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DYNAMINSPECT
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TECHNICAL DATASHEET

ISO 7626 Mechanical Impedance Analysis Software

Version 3.0
December 2025

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1. Overview

DynamInspect is a comprehensive software solution for mechanical impedance analysis conforming to ISO 7626 standards. Developed by SADAP GmbH, it provides a complete workflow from raw measurement data validation through advanced machine learning-based quality assessment.

Analysis Framework

Each phase has four complementary analysis tools:

Tool	Purpose	When to Use
Analysis Metrics	Visual inspection of key plots	Automatic after phase completion
Statistical Analysis	Quantitative assessment with statistics	Manual, for detailed investigation
Uncertainty Analysis	Measurement confidence & ISO compliance	Manual, for quality assurance
Waterfall Analysis	Time-frequency evolution visualization	Manual, for transient/stability

Data Flow Between Phases

Phase 1 (Initial Check) → Raw: force_data, displacement_data

Phase 2 (Data Preparation) → Processed: processed_force_data, processed_displacement_data

Phase 3 (Impedance Analysis) → Results: $Z(f)$, $\gamma^2(f)$, $\varphi(f)$, modal_params

Phase 4 (Stiffness Analysis) → Results: $K(f)$, $C(f)$, $\eta(f)$

ML Analysis → Quality assessment, anomaly detection, health score

2. Phase 1: Initial Check

Purpose: Verify raw measurement data quality before any processing. Detect fundamental issues that would invalidate subsequent analysis.

Data Source: raw force signal, raw displacement signal

2.1 Analysis Metrics (6 Plots)

Plot	Content	What to Look For
Force Time Domain	F(t) waveform	Clipping, saturation, dropouts, drift
Signal Statistics	Mean, RMS, peak, crest factor	Abnormal values indicating sensor issues
Power Spectral Density	PSD of both channels	Expected frequency content, noise floor
Amplitude Distribution	Histogram of amplitudes	Gaussian-like distribution (healthy signal)
Cross-Correlation	F×D correlation	Peak at zero lag (synchronized signals)
ISO Compliance	Pass/fail indicators	Green checkmarks for all requirements

2.2 Statistical Analysis (5 Types)

Analysis Type	Metrics Computed	ISO Relevance
Signal Quality Assessment	SNR, dynamic range, noise floor, THD	ISO 7626 §5.3: Signal quality
Distribution Analysis	Skewness, kurtosis, normality tests	Validates statistical assumptions
Stationarity Test	ADF test, KPSS test, trend analysis	ISO 7626 §5.2: Stationary signals required
Coherence Preview	$\gamma^2(f)$, mean coherence, dropout %	ISO 7626 §6.4.2: $\gamma^2 \geq 0.9$
Cross-Correlation Analysis	Lag, correlation coefficient, sync error	ISO 7626 §5.4: Time alignment

2.3 Uncertainty Analysis (5 Types)

Analysis Type	Uncertainty Sources	Key Formula
Combined Initial Check	All sources weighted	$u_c = \sqrt{\Sigma w_i \cdot u_i^2}$
Time Synchronization	Channel alignment error	From cross-correlation peak width
Coherence Quality	Input-output relationship	$u(\gamma^2) = (1-\gamma^2)^2/\sqrt{2n}$
Noise Floor (SNR)	Measurement noise	$u_{noise} = \sigma_{noise}/\sqrt{n}$
Sampling Rate Jitter	ADC timing variations	$u_{fs} = \sigma_{\Delta t}/\mu_{\Delta t}$

Theory: At 1000 Hz, a 0.5 ms time offset causes 180° phase error! $\Delta\varphi = 2\pi f \cdot \Delta t$

2.4 Waterfall Analysis (5 Types)

Analysis Type	3D Visualization	ISO Relevance
Signal Stationarity Map	RMS, centroid evolution over time	ISO 7626 §5.2: Stationarity

Analysis Type	3D Visualization	ISO Relevance
Coherence Evolution	$\gamma^2(f,t)$ 3D coherence surface	ISO 7626 §6.4.2: γ^2 temporal stability
50Hz Harmonic Monitor	Harmonic contamination vs time	Mains interference detection
Swept Sine Verification	Frequency sweep tracking	Excitation coverage verification
SNR Time Evolution	Signal-to-noise ratio over time	ISO 7626 §5.3: Consistent quality

2.5 Phase 1 Summary

The Initial Check phase answers: "Is this data worth analyzing?"

