Appendix I
Nomenclature

1. Latin Letters

A	Amplitude, area, section area of draft tube
A_r	Turbine gain factor
$\bar{A}$	Relative amplitude
$[\boldsymbol{A}]$	"Stiffness" matrix in FEM
$[\boldsymbol{A}]$, $[\boldsymbol{B}(\boldsymbol{X})]$	State global matrices
$[\widetilde{A}]$	Dynamic matrix
a	Complex amplitude, sound speed in water, distance between upper bearing and disc mass centre (Fig. 4.2.1) opening of guide vanes
$a_i(t)$	Generalized coordinates
$\{\boldsymbol{a}\}$	Unit direction vector, amplitude vector, vector containing generalized coordinates
B	Relative frequency of $f_{k,}$ amplitude, Greitzer's factor
$\hat{B}$	Average magnetic flux density
$\{\boldsymbol{B}\}$	Right vector in FEM
$[\boldsymbol{B}]$	Compliance matrix
$[B(x,y,z)]$, $[B]$	Matrix with derivatives of shape functions
$[\tilde{B}]$	Input gain matrix
b	Mean sealing gap width
b_2	Pump impeller exit width
C	Constant, capacitance, cavitation compliance,
C	Mean velocity in a section
C_H	Head coefficient $C_H = gH/N^2d^2$
C_h	Hydraulic capacitance
C_Q	Flow coefficient $C_Q = Q/N\mathrm{d}^3$
C_{QM}	Operation dimensionless relation of turbine
$C_{M\alpha}$	Damping of oil film created by thrust disc swing
C_{xy}, C_{yx}	Cross-damping coefficient reflecting oil film

Y. Wu et al., *Vibration of Hydraulic Machinery*,
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C'	Lineic hydroacoustic capacitance $C' = gA/a^2$
C'_e	Electrical capacitance of unit length
$[\boldsymbol{C}]$	Damping matrix
$[\tilde{\boldsymbol{C}}]$	Output gain matrix
$\{\boldsymbol{C}_i\}$	Constraint force
c	Damping coefficient, wave speed in fluid
c_i	Constants defining $w(\boldsymbol{x})$
c_n	Non-rotating damping coefficient
c_r	Rotating damping coefficient
c_{xxi}, c_{xyi}, c_{yxi}, c_{yyi}	Damping factors of the *i*th pad
$c_{\theta 2}$	Swirl velocity
D	Damping coefficient, per unit load damping constant, character diameter of runner
D_1	Runner exit diameter at band
D_e	Draft tube inlet diameter
$[\boldsymbol{D}]$	Transfer matrix
$[\tilde{\boldsymbol{D}}]$	Matrix describing influence of inputs on outputs
d	Radius of long circular cylinder, turbine characteristic diameter
E	Young's modulus, output of turbine
E_c	Young's modulus for cable
E_r	Relative internal energy
E_{nD}	Unit energy coefficient
E_{pipe}	Pipe wall material viscoelastic behavior
E'	Transient electric potential of generator
$[\boldsymbol{E}]$	Stiffness matrix of material, Green-Lagrangian strain tensor
e	Base of exponential function
$\boldsymbol{e}_x$, $\boldsymbol{e}_y$	Unit vectors along x and y axes
e	Constant, eccentric distance of vortex rope
$\{\boldsymbol{e}\}=\{\theta_y, \theta_x, y\}^T$	Displacement vector
F	Force
F_0	Radial force
F_D	Damping force
F_{ex}	External force
F_i	Spectrum value
F_k	Restoring force
F_{sm}	Amplitude of stator magnetic potential
F_{jm}	Amplitude of rotor magnetic potential
F_x F_y	Forces of oil film on *xoz* and *yoz* planes
F'_{sx} F'_{sy}	Unbalanced force
$F(w)$	Energy functional
$\{\boldsymbol{F}_{dn}\}$	Force due to non-rotating damping
$\{\boldsymbol{F}_{dr}\}$	Force due to rotating damping

