00e-01</td>
<td>3.00e-01</td>
</tr>
<tr>
<td>Rumsberg-Dugood parameter</td>
<td>25.00</td>
<td>10.40</td>
<td>10.40</td>
<td>10.40</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>2.78e-05</td>
<td>2.78e-05</td>
<td>2.78e-05</td>
<td>2.78e-05</td>
</tr>
</tbody>
</table>

Figure 2: Additional window to specify material properties.

Design requirements

<table>
<thead>
<tr>
<th>Load case</th>
<th>Load case</th>
<th>Load case</th>
<th>Load case</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>#2</td>
<td>#3</td>
<td>#4</td>
</tr>
<tr>
<td>Bending moment (N:mm)</td>
<td>8.0000e+06</td>
<td>-3.2000e+06</td>
<td></td>
</tr>
<tr>
<td>Horizontal coordinate shear force (N:mm)</td>
<td>375.00</td>
<td>375.00</td>
<td></td>
</tr>
<tr>
<td>Shear force (N:mm)</td>
<td>200000.00</td>
<td>-80000.00</td>
<td></td>
</tr>
<tr>
<td>Twisting moment (N:mm)</td>
<td>4.0000e+07</td>
<td>-1.0000e+07</td>
<td></td>
</tr>
</tbody>
</table>

Minimum torsional stiffness (N:mm/rad/mm): 1.75000e+13

Figure 3: Additional window to specify design requirements.

Different material data can be specified for the upper skin panel, lower skin panel, front spar web and rear spar web. Alternatively one of the standard materials in the program can be chosen.

Up to four loading cases can be specified, with different combinations of bending moment, shear force and twisting moment on the wing cross-section. In addition, a minimum torsional stiffness can be specified.

The stringers and stiffeners used in the design may be confined to a series of ‘standard’ sections. The available sizes in the various types can be displayed in the Help window (Fig. 4). This panel can also be referred to for the sign conventions of the loading on the cross-section.
1.2 Program WingDesignmedusa

The geometric data defining the shape of the cross-section are obtained from a MEDUSA drawing sheet by the program WingDesignmedusa. It scans the database searching for data concerning the geometry. Because a drawing sheet also contains many elements which are irrelevant to the geometry, such as texts for the drawing administration, the cross-section is re-defined with special element types used exclusively for that purpose. Figure 5 shows how the wing profile can be so marked. On top of the upper and lower skin two STK line elements are drawn, each with up to nine points. The line width which must be specified for this line type is of no relevance, so it can be chosen arbitrarily by the user. The front and rear spar locations are indicated with two TC2 text elements containing the strings ‘front’ and ‘rear’ respectively. The special elements can be selected by the user from the menu field provided for this part of the task. For a more detailed description of the development of an interface program similar to WingDesignmedusa refer to Refs. 3 and 4.

Figure 5: Definition of the shape of the cross-section with special element types.
1.3 Presentation of the results

As well as a hard copy of all numerical values defining the status of the design, the user can get a drawing of the cross-section of the structure which has been designed. This drawing is obtained by running an LCIS-macro within MEDUSA. (LCIS is the command language used by MEDUSA.) The macro, produced by WingDesign, contains the necessary commands to create the drawing. Certain aspects need some further explanation. The user has the choice to locate the stringers at a specified distance (offset) from the front spar, a certain distance from the rear spar, or to centre them between the two spars. Figure 6 shows the three possibilities. When the stringers are centred, the program chooses the distance \( \Delta x \) so that it is between one whole stringer pitch and one-half of the stringer pitch. Furthermore, the user can specify whether he wants the stringers to be drawn as a folded or an extruded profile.

*Left justification:*

*Centre justification:*

*Right justification:*

*Figure 6: Positioning of the stringers in the MEDUSA drawing.*
A given wing-section has a chord of 3000 mm and a thickness/chord ratio of 13%. The distance between the front and the rear spar is one-half of the chord. Two loading cases are considered: positive (upward) bending moment $0.8 \times 10^9$ Nmm and shear force $0.2 \times 10^9$, and negative bending moment and shear force each 40% of the corresponding positive values. (Note that this example is the same as used in Ref. 1.) Figure 7 presents a drawing of the wing profile.

