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DYNAMIC RESPONSE OF ROTATIONALLY PERIODIC STRUCTURES

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ABSTRACT

Due to their structural dynamics, rotationally periodic structures (RPS) have always been an area of interest for engineers and scientists. RPS is found in almost all industries and could be as large as jet turbines to as small as hard disk drives. We come across with RPS on daily routine like washing machine tub, small gears in home appliances and brakes in automobile etc. With such an influence in our life, an RPS dynamic response to the environment is crucial to keep them working and hence is the focus of the thesis. The research involves three major responses on rotationally periodic structures (RPS) namely vibration, thermal and shock. Hard disk drives and integrally bladed rotors (IBR) has been selected as research models.

On vibratory response in rotationally periodic structures, effects on structural designs and free vibrations of integrated bladed rotor (IBR) have been investigated in this research. The migration of natural frequencies is characterized through parametric studies considering changes in blade angle and blade thickness of an underlying uniform axis-symmetric rotor. Recurring coupled repeated doublet modes, defined as replica modes, have been observed in this study by characterizing blade vibrations in-phase or out-of-phase to disk vibrations. Veering and clustering of replica modes’ natural frequencies are observed with respect to the blade design parameters. Existence of replica modes has been verified via experimental studies. Fourier content for the low frequency replica component is found to be sensitive and tuneable to blade angle design.

For the thermal response of RPS, structural thermal analysis of spindle disk assembly used in hard disk drives (HDDs) was adopted. With the view toward understanding the underlying physics and to minimize the corresponding repeatable run-out (RRO) of track following position error signal (PES) in high track per inch (TPI) magnetic disk drives, analytical representations of thermal expansion mismatch between disk and spindle hub structure formulated in form of operators and finite element analysis (FEA) are employed. Parametric studies with analysis taken at different operational temperatures suggested that RRO can be minimized significantly when location of spindle notch is properly located. RRO harmonics resulted from the thermal expansion mismatch and structure misalignments are studied and concluded with simple algebraic expression related to number of fasteners used in the disk-spindle assembly.
On shock response of RPS, head gimbal assembly (HGA) in HDD was analysed. Experimental observation of de-bonding phenomena between head gimbal assembly (HGA) and suspension for a commercial 3.5-inch enterprise HDD under non-operational 250G shock test was performed. In this research the experimental observation and numerical finite element studies were conducted to understand the effect on the mechanical failure of HGA when it is subjected to non-operational shock in the parked position on the ramp. Different design modifications were adapted to withstand shock waves. It was observed that by changing flexure angle in HGA, shock stress can be reduced. FEA simulation results have been presented to verify the findings.

The research findings in this thesis can be implemented in the industry where RPS has been widely used, as for example the new replica modes discovery in bladed rotors can also been applied on small scales like as on hard drive, where no. of blades can be replaced by no. of fasteners and the spinning hard drive will be benefited by studying its vibrations with concentration on replica modes. Furthermore, the serendipitous finding of HDD platters expansion under thermal stress can be beneficial in actually storing more data per inch as it has been recently used in TAMR (thermally assisted magnetic recording) technology. Gears, brakes, washing machines to name a few can get supported from the findings in the thesis where controlling vibrations, shock and heat is crucial.
# Table of Contents

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Acknowledgement

Chapter 1 Introduction

1.1 What is a Rotationally Periodic Structure?

1.2 Topological Affinity of Rotationally Periodic Structures

1.3 Motivations and Model Selections

1.3.1 Vibrational Response on Rotationally Periodic Structures

1.3.2 Thermal Response on Rotationally Periodic Structures

1.3.3 Shock Response on Rotationally Periodic Structures

1.4 Aim and Objectives

1.5 Scope and Contributions

1.6 Thesis Organization

Chapter 2 Literature Review

2.1 Rotationally Periodic Structures

2.2 Applications of Rotationally Periodic Structures

2.2.1 Brakes

2.2.2 Gears

2.2.3 Hard Disk Spindle System

2.2.4 Turbines

2.2.4.1 Discrete to Continuous Models

2.2.4.2 Point Stiffness Considerations

2.2.4.3 Coupled Bladed Disk to Integrally Bladed Rotors
### Chapter 3  Free Vibration Response of Rotationally Periodic Structures