$\{\boldsymbol{F}_e\}$	Elastic force
$\{\boldsymbol{F}_i\}$	Applied forces
$\{\boldsymbol{F}_n\}$	Force due to no-rotating damping, static load
$\{\boldsymbol{F}_{rxy}\}$	Force due to rotating damping in *xy*-plane
$\{\boldsymbol{F}_{r\xi\eta}\}$	Force due to rotating damping in $\xi\eta$-plane
$\{\boldsymbol{F}\sigma\}$	Loading vector caused by initial stresses at nodes
$[\boldsymbol{F}]$	Deformation gradient tensor
f	Unit external force, giving force in domain electric net frequency, cross-sectional area
f_0	Natural vibration frequency in draft tube
f_i	Generalized forces
f_b	Blade passing frequency
f_g	Guide vane passing frequency
f_k	Karman vortex street frequency
f_{oil}	Self-excitation frequency of oil film in bearing
f_{p2}	Per unit tunnel head loss coefficient
f_S	Stay vane passing frequency
f_n	Precession frequency of vortex rope, per unit head loss coefficient
f_r	Ratio of precession frequency
f_{rope}	Frequency of vortex rope
f_v	Frequency of pressure pulsation by vortex rope
f_{wh}	Hydraulic vibration frequency in penstock
f_x	Component along *x* axis of force
f_y	Component along *y* axis of force
$f(x, t)$	Function at Eulerian coordinates
$f^*(x, t)$	Function at reference coordinates
$f^{**}(x, t)$	Function at Lagrangian coordinates
$\{\boldsymbol{f}(x, y, z, t)\}$	Giving force vector
$\{\boldsymbol{f}\}$	Unit external force vector, body force
$\{\boldsymbol{f}^s\}$	External force of structure
$\{\boldsymbol{f}_g\}$	Body force in global frame in FEM
$\{\boldsymbol{f}(t)\}$	Forcing function
$\{\boldsymbol{f}(\sigma_f)\}$	Surface deformation due to fluid loads
$\{\boldsymbol{G}\}$, $\boldsymbol{G}$	Gravity force vector
G	Gravity force magnitude, shear modulus
G_x, G_y, Gx, Gy	Turbulent factor of oil
G^{ij}	Components of contravariant metric tensor
$\bar{G}$	Per-unit guide vane opening
$[\boldsymbol{G}]$	Skew-symmetric gyroscopic matrix
g	Gravity acceleration, giving condition on Neumann boundary
$\{\boldsymbol{g}\}$	Given function in flow on Dirichlet boundary
$\{\boldsymbol{g}(\boldsymbol{x}_s)\}$	Change of fluid stress from surface deformation

$\{\boldsymbol{H}\}$	Moment vector
$[\boldsymbol{H}]$	Skew-symmetric circulatory matrix with rotating, damping
H	Water head, chamber height of turbine, inertia constant of shaft
H_r	Relative total enthalpy (rothalpy)
H_n	Normalization helicity
$\bar{H}_0$	Per unit total head
$\bar{H}_{12}$	Per unit head loss in the tunnel
$\bar{H}_l$	Per unit head loss in the penstock
$\bar{H}_r$	Per-unit surge tank head
$\bar{H}_t$	Per-unit turbine head
ΔH	Pressure fluctuation amplitude
h	Thickness of oil film, piezometric head, distance between two rows of vortices, gap clearance
$h(t_1, t_2)$	Impulse response of a linear system
h_n	Oil film thickness at pad pivot
$\{\boldsymbol{h}\}$	Given function in flow on Neumann boundary
I	Phase current of generator
$\{\boldsymbol{I}\}$	Unit vector
$[\boldsymbol{I}]$	Identity tensor (diagonal unit matrix)
Im	Imaginary part
i	Imaginary number
i	Electrical current
J	Second moment of area, rotational inertia of shaft syste
J_t	Time-dependent Jacobian transversal moment of inertia around axis
$J(t)$	Jacobin in time t
Jp	Torsional moment of inertia polar moment of inertia around rotation axis
$J_{\beta j}$, $J_{\gamma j}$	Pad moment of inertia around pivot in circumferential and axial direction
$J_{di\text{-}1}$, J_{di}, $J_{pi\text{-}1}$, J_{pi}	Moment of inertia per unit length
$k = n - m$	Lag time between stimulus at time m and response at time n
K	Cavitation compliance
K, K'	Factors
$K_{x\beta}$, $K_{y\alpha}$, $K_{M\alpha}$, $K_{M\beta}$	Stiffness of oil film created by thrust disc swing
K_{xy}, K_{yx}	Cross-stiffness reflecting oil film force
$[\boldsymbol{K}]$	Stiffness matrix
$[\boldsymbol{K}_g]$	Stiffness matrix in global frame in FEM
$[\boldsymbol{K}_r]$	Diagonal matrix of stiffness
$[\boldsymbol{K}_{12}]$	Stiffness matrix of air gap magnetic field
$[\boldsymbol{K}_{ss}]$	Matrix of stiffness of structure to structure (FSI)
$[\boldsymbol{K}_{sf}]$	Matrix of stiffness of structure to fluid (FSI)
$[\boldsymbol{K}_{fs}]$	Matrix of stiffness of fluid to structure (FSI)

