RAMS

Reliability, Availability,
Maintainability, and Safety

This is the Title of my Thesis

Your Name

August 2014

PROJECT / MASTER THESIS

Department of Production and Quality Engineering

Norwegian University of Science and Technology

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Supervisor 2: Professor Fingal Olsson

Preface

Prosjektoppgaven endte opp med følgende problemstilling: *Hvordan modellere vertikaler i jernbanebru uten vindfagverk i overdelen?* Jernbanebruer uten vindfagverk i overdelen, trenger en alternativ måte for avstivning av "veggfagverket". I eldre jernbanebruer er dette gjort på en interessant måte, vertikalene får en ekstra "del" tilsatt, heretter "vertikalavstiver". Denne delen er typisk satt sammen av en buet plate forbundet sammen med nedre del av brua, og et lite fagverk som følger den buede delen av plata (L-profil) og som etter platen er bundet til vertikalen som et fagverk.

Intensjonen med dette prosjektet er å finne ut hvordan man kan modellere denne heller kompliserte delen på en enkelere måte og likevel inneha de samme egenskapene i så stor grad som mulig.

Jeg vil ta utgangspunkt i å lage en detaljert modell av en vertikalavstiver. Kjøre analyser av hvordan denne vil reagere på forskyvninger og last, samt å finne dens egenfrekvenser. Dette arbeidet vil dokumenteres og dataene lagres for framtidige sammenligninger av alternative deler. Det burde også legges litt arbeid i å finne ut nøyaktig hvilke egenskaper som er viktig for denne delen, og dermed hvilke data som vil være mest naturlig å sammenligne.

Etter at en nøyaktig modell av eksisterende vertikalavstiver er laget, og testet, vil jeg prøve ut alternative varianter. En naturlig tilsvarende del vil være et fagverk bestående av rette elementer. En annen variant er rett og slett å finnne best mulig approksimasjon av selve vertikalen slik at den innehar de riktige egenskapene.

For å lage disse modellene vil jeg ta i bruk abaqus. Den orginale vertikalavstiveren vil utføres som en skallmodell. Fagverksmodellen som "wire feature". Vertikalen i siste tilfelle, vil utføres enten som en skallmodell, som gjør det mulig å variere tverrsnittet med høyden både lineær og ellers, eller som en "wire feature" der tverrsnittet varieres underveis og arbeidet stort sett blir i å lage så gode tilnærmelser av egenskapene i vertikalstiveren som mulig i tverrsnittene som utgjør vertikalen.

Trondheim, 2012-12-16

(Your signature)

Ola Nordmann

Acknowledgment

I would like to thank the following persons for their great help during ...

If the project has been carried out in cooperation with an external partner (e.g., a company), you should acknowledge the contribution and give thanks to the involved persons.

You should also acknowledge the contributions made by your supervisor(s).

O.N.

(Your initials)

Summary and Conclusions

Here you give a summary of your your work and your results. This is like a management summary and should be written in a clear and easy language, without many difficult terms and without abbreviations. Everything you present here must be treated in more detail in the main report. You should not give any references to the report in the summary – just explain what you have done and what you have found out. The Summary and Conclusions should be no more than two pages.

You may assume that you have got three minutes to present to the Rector of NTNU what you have done and what you have found out as part of your thesis. (He is an intelligent person, but does not know much about your field of expertise.)

Contents

Chapter 1

Introduction

This will be a summary of the book: Design of modern steel railway bridges.

1.1 History and Developement of Steel Railway Bridges

The first railway bridge in the U.S was a wooden arch-stiffened truss built in 1830. Increasing locomotive weights provoked an increasing demand for longer and stronger railway bridges. The response was a great many metal girder, arch, truss and suspension bridges. In the beginning the bridges were built with wood and masonry and evolved further to cast and wrought iron and eventually to steel. One of the first steel railway bridge was built in 1871 in France.

Problem Formulation

You should define your problem in a clear an unambiguous way and explain why this is a problem, why it is of interest—and to whom. It is also important to delimit the problem area.

