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Observer-Based Fault Detection and Estimation of Rolling Element Bearing Systems

**Observer-Based Fault Detection and Estimation of
Rolling Element Bearing Systems**

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List of Notations

Abbreviations

Abbreviation	Expansion
ALE	adaptive line enhancer
ANC	adaptive noise cancellation
ANNs	artificial neural networks
ARMA	autoregressive moving average
BPM	ball pass frequency on the inner race
BPMO	ball pass frequency on the outer race
BSF	ball/roller spin frequency
DO	diagnostic observer
DOF	degree of freedom
EEMD	empirical mode decomposition
EHL	elastohydrodynamic lubrication
EMD	ensemble empirical mode decomposition
FD	fault detection
FDD	fault detection and diagnosis
FDF	fault detection filter
FDI	fault detection and isolation
FE	fault estimation
FFT	fast Fourier transform
FIR	finite impulse response
FRF	frequency response function
FTF	fundamental train frequency
IMF	intrinsic mode function
LCF	left coprime factorization
LMS	least mean squares
LTI	linear time-invariant
LS	least square
MED	minimum entropy deconvolution
PS	parity space

RMS	root mean square
SANC	self-adaptive noise cancellation
SISO	single-input single-output
SNR	signal-to-noise ratio
STFT	short-time Fourier transform
SVD	singular value decomposition
SVM	support vector machine
WT	wavelet transform
WPT	wavelet packet transform

Mathematical notations

Notation	Description
$\forall$	for all
$\in$	belong to
$\approx$	approximately equal
$\neq$	not equal
$:=$	defined as
$\implies$	imply
$\iff$	equivalent to
$\lim$	limit of a function
$\max(\min)$	maximum (minimum)
$\ \cdot\ $	Euclidean norm of a vector
$\ \cdot\ _2$	$\mathcal{L}_2$ norm of a signal
$\hat{x}$	estimate of the state vector x
X^T	transport of X
X^{-1}	inverse of X
$X > 0$	X is positive definite matrix
X^*	complex conjugate transpose of X
$X^\perp$	orthogonal complement of X
$\text{rank}(X)$	rank of X
$\det(X)$	determinant of X
$\text{col}(X)$	column-wise re-ordering of X
$\text{tr}(X)$	trace of X
$\text{Re}(X)$	real part of X
$\mathcal{R}^n$	space of n -dimensional vectors
$\mathcal{R}^{n \times m}$	space of n by m matrices

$I_{m \times m}$	m by m identity matrix
$\delta(t)$	unit impulse
$g * f$	convolution of g and f
$\otimes$	Kronecker product
$\mathcal{RH}_\infty$	the set of all stable transfer matrices