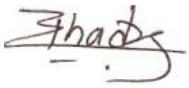
Declaration

I hereby declare that the work presented in this Thesis titled *Assessment of nonlinear responses and bifurcation analysis of light-weight shaft disk system with different loading configurations*, submitted to the Indian Institute of Technology Jodhpur in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy, is a bonafide record of the research work carried out under the supervision of Professor *Dr. Barun Pratiher*. The contents of this thesis in full or in parts, have not been submitted to, and will not be submitted by me to, any other Institute or University in India or abroad for the award of any degree or diploma.



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Certificate

It is certified that the work contained in this thesis entitled **"Assessment of nonlinear responses and bifurcation analysis of light-weight shaft disk system with different loading configurations"** submitted by **Mr. Phadatare Hanmant Pandurang** to the Indian Institute of Technology Jodhpur for the award of the degree of Philosophy has been carried out under my supervision in the Department of Mechanical Engineering, Indian Institute of Technology Jodhpur. This work has not been submitted elsewhere for the award of any other degree or diploma.

The thesis, in my opinion, has reached the standard fulfilling the requirements for the award of the degree of Doctor of Philosophy in accordance with the regulations of the Institute.

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List of Symbols

Symbols	Descriptions
A	Cross sectional area of the Shaft in m^2
c	Viscous Damping coefficient of the shaft Ns/m
c_b	Damping coefficient of bearing in Ns/m
E	Modulus of elasticity N/m^2
e	Strain along shaft axis in m
e_v	Eccentricity of the shaft in y direction in m
e_w	Eccentricity of the shaft in z direction in m
F_x	Rubbing force in Y direction
f_x	Non dimensional Rubbing force in Y direction
F_y	Rubbing force in Y direction
f_y	Non dimensional Rubbing force in Y direction
h	Thickness if the disk in m
$I1$	Polar mass moment of inertia $kg\text{-}m^2$
$I2$	Diametrical mass moment of inertia $kg\text{-}m^2$
I_A	Area moment of inertia in mm^4
K_l	Linear stiffness coefficient of a bearings in N/m
K_{nl}	Nonlinear bearing stiffness coefficient in N/m^3
K_r	Stiffness of rub surface
L,	Length of the shaft in m
L_d	Disk location from one of the ends of the shaft in m
m	Mass of the shaft in kg
M	Mass of the disk in kg
m_u	Unbalance Mass in kg
N	Number of discs
N_b	Linear forward natural frequency
N_{bn}	Non-linear forward natural frequency
N_f	Linear forward natural frequency
N_{fn}	Non-linear forward natural frequency
P_o	Static axial force in N
P_1	Pulsating axial force in N
r_1	Eccentricity of the unbalance mass in m
R_d	Radius of the disk in m
R_s	Radius of the shaft in m
u, v, w	Displacements in x, y and z directions
Z_a, W_b	Amplitude of base excitation
ψ, ϑ and θ	Angular displacement about the axes of Z, Y, and X
θ_1	Non dimensional disk mass

β_2	Non dimensional unbalance mass
δ	Loss Factor or Clearance between rotor and stator
Δx	Eccentricity of stator axis with rotor in Y direction
Δy	Eccentricity of stator axis with rotor in Z direction
η	Coefficient of friction
λ	Eigen value of mode shape function
ρ	Mass Density of the shaft in kg/m^3
σ	Detuning parameter
Ω	Rotating speed/ Excitation frequency in rad/s
Ω_1	Frequency of an axial force excitation in rad/s
ω_1	Forward Natural frequency in rad/s
Ω_2	Spinning speed of the rotor in rad/s
ω_2	Backward Natural frequency in rad/s
ω_e, Ω_b	Base excitation frequency

List of Abbreviations

Abbreviation	*Full form*
BNF	Backward Natural Frequency
BNNF	Backward Nonlinear Frequency
DOF	Degree of Freedom
FFT	Fast Fourier Transform
FNF	Forward Natural Frequency
FNNF	Forward Nonlinear Natural Frequency
HBM	Harmonic Balance Method
MI	Moment of inertia
MMS	Method of Multiple Scales
NNM	Nonlinear Normal Mode
Ph.D.	Doctor of Philosophy
S-N	Saddle Node