Literature Survey

You should here present the main books and articles that treat problems that are similar to what you are studying. If you, later in your thesis, describe the "state of the art" – with a detailed literature survey, you may just give a very brief survey here (approx. a quarter of a page). If this is the only literature survey, you need to go into more details. An objective of the literature

survey is to show the reader that you are familiar with the main literature within your field of research – so that you do not "reinvent the wheel."

References to literature can be given in two different ways:

- As an *explicit* reference: It is shown by Lundteigen and Rausand (2008) and partly also by Rausand (2014) that ....
- As an *implicit* reference: It is shown (e.g., see Rausand and Høyland, 2004, Chap. 4) that ....

In the example above, we have used "author-year" references, which is the preferred format.

Remark: Following agreement with your supervisor, you may also refer by numbers, for example, [1]. To do this, open the file `ramsstyle.sty` and comment out (by %) the command `\usepackage{natbib}` and un-comment the corresponding command `\usepackage[numbers]{natbib}`.[1]

You may include a link to the Internet in the text or in a footnote by using a command like: `http://www.ntnu.edu/ross`.

When you refer to the scientific literature, you should always write in *present* tense. Example: Rausand and Høyland (2004) show that ....

Remark: Hyperlinks are included by the command `\usepackage{hyperref}` in `ramsstyle.sty`. If you feel that the hyperlinks are disturbing when you enter the text, or want to avoid the hyperlinks in printed text, you may either comment out or edit this command in `ramsstyle.sty`.

What Remains to be Done?

After you have defined and delimited your problem – and presented the relevant results found in the literature within this field, you should sum up which parts of the problem that remain to be solved.

[1] Notice the strange way we have to write the "backslash" in the text. This is because the "backslash" is a command in LaTeX.

1.2 Objectives

The main objectives of this Master's project are

1. This is the first objective
2. This is the second objective
3. This is the third objective
4. More objectives

The objectives shall be written as *fundamental objectives* telling what to do and not *means objectives* telling how to do it.

All objectives shall be stated such that we, after having read the thesis, can see whether or not you have met the objective. "To become familiar with ..." is therefore not a suitable objective.

1.3 Limitations

In this section you describe the limitations of your study. These may be related to the study object (physical limitations, operational limitations), to the environmental and operational conditions, to the thoroughness of the analysis, and so on.

1.4 Approach

Here you should describe the (scientific) approach that you will use to solve the problem and meet your objectives. You should specify the approach for each objective.

If there are any ethical problems related to your approach, these should be highlighted and discussed.

1.5 Structure of the Report

The rest of the report is organized as follows. Chapter 2 gives an introduction to ...

Remark: Notice that chapter and section headings shall be written in lowercase, but that all main words should start with a capital letter.

The report should be no longer than 60 pages in this format (+ the CV).

Chapter 2

Equations, Figures, and Tables

The content of Chapter 2 will vary with the topic of your thesis. This chapter only gives guidance to some technical aspects of LaTeX.

Remark: If you want a shorter chapter or section title to appear in the Table of Contents and in the headings of the chapter, you just include the short title in square brackets before the title of the chapter/section. Example:

```
\section[Short Title]{Long Title}
```

.

2.1 Simple Equations

Mathematical symbols and equations can written in the text as λ, $F(t)$, or even $F(t) = \int_0^t \exp(-\lambda x)\,dx$, or as displayed equations

$$F(t) = \int_0^t \exp(-\lambda x)\,dx \tag{2.1}$$

The displayed equations are automatically given equation numbers – here (2.1) since this is the first equation in Chapter 2. Note that you can refer to the equation by referring to the "label" you specified as part of the equation environment.