![Figure 7: MEDUSA drawing of the wing-section used in this tutorial.](image)

2.1 Definition of the shape of the wing-section

The first step is to start the MEDUSA system and make a drawing such as the one shown in Fig. 7. The upper and lower skin, and the front and rear spar have to be indicated with special element types. In the LR drawing aids system (Ref. 5) a special menu field is available which contains icons for use with WingDesignmedusa. You can go to the special field by selecting the following icons:
Figure 8: Command sequence to go to the WingDesign menu field.

The special element types can be created with the icons of Fig. 9.

Figure 9: Icons to create the special element types.

Figure 10 shows the wing-section with the special elements drawn on top of it.

Figure 10: Wing-section with special elements drawn on top of it.

Now the program WingDesignmedusa can be executed to scan the MEDUSA database: select the icon of Fig. 11.
Figure 11: Scanning the MEDUSA database.

First you have to choose a name for the job. After entering it, the special elements in the drawing will 'flash' in order to signal that their data is being processed by the program. If no errors occur, the geometry is stored in a file which is given the extension '.wng'. You can then leave the MEDUSA system, the most convenient way being to close the MEDUSA shell by selecting:

Figure 12: Closing MEDUSA to an icon.

2.2 Design of the structure

After you leave MEDUSA you open a new shell: move the cursor to the grey background and hold the right mouse button down. A popup menu appears from which you have to select the 'ShellTool' option (Fig. 13).

Figure 13: Popup menu to open a new shell.

A new shell appears. The user interface of the program WingDesign can be started by typing in this shell:

\[ \text{wingdesign tool} \quad <\text{enter}> \]

After a few moments the WingDesign tool window as shown in Fig. 14 appears on the screen.
The window consists of several panels, each having its own specific function. Each panel contains several 'items', such as:

- command buttons to invoke a command (Fig. 15.a)
- fields used for specifying some value ('Form Fill-in') (Fig. 15.b)
- cycle items to choose between some alternatives (Fig. 15.c)
- texts displaying information (Fig. 15.d).

(a) Some command buttons.  
(b) Field (currently empty) preceded by a text item.
(c) Cycle item.  
(d) Text displaying a feedback message.

Figure 15: 'Items' contained by the panels.
A window can be manipulated with the mouse. If the cursor is moved to the border of the window it will turn into a 'bulls-eye' (Fig. 16.a). When the right mouse button is pressed and held down, a popup menu appears (Fig. 16.b). The window can be moved, resized and so on by selecting the appropriate option and following the instructions given by the computer.

![Cursor turned into a 'bulls-eye'.](image)

(b) Manipulation menu for the window.

Figure 16: Manipulating the window.

First you specify the name of the file produced by WingDesignmedusa in the previous section: invoke the load command by selecting the 'Load' button. A command button can be selected in two different ways:

- One way is to move the cursor to the button and press the left mouse button.
- An alternative way is provided in order to inquire the meaning of a command without executing it: if you press the right mouse button and hold it down a popup menu appears containing a description of the command involved (Fig. 17.a). The command is invoked by selecting the menu item (Fig. 17.b). To cancel, just move the cursor away and release the mouse button.

Note that the mouse buttons have a different use in MEDUSA.

![Command button with menu.](image)

(b) Invoking the command.

Figure 17: Invoking a command with the right mouse button.

After selecting the 'Load' button, the popup window of Fig. 18 appears in which you specify the name of the job (without extension ' .wng'). The corresponding file is loaded after selecting the 'Ok' button.

![Popup window to specify the name of the job.](image)

Figure 18: Popup window to specify the name of the job.
The next step is to specify all dimensions, material properties and design requirements. Two additional windows appear automatically (Fig. 19).

