# Review of Doctoral Dissertation of Mr Krzysztof Woloszyk

**Title of the dissertation:** Experimental and numerical investigations of ultimate strength of degradated structures

**Reviewer:** Dr Yongchang Pu

## 1. Dissertation Characteristics

The main objective of this thesis is to investigate the ultimate strength of corroded stiffened panels in ship structures.

The dissertation is very well organized with 12 chapters.

Chapter 1 has introduced the background of the research. The state-of art techniques for assessing the effects of corrosion on the ultimate strength of ships have been comprehensively reviewed in Chapter 2. Based on the findings of literature review, the objectives of the research are clearly defined in chapter 3.

From Chapter 4 to chapter 9, various issues including corrosion tests of small specimens and stiffened plates, mechanical tests consisting of tensile tests of corroded specimens and compressive tests of stiffened plates, application of random field to corroded surface, numerical simulation of corroded specimens, and numerical simulation of corroded stiffened plates. Four different methods have been applied to investigate the effects of corrosion on the ultimate strength of stiffened plates under uni-axial compression.

In chapter 10 an empirical formula is derived for fast estimation of the ultimate strength of corroded stiffened plates. Chapters 11 is dedicated to structural reliability analysis of corroded stiffened plates and hull girders. The conclusions are drawn in chapter 12.

## 2. Critical awareness of the subject

The author has comprehensively and critically reviewed the existing techniques relating to the effects of corrosion on the ultimate strength of corroded ship structures with 301 references. Broad cross-reference to others' work in his validation and discussions of the obtained results are very evident.

## 3. Main achievements

Corrosion can significantly reduce the ultimate strength of stiffened panels and ship hull girders. Although significant amount of research has been conducted on this subject, comprehensive experimental and numerical investigations are still limited. The current research has successfully enhanced the existing understanding on this topic.

Both experimental tests and finite element analysis of corroded stiffened plates have been conducted. The results are validated by comparing those results and other published data. In FE simulations of corroded stiffened panels, four different modelling techniques, namely uniform corrosion, non-uniform corrosion, uniform corrosion plus modified mechanical properties, non-uniform corrosion plus modified mechanical properties, have been applied. It proves that non-uniform corrosion plus modified mechanical properties has produced the best results.

An empirical formulation has been derived for quick assessment of the ultimate strength of corroded stiffened panels. It is desirable to have the mean and cov of the formula so that the accuracy of it could be known.

Structural reliability of corroded stiffened plates and hull girders has been predicted. The influential variables have been identified through sensitivity factors.

## 4. Conclusions

This dissertation has successfully achieved its proposed objectives.  The report is well presented. The author has clearly demonstrated his ability to explore, evaluate and test his ideas, and those of others, and relate them to a wider body of knowledge. He has very good understanding of research methods and is able to conceive and implement a research project at the forefront of structural strength assessment of ship structures.

The quality of this research is considered being outstanding because:

Firstly, the outcome of this research is a timely addition of knowledge in the structural assessment of corroded ships.

Secondly, several demanding techniques, such as stochastic finite element methods, random field method, explicit dynamic analysis, have been innovatively applied in this research project.

Thirdly, the amount of work is considerably more than majority of PhD studies.

Fourthly, 12 papers were published based on the work of this dissertation.

Therefore, in my view, the quality of this dissertation meets the requirements of a PhD degree. I recommend that the assessment of this dissertation proceed to the next stage.

I have the following questions for the author to consider further.

1). A key hypothesis in this research is that corrosion would reduce the mechanical properties of the metal. The proposed way to consider these effects is to conduct tensile tests on corroded specimens to determine the constitutive law of the corroded metal. The modified mechanical properties are then used in the finite element analysis of corroded stiffened plates.

When the stress-strain curve is plotted, the average thickness of the corroded specimens is used to calculate the stress. If the minimum thickness is used, what would the stress-strain curve be? The most likely location for rupture of a corroded specimen would be in the minimum thickness and the locations with high stress concentration.

What is applicability of the obtained modified stress-strain curves? DOD is obviously a factor based on the dissertation. How about the thickness of the plates? In another word, could the stress-strain curves of 5mm corroded specimens be applied to the plates with 20 mm thickness?

2). It could be interesting to see the physical meanings of mechanical property changes of corroded plates. When a plate is corroded, the materials near the corroded surface could possibly experience changes in microstructure, chemical substances, and micro-cracks. The materials far away from the corroded surface would be expected to maintain the original properties.

When the behaviour of a welded structure is investigated, the structure is divided into three distinctive regions, namely the weld, HAZ (heat affected zone), and the base materials. The mechanical properties of each region are obtained by separate tensile tests on the specimens taken from each region. Could a similar method be applied to corroded plates?

3). A constitutive law of a given material is the same for every single point of a homogeneous material. In order to ensure that a stress-strain curve could be applied to every single point, the standard test specimens have a gage section, across which all the cross-sections have the same dimensions so that the stress distribution on a cross-section could be assumed being uniform. However, the corroded specimens in the dissertation have different thicknesses across the gage section. This condition could potentially cause stress concentration at least. If micro cracks exist as well, stresses on a cross-section may not be uniformly distributed. This could possibly produce inaccuracy in the obtained stress-strain curves. Could you comment on this issue?

4). The limit state function in Eq. (11.28) considers the uncertainties of initial imperfection and welding-induced residual stress by introducing two random variables, $(\tilde{X}_I)$, $(\tilde{X}_R)$ .

Initial imperfections include both initial deflection of the plate, the stiffened plate, and residual stresses. Your "initial imperfection" is perhaps initial deflection.

The first term in Eq. (11.28) should be the "true" capacity of stiffened plates. Do you believe that $\tilde{X}_R \tilde{X}_I \sigma_u$ is the true capacity? A better way is to use a model uncertainty to replace both $\tilde{X}_R \tilde{X}_I$. A model uncertainty is supposed to include all the uncertainties of a given formula.