$[\boldsymbol{K}_{ff}]$	Matrix of stiffness of fluid to structure (FSI)
k	Stiffness, thermal conductivity, fluid volumetric modulus
k, l, m, n	Integers
k_i	Generalized stiffness in FEM
k_0	Efficient of unbalanced magnetic forces
$k_{xxi}, k_{xyi}, k_{yxi}, k_{yyi},$	Damping factors of the ith pad
$k*$	Non-dimensional frequency, $k* = k*_R + \mathrm{i}\ k*_I$
$\{\bar{\mathbf{k}}\}$	Rotor vibration eccentric vector
L	Moment, length of bearing, axial length of radial magnetic loop
L_h	Hydraulic inductance
L_u	Impeller loss coefficient
L_x, L_y	Moments of oil film on xoz and yoz planes
L'	Lineic hydroacoustic inductance $L' = 1/(gA)$
L'_e	Electrical inductance of unit length
l	Length of axis (in Fig. 4.2.1), length of penstock
l_i	Direction cosine of the axes x in global frame
l_s	Sealing passage length
$\{\boldsymbol{l}\}$	Torque vector
δL	Virtual work δL
M	Mass, bending moment, mass flow gain factor
M	Mole number of molecular weight
M_2, M_4	Second and fourth-order statistics moment
M, N	Number of sample points
M_x, M_y	Pressure moment on pad around x and y axises
M_{bx}, M_{by}	Bearing bracket equivalent masses along x and y
M_A	Normalized amplitude of pump driving torque
$\{\boldsymbol{M}\}$	Moment vector
$\{\boldsymbol{M}_g\}$	Moment of inertia force
$[\boldsymbol{M}]$	Mass matrix damping, and stiffness matrices
$[\boldsymbol{M}_g]$	Geometric stiffness matrix, mass matrix in global frame in FEM
$[\boldsymbol{M}_y]$	Diagonal matrix of mass
m	Mass, unbalanced mass number of resonance order of water
m_D	Magnetic torque of generator damping winding
m_e	Electro-magnetic torque of generator
m_g	Generator load torque (whole damping torque)
m_i	Direction cosine of the axes y in global frame
N	Number of degrees of freedom
N_{12}	Potential energy in the air gap of generator
N_D	Specific speed
N_{BF}	Noise bandwidth
$NPSH$	Net positive suction head

