Stresses in a stainless steel cover TVS-9500

Citation for published version (APA):

Document status and date:
Published: 01/01/1995

Publisher Version:
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher’s website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain.
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:
www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:
openaccess@tue.nl
providing details and we will investigate your claim.

Download date: 24. Aug. 2020
Stresses in a stainless steel cover TVS-9500

Dr. ir. L.H. Braak
Mak.Müh. M.E. Dukul

Report WFW 95.050a

In order of:

Howden Food Equipment
P.O. Box 2261
5202 CG 's Hertogenbosch

April 1995
CONTENT

1. Introduction
2. Models
3. Computations
4. Results
5. Conclusions
   Plots
1. INTRODUCTION

Howden Food Equipment is a manufacturer of packing machines in the food industry. Vacuum is used to seal meat, fish and other consumable merchandise. The growing demand for bigger machines asks for a careful design of high loaded machine parts. The stainless steel cover is such a part, where high stresses may lead to failure due to fatigue.

The section of Computational and Experimental Mechanics of the Eindhoven University of Technology is asked to perform a stress and displacement study for a stainless steel cover, to get insight in the stress distribution and in the expected lifetime of the involved machine part. Results of the computations, executed by means of the finite element method, will be presented in this report.

2. THE MODEL

The cover investigated is known as:
- TVS 9500; with main dimensions: 1010 * 605 mm

Boundary conditions

Due to symmetry numerical models can be restricted to a half or a quarter of original constructions.

Boundary conditions in the contact area between cover and the machine frame are:
- no indentation in the machine frame,
- no displacements normal to the sides of the covers.

The load

The load on the cover consists of a pressure of 1 bar (1 \* 10^5 N/mm^2), normal to each area of the cover.

Elements

The numerical models of the cover consist of four noded shell elements of constant thickness.
Material properties

From a handbook on material data (Boller, Chr. Seeger, T. Materials data for cyclic loading, part C: high alloy steels. Elsevier, 1987) the following data are taken for AISI 304:

- Young’s modulus : 210,000 N/mm²
- Poisson’s ratio : 0.3
- Tensile strength : 200 N/mm²
- Fatigue limit : 122 N/mm² at 100,000 cycles.
  : 42 N/mm² at 2.10⁶ cycles

For SUS 304-B the fatigue limit at 2.10⁶ cycles is given as 112 N/mm².

From TNO Metals Research Institute some more information was taken on the fatigue stress of AISI 304.

For AISI 304 (Werkstoffnr 1.4301) they reported:

- Tensile strength : 580-760 N/mm²
- Fatigue stress : 240 N/mm²

From the 'Atlas of fatigue curves'; ASM, ISBN 0-87170-214-2, the conclusion can be drawn that for polished test specimen the fatigue stress in bending and/or tension is more than 200 N/mm².

The fatigue limits will be influenced by the welding process, but no specifications are given for correction factors or things like that.

As a rule of thumb a fatigue limit of 100-125 N/mm² seems a reasonable estimation, given the available data.

N.B. The given data on stress limits in fatigue are amplitudes of stress levels. The calculated stresses in the covers vary between zero and a extremum; so the averaged stress and the stress amplitude is half the stress values calculated with the finite element analysis.
3. COMPUTATIONS

The calculations of displacements and stresses is carried out by means of the finite element package I-DEAS from SDRC, Ohio. The material behaviour has to be linear and in theory there is no difference between the deformed and undeformed geometry. All non linear effects, as yielding or buckling, are not predictable with the package used.

A numerical model is well defined when, after a suitable element mesh is generated, load and boundary conditions are specified. The program calculates as a first step to the complete solution, the unknown node displacements. Then the deformed geometry can be plotted and a check on load direction and proper boundary conditions is possible. In the next step strains and stresses are calculated for each element; this data is available for the top, middle and bottom surface of the shell. In the post processing phase all kinds of plots can be made, e.g. averaged Von Mises stress per node in continue tone etc.

4. RESULTS

4.1 Mesh

In Figure 1 the generated mesh is presented for half a cover.

4.2 Displacements

A global impression of the displacements of the cover can be get from Figure 2. The solid lines represent the deformed geometry, the dotted lines the undeformed geometry. As can be seen there is hardly any displacement at the fold lines of the cover. The maximum of the displacements is given below.