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Introduction</td>
<td>19</td>
</tr>
<tr>
<td>3.2 Finite Element Model</td>
<td>20</td>
</tr>
<tr>
<td>3.2.1 Convergence Study</td>
<td>21</td>
</tr>
<tr>
<td>3.3 Replica Modes</td>
<td>23</td>
</tr>
<tr>
<td>3.4 Lumped Mass Model Approach</td>
<td>26</td>
</tr>
<tr>
<td>3.4.1 Equivalent IBR Model</td>
<td>27</td>
</tr>
<tr>
<td>3.4.2 Equation of Motion (EOM)</td>
<td>28</td>
</tr>
<tr>
<td>3.5 Parametric Study</td>
<td>30</td>
</tr>
<tr>
<td>3.5.1 Replica Modes with Varying Blade Angles</td>
<td>30</td>
</tr>
<tr>
<td>3.5.2 Replica Modes with Varying Blade Thickness</td>
<td>34</td>
</tr>
<tr>
<td>3.6 Modulated Stiffness Analysis</td>
<td>36</td>
</tr>
<tr>
<td>3.7 Experimental Modal Analysis</td>
<td>41</td>
</tr>
<tr>
<td>3.7.1 Experimental Setup</td>
<td>42</td>
</tr>
<tr>
<td>3.7.2 Experimental Investigation</td>
<td>44</td>
</tr>
<tr>
<td>3.8 Chladni’s Pattern</td>
<td>49</td>
</tr>
<tr>
<td>3.8.1 Experimental Setup</td>
<td>50</td>
</tr>
<tr>
<td>3.9 Conclusion</td>
<td>51</td>
</tr>
</tbody>
</table>

### Chapter 4  Thermal Response of Rotationally Periodic Structures

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Introduction</td>
<td>54</td>
</tr>
<tr>
<td>4.2 Experimental Observations</td>
<td>56</td>
</tr>
<tr>
<td>4.3 Finite Element Model</td>
<td>60</td>
</tr>
<tr>
<td>4.3.1 Modification in Finite Element Model</td>
<td>61</td>
</tr>
<tr>
<td>4.3.2 Interrelation at Increased Temperatures</td>
<td>63</td>
</tr>
<tr>
<td>4.4 Perturbation Study</td>
<td>65</td>
</tr>
<tr>
<td>4.5 Reduction of 2X RRO</td>
<td>68</td>
</tr>
</tbody>
</table>
# Chapter 5  Shock Wave Response of Rotationally Periodic Structures

5.1  Introduction
5.2  Experimental Observations
5.3  Finite Element Model
5.4  Minimization of Shock Effect
5.5  Conclusion

# Chapter 6  Conclusion

6.1  Summary
6.2  Limitations
6.3  Future Work
   6.3.1  Forced Vibration Response on Replica Modes
   6.3.2  Damping of Replica Modes
   6.3.3  Mistuning Effects on Replica Modes

References

Appendices

Appendix A
Appendix B
Appendix C

List of Publications
LIST OF FIGURES

Chapter 1

Fig. 1.1 Rotationally periodic structure example (Integrated bladed rotor) 2
Fig. 1.2 Frequency analysis on (a) IBR (c) DSA and (b) its corresponding 3
modeshape (0,3) at outer edge of disk near blades (d) and outer edge
of DSA near Screw locations respectively
Fig. 1.3 Graphical hierarchy of Thesis organization 9

Chapter 2

Fig. 2.1 Typical bladed section of a reaction turbine rotor 10
Fig. 2.2 Slotted Brake Rotors (source: www.turnermotorsport.com) 11
Fig. 2.3 A typical spur and bevel gears (source: www.gearsandstuff.com) 12
Fig. 2.4 Hard disk drive spindle system (Source: www.hddoctor.net) 14
Fig. 2.5 Schematic of a gas turbine engine 15
Fig. 2.6 Integrated bladed rotor ( IBR ) 17