n	Constant defining $w(\boldsymbol{x})$, frequency of surge, order number of Taylor series, rotating speed of runner, number of frequency bands within the spectrum F_i spectrum value
n_{11}	Unit speed
n_i	Direction cosine of the axes x in global frame
n_{QE}	Unit rotating speed coefficient
$\{\boldsymbol{n}\}$	Unit normal vector
QA	Band vibration level
$O\xi\eta z$	Rotating reference frame
P	Dimension, pressure pair number of generator poles
P	Force acting on the bluff body, turbine output force acting on blade from Karman vortex
P_{11}	Unit power
$P_{r,}\ P_{\varphi}$	Nonlinear active force of bearing pad
$P_N(z,t)$	Pressure excitation
$\bar{P}_{\text{mechanical}}$	Per unit turbine mechanical power
$\bar{P}_{\text{load}}$	Per unit non-frequency-sensitive load
$\tilde{P}_{\text{Erms}}$	Dimensionless pulsation amplitude
Δp	Flow pressure drop
Q	Shearing, flow rate of turbine
Q_{11}	Unit flow rate
Q_{nD}	Unit flow rate coefficient
$\{\boldsymbol{Q}_i\}$	ith generalized force
$\{\boldsymbol{Q}(t)\}$	Generalized forces
q	Amplitude of excitation, modal participation factor
q_i	Generalized displacement in FEM
$q(s_i)$	Cavity region
$\{\boldsymbol{q}\}$	Transformed displacement vector, vectors of coordinates $\{\boldsymbol{q}\} = \{z, \boldsymbol{\phi}\}^{\mathrm{T}}$ real coordinates, solution of rotor dynamic equation, for example $\{\boldsymbol{q}\} = \{\boldsymbol{r}_1\}e^{i} + \{\boldsymbol{r}_2\}$ $e^{i(2\Omega-\omega)t}$
$\{\boldsymbol{q}_i\}$	Displacement vector in FEM
$\{\boldsymbol{q}_g\}$	Displacement vector in global frame in FEM
$\{\boldsymbol{q}_i(x, y, z)\}$,	Assumed modes
q_i	Eigenvectors component
R	Restoring force magnitude, parameter in disc rotor $2R^2 = J_p/m$, inner radian of the pad, vortex rope radius, viscoelastic resistance
R_a	Resistance of generator armature
R_1	Inner radius of the stator
R_0	Outlet radius of generator rotor
$\mathbb{R}^3$	3 dimensional space
$\{\boldsymbol{R}\}$	Restoring force vector, vector from grid origin to mass particle, concentrated force vector

$[\boldsymbol{R}]$	Rotating matrix (FEM)
$[\mathbf{R}']$	Assembled rotating matrix (FEM)
$[\boldsymbol{R}pq(\mathrm{i}\omega)]$	Vector of transfer functions
Re	Real part
Re	Reynolds number (Fluid Mechanics)
Re_x	Reynolds number based on blade length
R_h	Hydraulic resistance
$R_h = Uh\rho/\mu$	Reynolds number in oil film
$R*$	Measure of draft tube core size
R'	Lineic hydroacoustic resistance $R' = \lambda/(2gDA^2)$
R'_e	Electrical resistance of unit length of conductor
r	Radius, coefficient
r_p	Radial coordinate of pivot in inertial coordinates
$\boldsymbol{r}_1$	Mean inflected shape
$\boldsymbol{r}_2$	Component of deflected shape
$\{\boldsymbol{r}\}$	Vector from grid origin to mass particle, radial vector, position vector, sum vector of internal and external forces/fluxes, set of complex coordinates $\{\boldsymbol{r}\} = \{\boldsymbol{q}\}\mathrm{e}^{\mathrm{i}\Omega t}$
S	Finite dimensional subspace, boundary surface, runner exit area
Sh	Strouhal number
S_n	Constant
S_ϕ	Source term of ϕ
S_{ij}	Mean strain rate tensor
$\bar{S}_{ij}$	Rate-of-strain tensor for resolved scale
$\{\boldsymbol{S}_0\}$	First station vector
$\{\boldsymbol{S}_n\}$	Last station vector
$\{\boldsymbol{S}_{\mathrm{R}i}\}$, $\{\boldsymbol{S}_{\mathrm{L}i}\}$	State vectors at left and right ends of field
$[\boldsymbol{S}]$	2nd Piola–Kirchoff stress tensor
s	Circumferential wavelength, time of stimulus
T	Period, modal responses, torque on a section, torque of the fluid acting on the component, rotating period
T_0	Period
T(t)	Torsional torque around the disc center
$\hat{\boldsymbol{T}}_{ij}$	First order of Piola-Kirchhoff stress tensor
$[\boldsymbol{T}]$, $[\boldsymbol{T}_{ft}]$	Transfer matrix
$[\boldsymbol{T}_G]$	Overall transfer matrix
$\{\boldsymbol{T}\}$	External surface forces
T_g	Main servomotor time constant
T_{Wp}	Water starting time of penstock
$\tilde{T}$	Kinetic energy
t	Time, time of response
t_f	The end of time step of CFD
t_s	The end of time step of CSD

