DEVELOPMENT OF SAFE OPERATIONAL CRITERIA FOR SHIPS BASED ON VIBRATION ANALYSIS

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Degree of Master of Philosophy

Department of Mechanical Engineering

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DECLARATION OF THE CANDIDATE AND SUPERVISOR

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Signature Date

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D.M.P.M Dasanayaka

Abstract

The origin of shipboard vibrations is dominantly determined by vessels propulsion system, main machinery, auxiliary systems, pumps, breaking of the waves at the ship hull, etc. All of these peripherals and systems origin the static and dynamic induction of vibration onboard a ship while various analytical and statistical methods may be declared to assess the levels of vibration in order to declare a combined safe operational criteria for ships depending on the spectrums. Few similar researches had been completed on identification and quantified estimation of the noise or the multiple vibrations resulted from ship and machinery during passage.

However, those researches were addressed mainly towards developing a relationship for a single new ship or category particularly prior to commissioning. This research was focused on studying the shipboard transferred vibration (of the vessel's structure and to sea) and vibration spectra generated by shipboard machinery / structures using portable vibration analysers for in-service ships. Data was recorded onboard classes of ships/ craft (new and old) through a series of sea trials to establish a common relationship for ships and to comprehend use this methodology as a tool in understanding complex patterns of ship vibration spectra to predict possible defects.

The study commenced on 05th May 2014 under the patronage and guidance of the Department of Mechanical Engineering, University of Moratuwa to identify the unique patterns of shipboard vibration signatures generated whilst vessels are on sail, paying attention to the external forces and to develop a data base with existing vibration levels after being identified as safe operational limits (depending on the observations based on datum readings). The research data was collected using two modern vibration analysers (Make: Areva, Model: Oneprod MVP -2C, Country of Origin: France, Frequency Range: 0 – 40,000 Hz) integrated with Areva XPR 300 software system uploaded computers for the spectrum analysing task. Sea trials at following conditions had been carried out.

a. Sea State : 3 and below;
b. Ship Loading Condition : Full Load, Half Load;
c. Wind Condition : Moderate < 15 knots;
d. Sea Direction : Ahead, Astern

Numerical relationships and probabilities were established using practical outcomes of the sea trials. Data analysis and Spectrum datum comparison were used to identify and quantify the safe operational vibration limits with respect to individual classes of ships being the primary outcome. The similar defect patterns and respective statistics were averaged to find out a common relationship to identify a figure named “Shipboard Machinery Vibration Safety Index (S_v)”, which was the secondary outcome of the study.

Key words: Shipboard Vibration, Vibration spectra, Vibration analyser, Hull

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LIST OF ABBREVIATIONS

Abbreviation	Description
CBPM	Condition Based Predictive Maintenance
FAC	Fast Attack Craft
OPV	Offshore Patrol Vessel
LST	Landing Ship Tanker
FGB	Fast Gun Boat
LCU	Landing Craft Utility
FPC	Fast Personnel Carrier
FMV	Fast Missile Vessel
FPV	Fast Patrol Vessel
Aux	Auxiliary Ship
LCM	Landing Craft Mechanised
HAT	Harbour Acceptance Trials
MTTU	Machinery Testing and Trials Unit
PPM	Planned Preventive Maintenance
SAT	Sea Acceptance Trials
VA	Vibration Analysis
Vib.	Vibration
OES	Optical Emission Spectrometry
TAN	Total Acidic Number
TBN	Total Base Number
SLN	Sri Lanka Navy

SLNS	Sri Lanka Naval Ship
XPR	Version of Areva Vibration Analysis Software
MCR	Machinery Control Room
NDT	Non Destructive Testing
OEM	Original Equipment Manufacturer
G/B	Gear Box
M/E	Main Engine
D/A	Diesel Alternator
F/E	Free End
D/E	Drive End
Port	Port Side of Ship/ Machinery – Left viewed back
Stbd	Starboard Side – Right viewed from back
CPP	Controllable Pitch Propeller
SEMT	SEMT Pielstick Company
MTU	MTU Friedrichshafen Company
FWD or fwd	Forward end
AFT or aft	After end
MJP	Marine Jet Propulsion
UK	United Kingdom
CDL	Colombo Dockyard Pvt. Ltd, Sri Lanka
Max Acc	Maximum Acceleration
Min Acc	Minimum Acceleration
Max Vel	Maximum Velocity
Min Vel	Minimum Velocity
GMBH	Gesellschaft Mit Beschränkter Haftung, Germany
US	United States
USA	United States of America
RPM	Rounds/ Rotations per Minute
CPM	Cycles per Minute
RMS	Root Mean Square
ISO	Standards declared by International Organization for Standardisation

RIC	Reciprocating Internal Combustion
FFT	Fast Fourier Transform
MVP	Portable Version of Areva Analyser
RCM	Reliability Cantered Maintenance
VM	Vibration Monitoring
VA	Vibration Analysis
CM	Condition Monitoring
Dia	Diameter
GMF	Gear Mesh Frequency
Nb	Number of balls or Rollers
Bd	Ball or Roller Diameter (in or mm)
Pd	Bearing Pitch Diameter (in or mm)
BPF	Blade (or vane) Pass Frequency
BPFI	Ball Pass Frequency Inner
BPFO	Ball Pass Frequency Outer
FTF	Fundamental Train Frequency
BPF	Ball Pass Frequency
BSF	Ball Spin Frequency
BRF	Blade Rate Frequency
BR	Belt Rate / Frequency
Niv	Number of Impeller Vanes
Ndv	Number of Diffuser Vanes
K	Highest common factor of Niv and Ndv
Ns	Synchronous Speed
Fs	Slip Frequency
Fp	Pole Pass Frequency
RBPF	Rotor Bar Pass Frequency
Lt (E)	Lieutenant (Engineering)

LIST OF SYMBOLS

Abbreviation	**Description**
HP	Horse Power

rpm or RPM	Rounds per Minute
CPM	Cycles per Minute
NM	Nautical Mile
kW	kilowatt
MW	megawatt
kVA	kilo (Volt x Amperes)
Hrs	Hours
Hz	Hertz
mm/sec	millimetre per second
cm/sec^2	centimetre per second squared
In/sec RMS	Inches per seconds Root Mean Square
In/sec Peak	Inches per seconds Peak
$In/sec^{2`}$	Inches per second squared
mm/sec RMS	millimetre per second Root Mean Square
mm/sec Peak	millimetre per second Peak
mm/sec^2	millimetre per second squared
m/s	meters per seconds
cm	centimetre
g	Gravity
SE	Spike Energy
^oC	Celsius
s	seconds
1X	Fundamental frequency or first harmonic / first order
2X	Second harmonic / order
nX	n^{th} harmonic / n^{th} order
S_v	Safety Index

LIST OF APPENDICES