Chapter 3

Fig. 3.1 Schematics of rapid prototyped model of an integrally bladed rotor 20
Fig. 3.2 Convergence of frequency modes of the present IBR model at \( N_b =19, \beta=30^\circ \) 22
Fig. 3.3 Example of (a) = in-phase (↑↑) and (b) = out-of-phase (↑↓) replica 24
mode components of the IBR at \( N_b =19, \beta=30^\circ \)
Fig. 3.4 Finite Element Analysis pictures of in-phase (↑↑) and out-of-phase 25
(↑↓) replica mode components of the IBR at \( N_b =19, \beta=30^\circ \)
Fig. 3.5 Lumped mass model with flexible disk approach 26
Fig. 3.6 Lumped mass model with interbladed connectors 26
Fig. 3.7 Sophisticated Lumped mass model with interblade connectors 27
Fig. 3.8 Equivalent Integrally Bladed Disk (IBR) lumped mass model 28
Fig. 3.9 \( J^{th} \) sector of Integrally bladed disk (IBR) 28
Fig. 3.10 Schematics of different blade angle at (a) 30\(^\circ\), (b) 0\(^\circ\), (c) 15\(^\circ\), and (d) 31
50\(^\circ\)
Fig. 3.11 Migration of replica modes as a function of blade angle; \( N_b =19 \) and 31
\( T_b = 5\text{mm} \).
Fig. 3.12 Fourier amplitudes of replica (a) \( P(0,4)_{L} \) and (b) \( P(0,4)_{H} \) mode of 33
the model IBR with different blade angles
Fig. 3.13 Schematic illustrations of different blade thickness, \( T_b \) at (a) 14mm, 35
(b) 11mm, (c) 8mm, and (d) 5mm
Fig. 3.14 Migration of replica modes as a function of blade thickness; \( \beta=30^\circ \) 36
Fig. 3.15 Fourier amplitude of IBR at 1000N force with different blade angles 37
(\( \beta \))
Fig. 3.16 \( 1^{st} \) modulated wavenumber trend at different forces 38
Fig. 3.17 (a) \( 1^{st} \) harmonic trend with linear fitting (b) \( 2^{nd} \) harmonic trend with 40
second order polynomial fitting (c) \( 3^{rd} \) harmonic trend with third
order polynomial fitting
Fig. 3.18 Actual 3D prototype IBR developed for EMA 42
Fig. 3.19 Schematic of Experimental Modal Testing 42
Fig. 3.20 Input-output Measurement Locations for FRF 43
Fig. 3.21 Selection of Hammer tips for required FRF 45
Chapter 4
Fig. 4.1 (a) Mechanical components in a commercial HDD (b) Servo and data sectors on magnetic disk
Fig. 4.2(a) HDD deformed as a saucer against a disk flatness measurement
Fig. 4.2(b) The subsequent displacement plot at outer diameter (OD) of spindle assembly
Fig. 4.3 RRO PES spectra examples as seen on disk (a) OD, (b) MD, and (c) ID
Fig. 4.4 Repeatable Run-out Diagrams from disk OD to ID for (a) 2X, (b) 4X, (c) 5X, and (d) 6X RRO harmonics
Fig. 4.5 Finite Element Model of the Disk Spindle Assembly (DSA) of a HDD
Fig. 4.6 Comparison of (a) rotationally periodic and (b) non-periodic spindle assembly models and the corresponding disk radial deformation in (c) and (d), respectively. The resultant harmonics are shown in (e) and (f).
Fig. 4.7 Side view of (a) Original and (b) deformed spindle hub structure at 80°C and (c) Original and (d) deformed DSA at 80°C
Fig. 4.8 FEA results of interrelationship of 2X with 4X and 8X RRO scales at disk internal and Outer Dia. in (a) and (c), respectively; Interrelationship of 1X with 5X and 7X RRO scales at disk internal and outer diameter, in (b) and (d), respectively. [45]
Fig. 4.9 Elastic constrains of a disk clamped by six fasteners
Fig. 4.10 Spindle hub designs with different slot angles
Fig. 4.11 FEA nodal displacement plots at Disk OD at 80°C on (a) 0° slot angle (b) 15° slot angle (c) 30° slot angle and (d) 45° slot angle.
Fig. 4.1 RRO harmonics of OD radial displacement (mm) at different temperature and slot angle designs