t_r	Rise time
Δt	Time Increment
U	Numerical solution voltage, linear velocity, circumferential velocity
U_2	Runner exit peripheral speed
U_a	Steady uniform velocity
$\tilde{U}$	Potential energy
$\bar{U}_c$	Per unit velocity or flow rate in tunnel
$\bar{U}_{NL}$	Per unit no-load flow
$\bar{U}_t$	Per-unit water velocity in turbine or turbine flow
u	Per unit control effort deflection of structure, true solution
u_s, v_s	Steady disturbance
$\tilde{u}$, $\tilde{v}$	Unsteady disturbance
U_j	Curvilinear coordinate
$\boldsymbol{u}$	
$\{\boldsymbol{u}\}$	Deflection of structure real coordinates $\{\boldsymbol{u}\}=\{\mathrm{Re}\{\boldsymbol{q}\}^{\mathrm{T}}, \mathrm{Im}\{\boldsymbol{q}\}^{\mathrm{T}}\}^{\mathrm{T}}$
$\{\boldsymbol{u}\}(x, y, z, t)\}$	Displacement field
$\{\boldsymbol{u}(t)\}$	Inputs vector affecting behavior of system
$\{\boldsymbol{u}_1\}$	General coordinate vector of generator
$\{\boldsymbol{u}_r\}$	"Whirl" velocity
$\{\boldsymbol{u}^*\}$	Generalized coordinates, $\{X, \varphi_{X'}, Y, \varphi_y\}^{\mathrm{T}}$
$\bar{u}$	Vibration mode shape
u_D	Giving condition on Dirichlet boundary
V	Shearing force, solution domain, velocity of main stream outside of wake, absolute velocity
V_0	Influent velocity at runner brim gap
V_{c}	Cavity volume
V_r	Voltage at generator output ends
V_{vap}	Elastic volume
V_u	Absolute velocity circumferential component
∂V	Boundary of control volume V
$\{\boldsymbol{V}_0\}$, $\{\boldsymbol{V}_{\mathrm{N+1}}\}$	Vectors of dimension p
v	Relative velocity of vortex row to stream speed, velocity magnitude
v_θ	Absolute tangential velocity
$-\rho\overline{v_i'v_j'}$	Reynolds stresses
$\{\boldsymbol{v}\}$	Velocity vector, absolute velocity
$\{\boldsymbol{v}_r\}$	Relative velocity
$\{\boldsymbol{v}_\sigma\}$	Grid velocity of moving mesh, velocity of reference system
$\hat{v}$	Velocity of reference coordinates relative to space coordinates
$\{\boldsymbol{V}(\boldsymbol{X})\}$	Boundary conditions vector

W	Numerical basis function in FEM, mean velocity, relative velocity in runner complex potential
W_z	Pressure force on pad along z direction
W_∞^*	Free-stream axial velocity in draft tube
W^*_c	Centre line axial velocity in draft tube
ΔW^*	Velocity difference $\Delta W^* = W_c^* - W_\infty^*$
$W_x(t, f)$	Wigner distribution of $x(t)$
W_x	Window function
$[\boldsymbol{W}_k]$	$p \times p$ matrix
w_m	Meridian component of relative velocity
$w_i(x)$	Basis functions
Δw	Sample interval
X	Displacement material coordinates (Lagrangian description coordinates)
$\{\boldsymbol{X}\}$	Displacement amplitude vector, eigenvectors exact solution in FEM state vector
x	Ordinate, displacement, blade length space coordinates (Eulerian coordinates)
x_p	Excitation point
x_q	Generator shaft reactance
$x_d^{\prime}$	Generator shaft reactance at transient process
$x(t)$	System input function
$x_{i,}\ y_i$	Journal displacements
$x_{f,}\ y_f$	Bearing bracket displacements
$x(t)$	History signal
$x^*(t)$	Complex conjugate of $x(t)$
dx	Length
$\Delta x,\ \Delta y$	Small disturbances
δx	Virtual displacement
$\{\boldsymbol{x}\}$	Displacement vector, generalized coordinates
$\{\boldsymbol{x}^c\}$	Response displacement vector
$\{\boldsymbol{x}_s\}$	Surface position of structure wetted by fluid (FSI)
$\dot{x}$	Velocity
$\{\dot{\boldsymbol{x}}\}$	Velocity vector
$\ddot{x}$	Acceleration
$\{\ddot{\boldsymbol{x}}\}$	Acceleration vector
X_q	Reactance of generator armature
Y	Amplitude along y direction discretized solution, vibration amplitude
$\{\boldsymbol{Y}(t)\}$	Modal ordinates
y	Homogeneous solution, eccentricity, ordinate
$y_{\min}$	The shortest distance to wall from station
$y(t)$	System output function
$\{\boldsymbol{y}(t)\}$	Output vector

