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.

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(↑↑)	In-phase Mode
(↑↓)	Out-of-Phase Mode
D.S.A	Dynamic Signal Analyzer
DSA	Disk Spindle Assembly
EMA	Experimental Modal Analysis
EOM	Equation of Motion
FCA	Flexible Cable Assembly
FEA	Finite Element Analysis
FFT	Fast Fourier Transform
FRF	Frequency Response Function
HAS	Hard-disk Spindle Assembly
HCF	High Cycle Fatigue
HDD	Hard Disk Drive
HGA	Head Gimbal Assembly
IBR	Integrated Bladed Rotor
K_g	Structural Stiffness
K_β	Spatial modulated stiffness
LCF	Low Cycle Fatigue
N_b	No. of Blades
NF	No. of Fasteners
NVH	Noise Vibration Harness
PES	Position Error Signal
RPS	Rotationally Periodic Structures
RRO	Repeatable Run-out
T_b	Blade Thickness
TMR	Track Mis-Registration
TPI	Track per Inch
$U_{(k)n}$	Displacement
VCM	Voice Coil Motor
β	Blade Angle

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