Question	Analysis Tool	Metric
Are signals time-aligned?	Cross-Correlation	Lag < 0.5 ms
Is there enough signal?	SNR Analysis	SNR ≥ 20 dB
Is the data stationary?	Stationarity Test + Waterfall	ADF $p < 0.05$, RMS CV < 10%
Are channels correlated?	Coherence Preview + Waterfall	$\gamma^2 \geq 0.9$ temporally stable
Is there mains interference?	50Hz Harmonic Waterfall	Contamination < 2%

3. Phase 2: Data Preparation

Purpose: Apply signal conditioning while ensuring processing doesn't introduce artifacts or degrade measurement quality.

3.1 Analysis Metrics (6 Plots)

Plot	Content	What to Look For
Force Overlay	Original vs processed force	Preserved features, no distortion
Displacement Overlay	Original vs processed displacement	Same as above
Coherence Comparison	γ^2_orig vs γ^2_proc	Improved or maintained coherence
Spectrum Comparison	PSD before/after	No unexpected frequency changes
Processing Summary	RMS change, energy ratio	< 10% change typically
Compliance Panel	3 mandatory checks	All green

3.2 Statistical Analysis (4 Types)

Analysis Type	Metrics Computed	Acceptance Criteria
Before/After Comparison	RMS change, peak change, correlation	< 10% RMS change
Coherence Improvement	$\Delta\gamma^2$, band-by-band analysis	$\Delta\gamma^2 \geq -0.05$ (no degradation)
Spectral Quality	Spectral correlation, band energy	$r > 0.9$
Signal Integrity Check	Zero-crossings, envelope, phase	No anomalies

Acceptable: RMS change < 10%, Energy ratio 0.5-1.5

3.3 Waterfall Analysis (4 Types)

Analysis Type	3D Visualization	Purpose
Before/After Spectrogram	Side-by-side 3D spectrograms	Visual processing impact
Filter Response Verification	Transfer function evolution	Filter behavior over time
Energy Preservation Map	Energy ratio vs frequency & time	Identify signal loss regions
Coherence Change Visualization	$\Delta\gamma^2(f,t)$ surface	Processing effect on coherence

3.4 Phase 2 Decision Matrix

The Data Preparation phase answers: "Did processing help or hurt?"

Coherence Change	Energy Change	Waterfall Shows	Action
Improved	Preserved	Stable green	✓ Accept processing
Maintained	Preserved	Stable green	✓ Accept processing
Degraded slightly	Preserved	Minor blue regions	■ Review filter settings
Degraded	Lost	Large blue regions	✗ Reject, adjust parameters

4. Phase 3: Impedance Analysis

Purpose: Calculate mechanical impedance Z(f) with proper uncertainty quantification per ISO 7626.

4.1 Mechanical Impedance Theory

$Z(f) = F(f) / v(f) = F(f) / (j\omega \cdot X(f))$

Where: F = force, v = velocity, X = displacement, $\omega = 2\pi f$

4.2 Analysis Metrics (6 Plots)

Tab	Plots	What to Look For
Impedance	$\lvert Z(f)\rvert$, $\varphi(f)$, coherence	Resonance peaks, phase transitions
FRF Detail	Bode plot with uncertainty bands	Confidence in measurements
Nyquist	Re(Z) vs Im(Z)	Circles at resonances (SDOF behavior)
Modal	fn, ζ, Q for each mode	Properly identified modes
Compliance	ISO 7626 checklist	All requirements met

4.3 ISO 7626 §7 - Key Uncertainty Formula

$$u(|Z|)/|Z| = \sqrt{(1 - \gamma^2) / (2 \cdot n \cdot \gamma^2)}$$

Where: γ^2 = coherence, n = number of averages

γ^2	n	$u(\lvert Z\rvert)/\lvert Z\rvert$
0.95	50	2.3%
0.90	50	3.3%
0.80	50	5.0%

4.4 Statistical Analysis (5 Types)

Analysis Type	Metrics Computed	ISO Reference
Coherence Statistics	Mean, min, std, dropout %, by band	ISO 7626 §6.4.2
Modal Parameter Statistics	fn, ζ, Q distributions, confidence	ISO 7626 §7
Phase Linearity Analysis	Phase unwrapping quality, group delay	Non-minimum phase identification
THD Analysis	Total Harmonic Distortion	Nonlinearity indicator
Resonance Confidence	Peak detection reliability	Mode identification quality

4.5 Waterfall Analysis (5 Types)

Analysis Type	3D Visualization	ISO Relevance
Transfer Function Evolution	$\lvert H(f,t)\rvert$ 3D surface	FRF temporal stability
Modal Frequency Tracking	Mode tracks over time	Resonance stability
Phase Stability Map	$\varphi(f,t)$ surface	Phase consistency

Analysis Type	3D Visualization	ISO Relevance
Coherence Quality Map	$\gamma^2(f,t)$ surface	ISO 7626 §6.4.2 compliance
Cross-Spectrum Evolution	$\lvert G_{xy}(f,t)\rvert$ surface	Input-output relationship

Modal Frequency Tracking: Drift % = (max(fn) - min(fn)) / mean(fn) × 100. Requirement: Drift < 1% for stable modes.