Z	Partition function, blade number
$Z_{1,}$ Z_2	Complex constants
Z_g	Guide vane number
z	Axis ordinate
$z = x + \mathrm{i}y$	Complex number
z_0	Value of amplitude of z
$\mathbf{z}$	Complex coordinate $\mathbf{z} = x + \mathrm{i}y$
$\bar{\mathbf{z}}$	Complex conjugate $\bar{\mathbf{z}} = x - \mathrm{i}y$
$\{z\}$	State vector

2. Greek Letters

∇	Gradient
Λ_0	Mean magnetic conductance
α	Phase angle, angle deformation, pressure coefficient, angle between velocity vector and radius *R,* vortex type factor, normalized cavity volume
$\alpha*$	Stiffness ratio $\alpha* = k_\eta / k_\xi$
α, β	Torsional angle displacement a of thrust disc on *xoz* and *yoz* planes, scalar values of a system
α, q	AI/CI characters
β	Phase, characteristic factor, relative flow angle, dimensionless parameter, factor to consider deleting high order terms
β_0	Runner exit vane angle
β_j	Tilting angle of pad in radial direction
β_n	Non-rotating damping factor with nonlinear
β_r	Rotating damping factor with nonlinear effect
$\Delta\beta$	Attack angle
χ	Angle between symmetrical and rotating axises, reference coordinates, mass flow gain factor
$\{\boldsymbol{\chi}\}$	Deforming reference system
Δ	Laplace operator, Δ-criterion, the largest dimension of the grid cell, mesh scale, difference of momentum
δ	Dirac delta function, operation angle expressed as difference between torsion angle of shaft and its initial value, mean radius gap, added mass effect ratio
δ_0	Mean gap
δ_2	Blade thickness
δ_{Fe}	Equivalent gap coefficient of ferromagnet
δ_v	Virtual boundary layer thickness
ε	Turbulent dissipation rate, eccentricity, over time of end time of CSD (FSI), pipe perimeter deflection $\varepsilon = \mathrm{d}D/D$
$\varepsilon_{0,}$ φ_0	Equilibrium position ordinates of journal