Chapter 5
Fig. 5.1 Experimental setup for drop test analysis
Fig. 5.2 Sanity check of drop fixture
Fig. 5.3 Independent and tester accelerometer stability diagram
Fig. 5.4 De-bonding of flexure @250G and 2ms
Fig. 5.5 Photograph of small and large de-bonding resulting mechanical failure
Fig. 5.6 Photograph of dismantled enterprise HDD (a) and the corresponding finite element model in (b)
Fig. 5.7 Fig. 5.7 HGA designs with different flexure angle, α at (a) 1°, (b) 2°, (c) 3°, and (d) 4°
Fig. 5.8  Fig. 5.8 HGA impact stress history plot of four critical vertex points with flexure angle at $\alpha = 1^\circ$

Fig. 5.9  Maximum impact stress around HGA critical vertex points as function of drop heights with $\alpha = 1^\circ$

Fig. 5.10  Maximum impact stress around HGA critical vertex points as function of flexure angles at 200G/2m drop height

Fig. 5.11  Fig. 5.11 Simulated HGA with Stress concentration regions
LIST OF TABLES

3.1 Design parameters of the IBR 17
3.2 Natural Frequency Comparison of Replica Modes Through FEA, EMA and Chladni 44
5.1 (a) Drop Test Statistics & (b) Qualitative observation of Flexure De-bond 70
**LIST OF ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(↑↑)</td>
<td>In-phase Mode</td>
</tr>
<tr>
<td>(↑↓)</td>
<td>Out-of-Phase Mode</td>
</tr>
<tr>
<td>D.S.A</td>
<td>Dynamic Signal Analyzer</td>
</tr>
<tr>
<td>DSA</td>
<td>Disk Spindle Assembly</td>
</tr>
<tr>
<td>EMA</td>
<td>Experimental Modal Analysis</td>
</tr>
<tr>
<td>EOM</td>
<td>Equation of Motion</td>
</tr>
<tr>
<td>FCA</td>
<td>Flexible Cable Assembly</td>
</tr>
<tr>
<td>FEA</td>
<td>Finite Element Analysis</td>
</tr>
<tr>
<td>FFT</td>
<td>Fast Fourier Transform</td>
</tr>
<tr>
<td>FRF</td>
<td>Frequency Response Function</td>
</tr>
<tr>
<td>HAS</td>
<td>Hard-disk Spindle Assembly</td>
</tr>
<tr>
<td>HCF</td>
<td>High Cycle Fatigue</td>
</tr>
<tr>
<td>HDD</td>
<td>Hard Disk Drive</td>
</tr>
<tr>
<td>HGA</td>
<td>Head Gimbal Assembly</td>
</tr>
<tr>
<td>IBR</td>
<td>Integrated Bladed Rotor</td>
</tr>
<tr>
<td>K&lt;sub&gt;g&lt;/sub&gt;</td>
<td>Structural Stiffness</td>
</tr>
<tr>
<td>K&lt;sub&gt;β&lt;/sub&gt;</td>
<td>Spatial modulated stiffness</td>
</tr>
<tr>
<td>LCF</td>
<td>Low Cycle Fatigue</td>
</tr>
<tr>
<td>N&lt;sub&gt;b&lt;/sub&gt;</td>
<td>No. of Blades</td>
</tr>
<tr>
<td>NF</td>
<td>No. of Fasteners</td>
</tr>
<tr>
<td>NVH</td>
<td>Noise Vibration Harness</td>
</tr>
<tr>
<td>PES</td>
<td>Position Error Signal</td>
</tr>
<tr>
<td>RPS</td>
<td>Rotationally Periodic Structures</td>
</tr>
<tr>
<td>RRO</td>
<td>Repeatable Run-out</td>
</tr>
<tr>
<td>T&lt;sub&gt;b&lt;/sub&gt;</td>
<td>Blade Thickness</td>
</tr>
<tr>
<td>TMR</td>
<td>Track Mis-Registration</td>
</tr>
<tr>
<td>TPI</td>
<td>Track per Inch</td>
</tr>
<tr>
<td>U&lt;sub&gt;(k)n&lt;/sub&gt;</td>
<td>Displacement</td>
</tr>
<tr>
<td>VCM</td>
<td>Voice Coil Motor</td>
</tr>
<tr>
<td>β</td>
<td>Blade Angle</td>
</tr>
</tbody>
</table>
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