5. Phase 4: Stiffness Analysis

Purpose: Extract mechanical properties (K, C, η) from impedance with proper quality assessment.

5.1 Stiffness Extraction Theory

$Z(f) = K + j\omega C = K(1 + j\eta)$

$K = \mathrm{Re}(Z)$ [Dynamic stiffness, N/m]

$C = \mathrm{Im}(Z)/\omega$ [Damping coefficient, N·s/m]

$\eta = \mathrm{Im}(Z)/\mathrm{Re}(Z)$ [Loss factor, dimensionless]

5.2 Analysis Metrics (6 Plots)

Plot	Content	What to Look For
K(f)	Dynamic stiffness vs frequency	Stable regions, resonance effects
C(f)	Damping coefficient vs frequency	Positive values, reasonable range
η(f)	Loss factor vs frequency	0.1-0.5 typical for foil bearings
Phase Validity	Phase angle with validity markers	Stiffness-dominated regions
Distribution	Histograms of K, C, η	Identify outliers
Quality Summary	CV, valid %, extraction quality	Overall assessment

5.3 Foil Bearing Quality Assessment

Parameter	Healthy Range	Warning	Critical	Waterfall Check
K	10^5 - 10^8 N/m	Outside 2×	Outside 10×	Stable K(f,t) surface
η	0.1 - 0.5	< 0.05 or > 0.8	< 0.02 (blocking)	No η valleys
CV(K)	< 30%	30-50%	> 50%	Uniform CV map
Valid %	> 70%	50-70%	< 50%	Green regions dominate

Blocking Detection: η < 0.02 → WARNING: Possible bump foil blocking. This is a critical quality indicator for foil bearing manufacturing.

5.4 Waterfall Analysis (4 Types)

Analysis Type	3D Visualization	Purpose
Dynamic Stiffness Map	K(f,t) 3D surface	Stiffness stability
Loss Factor Evolution	η(f,t) 3D surface	Damping consistency
Extraction Quality Map	Valid points (f,t)	Identify reliable regions
Frequency Band Comparison	Band-averaged K over time	Compare frequency regions

6. Cross-Phase Relationships

6.1 Uncertainty Propagation Through Phases

Phase 1 Uncertainty → (affects coherence estimate)

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Phase 2 Uncertainty → (affects spectral quality)

↓

Phase 3 Uncertainty ← ISO 7626 §7 formula

↓

Phase 4 Uncertainty

6.2 Waterfall Analysis Connections

Phase 1: Stationarity Waterfall → Validates spectral assumptions

↓ (stable signals required)

Phase 2: Before/After Waterfall → Verifies processing preserves stability

↓ (preserved time-frequency structure)

Phase 3: Coherence Waterfall → Confirms ISO compliance temporally

↓ (stable coherence enables)

Phase 4: Stiffness Waterfall → Final property stability verification

6.3 Cumulative Quality Assessment

If Phase 1...	Then Phase 3...	And Phase 4...	Waterfall Indicator
Low coherence	High u(Z)	High u(K)	Red regions in all γ^2 maps
Time offset	Phase error	Wrong K/C split	Phase map artifacts
Poor SNR	Noisy impedance	Scattered stiffness	Noisy 3D surfaces
Non-stationary	Invalid spectral	Invalid extraction	Trending waterfall surfaces
50Hz contamination	Corrupted harmonics	Periodic K errors	Harmonic monitor spikes

7. ISO 7626 Compliance Chain

Complete ISO 7626 compliance requires verification at each phase:

Phase 1: Initial Check

- Verify γ^2 preview ≥ 0.9
- Stationarity waterfall stable
- SNR ≥ 20 dB

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Phase 2: Data Preparation

- Verify processing maintains γ^2
- Before/After waterfall matches
- Energy preservation 0.5-1.5

↓

Phase 3: Impedance Analysis

- Verify $\gamma^2 \geq 0.9$
- $n \geq 50$ averages
- $u(Z) < 10\%$ per ISO 7626 §7
- Coherence waterfall uniform

