ESTIMATION OF FATIGUE LIFE OF STEEL MASTS USING FINITE ELEMENT MODELLING

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The Research Thesis was submitted in partial fulfilment of the requirements for the Degree of Bachelor of Science of Engineering

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DECLARATION

"I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Dr. H.M.Y.C. Mallikarachchi

ABSTRACT

Estimation of Fatigue Life of Steel Masts using Finite Element Modelling

Fatigue is an important design consideration for tall steel structures. Accurate prediction of fatigue endurance is essential to design the elements subjected to wind and earthquake induced fatigue. The design guidelines given in codes of practices are applicable only to simple shapes and laboratory experimental verification is costly. Therefore, simulation using finite element software is becoming popular.

An attempt is made to couple Abaqus finite element analysis software and fe-safe software to estimate the fatigue life of a structure. First, the accuracy of the techniques and idealizations used in simulation are validated by simulating experiments available in the literature. Standard Uni-Axial fatigue experiments which were conducted at several strain amplitudes showed a closer relationship to simulation results. Moreover sensitivity of fatigue life to surface finish and stress strain dataset importing method in fe-safe software were evaluated. It was found that the surface finish is a highly sensitive parameter and it should be estimated accurately. Elastic plastic block method gave good results while elastic block method with neuter's rule results were poor. This indicates the importance of using elastic plastic block method for low cycle fatigue especially when stress redistribution is high. Simulation result of multi-axial fatigue experiment showed similar results to results obtained from physical experiments.

The verified technique was the applied to estimate the fatigue life of a 64 m tall steel mast with an opening located at the top of a 285 m tall concrete tower. The sensitivity of the plate thickness and shape of the opening of the mast were studied. It was found that small increase in plate thickness rapidly increases the fatigue endurance. This shows the importance of using stiffeners in fatigue prone areas. Comparison of the shape of the opening showed that square shape would have higher endurance than a circular shape of same opening area. However only monolithic sections were studied here and effects on welds and bolted connections are beyond the scope of this research.

Key Words:

Fatigue simulation, Abaqus, fe-safe, mast with an opening

DEDICATION

I dedicate my thesis to my family, friends and teachers. First of all a special feeling of gratitude to my loving parents, Upali Kariyawasm and Swarnalatha Kariyawasam whose good examples have taught me to work hard for the things that I aspire to achieve . My brother Ruchira and sister Ushara were always by my side and they are very special.

I want to dedicate this also to all my friends at the university who encouraged me and made my life at the university an interesting experience with a lot of memories.

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Research project was one of the most interesting works that I did and I found the passion of mine in doing research after doing my first research work. I want to thank everyone who helped in any way possible to make this a success.

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LIST OF ABBREVIATIONS

Abbreviation	**Description**
FE	Finite Element
FEA	Finite Element Analysis
FEM	Finite Element Modelling
ULCF	Ultra Low Cycle Fatigue
CAE	computer-aided engineering
C3D8R	8-node linear brick solid elements
3D	3 Dimensional
2D	2 Dimensional
S8R	Eight-node doubly curved thick shell elements

LIST OF SYMBOLS

Symbol	**Description**	**Units**
E	The elastic modulus	Pa
b	The fatigue strength exponent	
c	Fatigue ductility exponent	
F_{max}	Maximum force	kN
F_{min}	Minimum force	kN
F_{rn}	Detailed category	
K	The strain hardening coefficient	
K’	The cyclic strain hardening coefficient	
K_t	Elastic stress concentration factor	
n	The strain hardening exponent	
n’	The cyclic strain hardening exponent	
N_f	Number of cycles to failure	
Ni	cycles required to cause failure under the same amplitude	
ni	the number of stress cycles of the considered amplitude	
N_{in}	Number of cycles to crack initiation	
N_p	Number of cycles to crack propagation	
P_{max}	Maximum load induced	
P_{min}	Minimum load induced	
R	Load ratio	
R	Radius	mm
Ra	Surface roughness	µm
$\Delta\gamma_{max}$	Maximum shear strain range	
$\Delta\varepsilon$	Applied strain range	
$\Delta\varepsilon_n$	Range of strain normal to the maximum shear strain	
$\Delta\varepsilon_p$	Plastic strain range	
ε'_f	Fatigue ductility coefficient	
ε	Total stress	Pa
σ'_f	The fatigue strength coefficient	
σ_m	Mean stress	Pa