The material properties can be specified by typing them in the corresponding fields of the ‘Material Properties’ window. The current field is indicated by a ‘caret’ at the end of the value in that field. It can be moved among the fields in several ways. You can get to the next field by pressing <enter> or <tab>. Simultaneously pressing the <shift> key causes the caret to go back to the previous field. You can also use the mouse to proceed to an arbitrary field: place the cursor in the field involved and press the left mouse button. The text in the field lights up and can be edited. Note that the cursor has to be inside the window when you want to edit the contents of one of its fields. In the program, some standard materials can be chosen. Their properties are listed in the right-most column of the ‘Material Properties’ window. The materials are selected with the cycle item on top of the table: by moving the cursor to this item and pressing the right mouse button, a popup menu appears (Fig. 20). Alternatively toggle with the left mouse button, with or without simultaneously pressing the <shift> key. By selecting the ‘Set’ button the standard material properties are copied to the corresponding column. Of course, if necessary the individual properties can be altered as well. For the example in this tutorial, choose for the upper skin A17075-T6 and all other parts A12024-T3.
Up to four loading cases can be specified in the 'Design Requirements' window. Before the values can be entered, a loading case has to be made 'active' by selecting the corresponding cycle item. Furthermore, the required torsional stiffness has to be specified. For this example you can use the values in Fig. 3. If the windows for the material properties and design requirements are all filled in they can be closed by selecting the 'Done' button. By selecting the 'Materials' or 'Requirements' button they are displayed again.

The dimensions of the structure are specified in two panels of the WingDesign tool window. Stringer and stiffener type and size can be selected by means of cycle items. If non-standard stringers or stiffeners are chosen the dimensions have to be specified by the user. The values in Fig. 1 can be used for this example. What now remains is the stress distribution, strength, torsional stiffness and weight of the structure. These can be obtained by analysing the structure. An analysis is performed after selecting the 'Analyse' button: the results of the analysis are displayed in the lower-most panel and an illustration of the cross-section is made.

There is an option to optimize the structure for minimum weight. After you select the 'Optimize' button, a window appears in which bounds can be specified and variables can be 'fixed' or left 'variable' (Fig. 21). In this example the size and pitch of the stiffeners on the spar webs are 'fixed'. Furthermore, a restriction is placed on the stringer pitch: for both upper and lower skins this may not be less than 60 mm. After selecting the 'Ok' button an optimization is performed and after some time the screen is adjusted to the values resulting from the optimization. Note that you can reverse all changes made during the optimization by selecting the 'Undo' option.

![Image](image.png)

Figure 21: Panel to specify bounds or to 'fix' variables.

You can now proceed to design the structure (or to investigate the influence of certain changes of parameters on, for instance, the strength of the structure), using the options to 'fix' variables, specifying bounds, and so on as desired. If you obtain a satisfactory design, you can make a hard copy of the results by selecting the 'Print' option. After that, select the 'LCIS' button to get a macro with which a MEDUSA drawing can be produced. A popup window appears in which the justification and offset can be specified (Fig. 22).
In this case the stringers are placed at a distance of 100 mm from the rear spar.

![Stringer profile selection]

*Figure 22: Specification of justification and offset of the stringers in the MEDUSA drawing.*

You can store the results in a file by selecting the ‘Save’ button, which enables you to change the design if at a later stage it does not appear satisfactory. Then leave WingDesignTool by selecting the ‘Quit’ button.

### 2.3 Drawing of the cross-section of the wing structure

Re-open the MEDUSA shell and run the LCIS-macro by selecting:

![Running the LCIS-macro]

*Figure 23: Running the LCIS-macro.*

You are asked to probe a reference point. This is the origin of the coordinate system used in WingDesign and is defined at the location of the ‘front’ text. Figure 24 shows the result of running the macro.

![Cross-section drawing]

*Figure 24: Drawing of the cross-section of the designed wing structure as produced by the LCIS macro.*
You can remove the special element types with:

![Diagram](image1)

*Figure 25: Removing the special element types.*

The attachment points of the stringers, indicated with prims, can be used for dimensioning, drawing rivets, and so on. They can be removed by clicking:

![Diagram](image2)

*Figure 26: Removing the stringer attachment points.*
REFERENCES