$\hat{\varepsilon} = \varepsilon/\delta$	Relative eccentricity
$\{\varepsilon\}$	Strain
$\{\varepsilon^*\}$	Consistent strains
$\boldsymbol{\varepsilon}(\boldsymbol{v})]$	Strain-rate tensor
ϕ	complex angular coordinate $\phi = \varphi y - i\varphi_{X'}$ flow potential, flow coefficient of pump generator inner power coefficient general scalar
$[\phi]$	Matrix of equation character vectors
Φ	Amplitude of angular vibration phase of state unbalance vector response
$[\Phi]$	"$N \times L$" Solution matrix containing L spatial vectors without time
φ	Phase angle, angular position circumferential ordinate angular coordinate of any point on pad
$\varphi_{T1}, \varphi_{T2}, \cdots,$	Pad swing angle
$\{\boldsymbol{\varphi}(\{\boldsymbol{\chi}\}, \boldsymbol{t})\}$	Deformation with unique mapping
Γ	Modal participation factor, closed bounder velocity circulation, diffusion coefficient
Γ_D	Dirichlet boundary
Γ_N	Neumann boundary
Γ_t	Time dependent boundary
γ	Surface tension coefficient effect coefficient considering the shear stress
γ_i	Tilting angle of pad in circumferential direction
$\gamma_1(s_1), \gamma_2(s_2)$	Vortex distributions on blades
$\gamma_1(\xi)$	Free vortex distribution downstream of blades
η	Mass-proportional damping coefficient
η_h	Hydraulic efficiency
η_s	Dynamic viscosity
$(\eta_1, \cdots, \eta_N)$	Shape functions of elements
$[\Lambda]$	Character values diagonal matrix
λ	Coefficient, friction loss coefficient fluid circumferential average velocity ratio, wavelength
λ_m	Lam'e constant
μ	Dynamic viscosity coefficient of nonlinear term of stiffness coefficient of vortex rope
μ_0	Magnetic conductivity in the air space
μ_m	Lam'e constant
$\mu_{i\text{-}1}, \mu_i$	Mass per unit length
μ_t	Turbulent viscosity subgrid-scale turbulent viscosity
v	Kinematic viscosity
σ	Tomas coefficient, small unsteady change of pressure eigenvalues of velocity gradient tensor
σ_{kj}	Cauchy stress tensor at Eulerian system
$\{\boldsymbol{\sigma}\}$	Internal stresses

$\{\boldsymbol{\sigma}_f\}$	Stresses exerted by fluid on structure
$[\boldsymbol{\sigma}^S]$	Cauchy stress tensor of structure
θ	Torsional angle, inner power angle of generator, angular coordinate, small angle between source and observe
θ_p	Angular coordinate of pivot in inertial coordinate
θ_{yj}, θ_{xj}	Components of tilting angle of thrust block
θy, θ_x	Projected on pivot coordinate
ρ	Density
ρ^s	Material density of structure
ζ	Complex coordinates defined in $\xi\eta$-plane, local loss coefficient, damping factor or damping ratio
ζ_n, ζ_r	Damping ratios with the linearized system frame
τ	Torque, lag time between stimulus at time s and response at time t, $\tau=t-s$
$[\boldsymbol{\tau}]$, $[\boldsymbol{\tau}_r]$	Viscous stress tensor
τ_{ij}	Reynolds stress tensor
$\Omega\{\boldsymbol{\Omega}\}$	Angular velocity, angular velocity of rotor rotor,
Ω	Unit angular speed $\Omega=\pi D_1 n/(60(2gh)^{1/2})$
$\Omega_{cr\mathrm{I}}$	First order critical velocity
$\Omega_{cr\mathrm{II}}$	Second order critical velocity
Ω_t	Spatial domain
$\bar{\Omega}_r$	Per unit runner speed
Ω^*	Relative spin speed $\Omega^* = \Omega/\Omega_{cr\mathrm{I}}$
$\bar{\Omega}_r$	Angular momentum
Ω_c^*	Angular velocity at the axis in draft tube
$[\boldsymbol{\Omega}_h^2]$	Diagonal matrix
ω	Frequency, precession angular speed (whirl speed), system vibration frequency,complex frequency, specific dissipation
ω^*	Relative whirl speed in xy-plane $\omega^* = \omega/\Omega_{cr\mathrm{I}}$
ω_R	Real part of complex frequency
ω_I	Imaginary part of complex frequency damping rate
ω_N	Gyroscopic speed of water in gap
ω_n	Natural frequency
$\{\boldsymbol{\omega}\}$	Eddy of fluid flow
$\{\boldsymbol{\omega}_n\}$	Angular speed vector of precession rotation
Ω'	Complex whirl speed in $\xi\eta$-plane
Ω'^*	Relative complex whirl speed
ξ	Friction coefficient
$[\boldsymbol{\Psi}]$	Transfer matrix
$\boldsymbol{\Psi}$	Head coefficient, pressure coefficient
ς_{T}	Coefficient represented effect of runner
ς_2	Loss coefficient of draft tube
ς	Stiffness-proportional damping coefficient