You can also include equations without numbers:

$$F(t) = \sum_{i=1}^{n} \binom{n}{i} \sin(i \cdot t)$$

More Advanced Formulas

Long formulas that cannot fit into a single line can be written by using the environment `align` as

$$F(t) = \sum_{i=1}^{n} \sin(t^{n-1}) - \sum_{i=1}^{n} \binom{n}{i} \sin(i \cdot t) \tag{2.2}$$

$$+ \int_0^{\infty} n^{-x} e^{-\lambda x^t} \, dt \tag{2.3}$$

In some cases, you need to write ordinary letters inside the equations. You should then use the commands

```
\textrm  and/or \mathrm
```

The first command returns the normal text font and will be scaled automatically, while the second command will be scaled according to the use.

$$\mathrm{MTTF} = \int_0^{\infty} R_{\mathrm{avg}}(t) \, dt$$

Please consult the LaTeX documentation for further details about mathematics in LaTeX.

Definitions

If you want to include a definition of a term/concept in the text, I have made the following macro (see in `ramsstyle.sty`):

☞ **Reliability**: The ability of an item to perform a required function under stated environmental and operational conditions and for a stated period of time.

Figure 2.1: This is the logo of NTNU (rotated 15 degrees).

When text is following directly after the definition, it may sometimes be necessary to end the definition text by the command

`\newline`

I have not included this in the definition of the `defin` environment to avoid too much space when there is not a text-block following the definition.

2.2 Including Figures

If you use pdfLaTeX (as recommended), all the figures must be in pdf, png, or jpg format. We recommend you to use the pdf format. Please place the figure files in the directory **fig**. Figures are included by the command shown for Figure 2.1. Please notice the "path" to the figure file written by a *forward* slash (/). You should not include the format of the figure file (pdg, png, or jpg) – just write the "name" of the figure.

Each figure should include a unique *label* as shown in the command for Figure 2.1. You can then refer to the figure by the *ref* command. Notice that you can scale the size of the figure by the option `scale=k`. You may also define a specific width or height of the figure by replacing the `scale` options by `width=k` or `height=k`. The factor `k` can here be specified in mm, cm, pc, and many other length measures. You may also give `k` as a fraction of the width of the text or of the height of the text, for example, `width=0.45\textwidth`. If you later change the margins of the text, the figure width will change accordingly. As illustrated in Figure 2.1, you may also rotate the figure – and also do many other things (please check the documentation of the package `graphicx` – it is available on your computer, or you may find it on the Internet).

In LaTeX all figures are floating objects and will normally be placed at the top of a page. This is the standard option in all scientific reports. If you insist on placing the figure exactly where you

Table 2.1: The degree of newness of technology.

Experience with the operating condition	Level of technology maturity		
	Proven	Limited field history or not used by company/user	New or unproven
Previous experience	1	2	3
No experience by company/user	2	3	4
No industry experience	3	4	4

declare the figure, you may include the command `[h]` (here) immediately after `\begin{figure}`. If you will force the figure to be located either at the top or bottom of the page, you may alternatively use `[t]` or `[b]`. For more options, check the documentation.

Large figures may be included as a *sidewaysfigure* as shown in Figure 2.2:[1]

2.3 Including Tables

LaTeX has a lot of different options to include tables. Only one of them is illustrated here.

Remark: Notice that figure captions (Figure text) shall be located *below* the figure – and that the caption of tables shall be *above* the table. This is done by placing the `\caption` command beneath the command `\includegraphics` for figures, and above the command `\begin{tabular*}` for tables.

2.4 Copying Figures and Tables

In some cases, it may be relevant to include figures and tables from from other publications in your report. This can be a direct copy or that you retype the table or redraw the figure. In both cases, you should include a reference to the source in the figure or table caption. The caption might then be written as: *Figure/Table xx: The caption text is coming here (Rausand and Høyland, 2004).*

In other cases, you get the idea from a figure or table in a publication, but modify the figure/table to fit your purpose. If the change is significant, your caption should have the following

[1] You can use a similar command for large tables.

NTNU – Trondheim
Norwegian University of
Science and Technology

Figure 2.2: This is the logo of NTNU.

format: *Figure/Table xx: The caption text is coming here (adapted from Rausand and Høyland, 2004).*

2.5 References to Figures and Tables

Remember that all figures and tables shall be referred to and explained/discussed in the text. If a figure/table is not referred to in the text, it shall be deleted from the report.