Maximum displacement in mm

TVS 9500 : 2.02
4.3 Stresses

To get insight in the stress distribution and the stress levels plots are made in which the Von Mises equivalent stress is given for the top or bottom surface of the covers. The maxima of these stresses are given below.

Maximum Von Mises stress at the corners in N/mm²
(Stress amplitudes are half the calculated values)

<table>
<thead>
<tr>
<th>Model</th>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>TVS 9500</td>
<td>128</td>
<td>147</td>
</tr>
</tbody>
</table>

The high stressed region is located around the welded corners where the oblique sides of the cover come together; see Figure 3. From a detailed analysis it is learned that the middle surface of the shell elements is also stressed; so not only a bending stress, but also a remarkable membrane stress is present. The highest value of the Von Mises stress in the bottom face of the elements, this the inner side of the cover, is lower than the critical range with respect to fatigue. Small variations in material properties or in the quality of the welding process may have a significant effect on the life time of the cover.

At the boundary of the cover there are some points with a high stress, but these stresses are partly due to numerical artefacts and the simple modelling of the rubber sealing strip.
5. CONCLUSIONS

TVS 9500

High stressed regions are concentrated in the corners of the cover. The value of the equivalent Von Mises stress seems not to be critical with respect to fatigue; but the quality of the welding process has a significant influence on the ultimate fatigue limit. These influences can not be taken into account in the finite element analysis.
Fig. 1. Element mesh of half a cover; TVS 9500.
Fig. 2. (Un-)deformed geometry; TVS 9500.
Fig. 3. TVS-9500. Von Mises stress; top(left) and bottom(right).
In order of:

Howden Food Equipment
P.O. Box 2261
5202 CG 's Hertogenbosch

april 1995
CONTENT

1. Introduction
2. Models
3. Computations
4. Results
5. Conclusions

Plots
1. INTRODUCTION

Howden Food Equipment is a manufacturer of packing machines in the food industry. Vacuum is used to seal meat, fish and other consumable merchandise. The growing demand for bigger machines asks for a careful design of high loaded machine parts. The stainless steel cover is such a part, where high stresses may lead to failure due to fatigue.

The section of Computational and Experimental Mechanics of the Eindhoven University of Technology is asked to perform a stress and displacement study for a number of stainless steel covers, to get insight in the stress distribution and in the expected life time of the involved machine part. Results of the computations, executed by means of the finite element method, will be presented in this report.

2. MODELS

Two different types of covers are investigated:

- H5002 - 145; with main dimensions 1010 * 1030 mm
- H5002 - 144; with main dimensions 1010 * 1030 mm

After the first run a modification was suggested:

- H5002 - 145 with heightend sides.

Boundary conditions

Due to symmetry numerical models can be restricted to a half or a quarter of original constructions.

Boundary conditions in the contact area between cover and the machine frame are:
- no indentation in the machine frame,
- no displacements normal to the sides of the covers.

The load

The load on the covers consists of a pressure of 1 bar (1 * 10^5 N/mm²), normal to each area of a cover.

Elements

The numerical models of the various covers consist of four noded shell elements of constant thickness.
Material properties

From a handbook on material data (Boller, Chr. Seeger, T. Materials data for cyclic loading, part C: high alloy steels. Elsevier, 1987) the following data are taken for AISI 304:
- Young's modulus : 210,000 N/mm²
- Poisson's ratio : 0.3
- Tensile strength : 200 N/mm²
- Fatigue limit : 122 N/mm² at 100,000 cycles.
  : 42 N/mm² at 2.10⁶ cycles

For SUS 304-B the fatigue limit at 2.10⁶ cycles is given as 112 N/mm².

From TNO Metals Research Institute some more information was taken on the fatigue stress of AISI 304.
For AISI 304 (Werkstoffnr 1.4301) they reported:
- Tensile strength : 580-760 N/mm²
- Fatigue stress : 240 N/mm²

From the 'Atlas of fatigue curves' ASM, ISBN 0-87170-214-2, the conclusion can be drawn that for polished test specimen the fatigue stress in bending and/or tension is more than 200 N/mm².

The fatigue limits will be influenced by the welding process, but no specifications are given for correction factors or things like that.