3. Superscripts

-1	Inverse
$*$	Relative value, dimensionless, scale value
k	Addend
n, $n+1$	At current and next time level
s	Structure
T	Transpose
$\wedge$	At AEL reference coordinates
$[^{-}]$	Matrix in modal ordinates
‘	Smooth discrete Fourier transform

4. Subscripts

0	Initial condition, constant one, mean value
1	Nonlinear, at inlet upstream of the runner
2	Quadratic, at outlet at downstream side of runner
A	Angule
a	Air
av	Air vessel
B	Bearing bracket
C	Cos function
Cor	Coriols effect
c	Centre
ca	Cavitation
cr	Critical
comp	Complete
D	Design point, diaphragm
d	Under damped vibration, discrete Fourier transform
e	Exit, element
$elec$	Electromagnetic
eq, equ	Equivalent
f, $fluid$	Fluid
G	Gallery
gen	Generator
s	Sample
ST	Surge tank
T	Turbine runner
i	Inlet, ith elementary pipe
$inlet$	Inlet
I	Imaginary part
L	Left
M	Material coordinates

mag	Magnetic
max	Maximum
m, n	Order number
o	Optimum case
P	Penstock
p	Pump
pipe	Pipe
R	Real part, reference coordinates, vortex rope, right
r	Risel, rated, radius component, rotating
rad	Radial direction
ref	Reference
rop	Cavitation vertex rope
S	Sin function, space coordinates
s	Static, stationary
sk	Skew-symmetric
spin	Rotating effect
static	Static
sym	Symmetric
t	Turbine
tan	Tangential direction
throat	Throat in draft tube
tot	Total
u	Non-dissolved gas
v	Vapor, valve
ve	Viscoelastic
w	Water
x	Component along x axis
y	Component along y axis
z	Component along z axis
φ	Circumferential component
ξ	Component along ξaxis
η	Component along η axis
ζ	Component along ζ axis

Appendix II
Abbreviation

3-D	Three dimensional
ANC	Adaptive noise cancellation
AI	Absolute instability
AEL	Arbitrary Eulerian-Lagrangian method
BOP	Best operation point
CFD	Computational fluid dynamics
CI	Convective instability
CRS	Critical speed
CS	Controlling system
CSD	Computational solid dynamics
CTD	Computational thermal dynamics
DAF	Dynamic amplification factor
DFT	Discrete Fourier transformation
DGCL	Discrete geometric conservation laws
DES	Detatched eddy simulations
DNS	Direct numerical simulation
DSM	Differential stress models
D.T.	Draft tube
EVM	Eddy-viscosity models
FEM	Finite element method
FFT	Fast Fourier transform
FT	Fourier transform
FSI	Fluid solid interaction
GMWS	Geometric mean of WD and spectrogram
G.V.	Guide vanes
ISO	International Organization for Standardization
IEC	The International Electrotechnical Commission
LDV	Laser Doppler vibrometers
LES	Large-eddy simulation
LGB	Lower guide bearing of turbine unit
MED	Maximum eccentric distance

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MSM	Modal synthesis method
ND	Nodal diameters
NPSH	Net positive suction head
NLEVM	Non-linear eddy-viscosity models
Pre pul	Pressure pulsation
PWD	Pseudo Wigner distribution
RANS	Reynolds averaging Navier-Stokes equations
RCP	Reactor coolant pump
RLC	Resistance, inductance and capacitance
RMS	Root mean square
RNG	Renormalization group
RSI	Rotor stator interaction
RSMM	Riccati transfer matrix method
RSTM	Reynolds-stress transport models
SA	Averaged signal
S.C.	Spiral casing
SDTF	Sole draft tube flow
SNR	Signal to noise ratio
SOC	Second-order closure models
S.V.	Stay vanes
TFR	Time frequency representation
TGB	Turbine guide bearing
TMM	Transfer matrix method
TRTMM	Transfer Riccati transfer matrix method
UGB	Upper guide bearing of turbine unit
Vib	Vibration
VMS	Vibration monitoring system
WA	Wavelet analysis
WD	Wigner distribution
WFT	Windowed Fourier transform
WTF	Whole turbine flow
WVD	Winger-Ville distribution

Index

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