2.6 A Word About Font-encoding

When you press a button (or a combination of buttons) on your keyboard, this is represented in your computer according to the *font-encoding* that has been set up. A wide range of font-encodings are available and it may be difficult to choose the "best" one. In the template, I have set up a font-encoding called UTF-8 which is a modern and very comprehensive encoding and is expected to be the standard encoding in the future. Before you start using this template, you should open the Preferences ->Editor dialogue in TeXworks (or TeXShop if you use a Mac) and check that encoding UTF-8 has been specified.

If you use only numbers and letters used in standard English text, it is not very important which encoding you are using, but if you write the Norwegian letters æ, ø, å and accented letters, such as é and ä, you may run into problems if you use different encodings. Please be careful if you cut and paste text from other word-processors or editors into your LaTeX file!

Warning

If you (accidentally) open your file in another editor and this editor is set up with another font-encoding, your non-standard letters will likely come out wrong. If you do this, and detect the error, be sure *not* to save your file in this editor!!

This is not a specific LaTeX problem. You will run into the same problem with all editors and word-processors – and it is of special importance if you use computers with different platforms (Windows, OSX, Linux).

2.7 Plagiarism

Plagiarism is defined as "use, without giving reasonable and appropriate credit to or acknowledging the author or source, of another person's original work, whether such work is made up of code, formulas, ideas, language, research, strategies, writing or other form", and is a very serious issue in all academic work. You should adhere to the following rules:

- Give proper references to all the sources you are using as a basis for your work. The references should be give to the original work and not to newer sources that mention the original sources.
- You may copy paragraphs up to 50 words when you include a proper reference. In doing so, you should place the copied text in inverted commas (i.e., "Copied text follows ..."). Another option is to write the copied text as a quotation, for example:

> Birnbaum's measure of reliability importance of component i at time t is equal to the probability that the system is in such a state at time t that component i is critical for the system.
>
> Rausand and Høyland (2004)

Chapter 3

Summary and Recommendations for Further Work

In this final chapter you should sum up what you have done and which results you have got. You should also discuss your findings, and give recommendations for further work.

3.1 Summary and Conclusions

Here, you present a brief summary of your work and list the main results you have got. You should give comments to each of the objectives in Chapter 1 and state whether or not you have met the objective. If you have not met the objective, you should explain why (e.g., data not available, too difficult).

This section is similar to the Summary and Conclusions in the beginning of your report, but more detailed—referring to the the various sections in the report.

3.2 Discussion

Here, you may discuss your findings, their strengths and limitations.

3.3 Recommendations for Further Work

You should give recommendations to possible extensions to your work. The recommendations should be as specific as possible, preferably with an objective and an indication of a possible approach.

The recommendations may be classified as:

- Short-term
- Medium-term
- Long-term

Appendix A

Acronyms

FTA Fault tree analysis

MTTF Mean time to failure

RAMS Reliability, availability, maintainability, and safety

Appendix B

Additional Information

This is an example of an Appendix. You can write an Appendix in the same way as a chapter, with sections, subsections, and so on.

B.1 Introduction

B.1.1 More Details

Bibliography

Lundteigen, M. A. and Rausand, M. (2008). Spurious activation of safety instrumented systems in the oil and gas industry: Basic concepts and formulas. *Reliability Engineering and System Safety*, 93:1208–1217.

Rausand, M. (2014). *Reiability of Safety-Critical Systems: Theory and Applications*. Wiley, Hoboken, NJ.

Rausand, M. and Høyland, A. (2004). *System Reliability Theory: Models, Statistical Methods, and Applications*. Wiley, Hoboken, NJ, 2nd edition.

Curriculum Vitae

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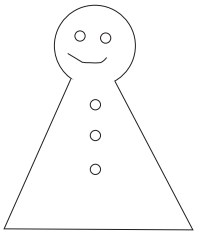

Your picture

Language Skills

Describe which languages you speak and/or write. Specify your skills in each language.

Education

- School 1
- School 2
- School 3

Computer Skills

- Program 1

- Program 2
- Program 3

Experience

- Job 1
- Job 2
- Job 3

Hobbies and Other Activities