As a rule of thumb a fatigue limit of 125-150 N/mm² seems a reasonable estimation, given the available data.

N.B. The given data on stress limits in fatigue are amplitudes of stress levels. The calculated stresses in the covers vary between zero and a extremum; so the averaged stress and the stress amplitude is half the stress values calculated with the finite element analysis.
3. COMPUTATIONS

The calculations of displacements and stresses is carried out by means of the finite element package I-DEAS from SDRC, Ohio. The material behaviour has to be linear and in theory there is no difference between the deformed and undeformed geometry. All non linear effects, as yielding or buckling, are not predictable with the package used.

A numerical model is well defined when, after a suitable element mesh is generated, load and boundary conditions are specified. The program calculates as a first step to the complete solution, the unknown node displacements. Then the deformed geometry can be plotted and a check on load direction and proper boundary conditions is possible. In the next step strains and stresses are calculated for each element; this data is available for the top, middle and bottom surface of the shell. In the post processing phase all kinds of plots can be made, e.g. averaged Von Mises stress per node in continue tone etc.

4. RESULTS

4.1 Meshes

In Figure 1 and 2 the generated meshes are presented for the two basic cover designs. The updated construction is sketched on the same page as the original.

4.2 Displacements

A global impression of the displacements of the covers can be get from the Figures 3 and 4. The solid lines represent the deformed geometry, the dotted lines the undeformed geometry.

As can be seen there is hardly any displacement at the fold lines of the covers. The maxima of the displacements are given below.

<table>
<thead>
<tr>
<th>Material</th>
<th>Displacement in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>H5002 - 145 low</td>
<td>1.18</td>
</tr>
<tr>
<td>H5002 - 145 high</td>
<td>1.02</td>
</tr>
<tr>
<td>H5002 - 144</td>
<td>2.89</td>
</tr>
</tbody>
</table>
4.3 Stresses

To get insight in the stress distribution and the stress levels plots are made in which the Von Mises equivalent stress is given for the top or bottom surface of the covers. The maxima of these stresses are given below.

Maximum Von Mises stress at the corners in N/mm²
(Stress amplitudes are half the calculated values)

<table>
<thead>
<tr>
<th>Model</th>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>H5002 - 145 low</td>
<td>105</td>
<td>125</td>
</tr>
<tr>
<td>H5002 - 145 high</td>
<td>99</td>
<td>115</td>
</tr>
<tr>
<td>H5002 - 144</td>
<td>189</td>
<td>283</td>
</tr>
</tbody>
</table>

**H5002 - 145**

This cover shows a stress distribution which is more or less evenly spread. See Figure 5 and 6. Relative high values of the Von Mises stress are present in the corners, but also at the folding lines and in the middle of the oblique sides of the cover. The numerical value of the highest stress is well below the fatigue limit.

An updated model with a heightened sides shows in general the same stress distribution as the original model, but the stresses in the middle of the sides are more pronouncedly at hand. Local buckling of the plates may occur, but the finite element program used, can not give information of these non linearities.

**H5002 - 144**

This model is more flat than the foregoing H5002-145. Stress concentrations occur in the cornerpoints. The numerical value of the Von Mises stress is up to the fatigue limit.
5. CONCLUSIONS

The more or less dome shaped design of the cover leads to a more or less evenly distribution of stresses. Numerical values of the Von Mises stress are in an acceptable range.

The updated model with heightened sides gives a similar stress distribution as the original model. Non linear effects, such as plate buckling, can not predicted with the finite element package used.

This design leads to high stress concentrations in the corners of the cover. The numerical value of the Von Mises stress reaches the fatigue limit. In long term use damage may be expected.
Fig. 1. Element meshes of a quarter of a cover; H 5002 - 145.
Fig. 2. Element meshes of a quarter of a cover; H 5002 - 144.
Fig. 3. (Un-)deformed geometry; H 5002 - 145.
Fig. 4. (Un-)deformed geometry; H 5002 - 144.
Fig. 5. H5002-145. Von Mises stress; top(left) and bottom(right)
Fig. 6. H5002-145(high). Von Mises stress; top(left) and bottom(right)
Fig. 7. H5002-144. Von Mises stress; top(left) and bottom(right)