↓

Phase 4: Stiffness Analysis

- Verify extraction quality > 50%
- Stiffness waterfall stable
- CV < 30%

↓

COMPLIANT: Full ISO 7626 measurement with temporal verification

7.1 Key Formulas Reference

Formula	Phase	Purpose
$SNR = 10 \cdot \log_{10}(Ps/Pn)$	1	Signal quality
$\gamma^2 = \|Sfd\|^2/(Sff \cdot Sdd)$	1,2,3	Coherence
$u(\gamma^2) = (1-\gamma^2)^2/\sqrt{(2n)}$	1	Coherence uncertainty
$u(\|Z\|)/\|Z\| = \sqrt{((1-\gamma^2)/(2n\gamma^2))}$	3	ISO 7626 §7
$K = Re(Z), C = Im(Z)/\omega$	4	Stiffness extraction
$\eta = Im(Z)/Re(Z)$	4	Loss factor
$CV = \sigma/\mu \times 100\%$	4	Variability

8. ML-Based Quality Assessment

Purpose: Provide automated machine learning-based quality assessment for ISO 7626 measurements. The ML module analyzes impedance and stiffness results to detect anomalies, assess sample health, and provide actionable recommendations.

The ML Analysis tab activates automatically after Stiffness Analysis (Phase 4) completes, using extracted K(f), C(f), η(f), and γ²(f) data.

8.1 Analyzer Modes

Mode	Application	Key Features
Foil Bearing Analysis	Gas foil bearings, air bearings	Blocking detection ($\eta < 0.02$), stiffness stability
General Viscoelastic	Rubber, polymers, composites	Frequency dependence, outlier detection
Auto-Detect	Automatic selection	Analyzes loss factor distribution to choose mode

8.2 System Characterization

The ML Config Suggester automatically characterizes the system based on phase analysis:

System Type	Phase Criteria	ML Implications
Stiffness Dominated	$\lvert\varphi\rvert < 45°$ for >60% of points	Focus on K stability, use stiffness features
Mass Dominated	$\lvert\varphi\rvert > 135°$ for >40% of points	Include extraction validity checks
Damping Dominated	$45° < \lvert\varphi\rvert < 135°$ for >50%	Prioritize loss factor analysis
Multi-Resonant	≥3 phase sign changes	Focus on modal features, peak prominence
Mixed	Variable behavior	Use comprehensive feature set

8.3 Anomaly Detection Methods

8.3.1 Foil Bearing-Specific Detections

Anomaly Type	Detection Method	Threshold	Severity
Bump Foil Blocking	Loss factor analysis	$\eta < 0.02$	CRITICAL if >20% affected
Stiffness Instability	CV% + Isolation Forest	CV > 30%	HIGH if CV > 50%
Coherence Drop	Temporal γ^2 analysis	$\gamma^2 < 0.90$	HIGH if >15% dropout
Harmonic Contamination	PSD at 50Hz harmonics	>5% power	MEDIUM

8.3.2 General Material Detections

Anomaly Type	Detection Method	Key Metric
Frequency Dependence	Power law fit: $K \propto f^\alpha$	$\lvert\alpha\rvert > 0.5$ or $R^2 < 0.5$
Outlier Clusters	Isolation Forest on K(f)	>15% outliers
Damping Anomaly	Loss factor range check	$\eta < 0.01$ or $\eta > 2.0$
Phase Discontinuity	Phase unwrapping analysis	Sudden jumps > 90°

8.4 ML Algorithms

Algorithm	Purpose	Default Parameters
Isolation Forest	Unsupervised outlier detection	n_estimators=50-200, contamination=0.05-0.1
One-Class SVM	Novelty detection	kernel=rbf, ν=contamination
PCA	Feature dimensionality reduction	n_components=min(n_features-1, 5)
Statistical IQR	Fallback outlier detection	1.5×IQR rule

8.5 Health Scoring System

The overall health score (0-100) is calculated based on detected anomalies:

Score = max(0, 100 - Σ(severity_weight × confidence))

Severity	Weight	Health Status Thresholds
None	0	Score ≥ 85 → HEALTHY (green)
Low	5	Score ≥ 60 → MINOR ISSUES (yellow)
Medium	15	Score ≥ 30 → REVIEW REQUIRED (orange)
High	25	Score < 30 → CRITICAL (red)
Critical	40	—

8.6 Reference Ranges (Foil Bearings)

Parameter	Healthy Range	Warning	Critical
Loss Factor η	0.05 - 0.50	< 0.05 or > 0.80	< 0.02 (blocking)
Stiffness CV%	< 30%	30% - 50%	> 50%
Coherence γ^2	> 0.90	0.80 - 0.90	< 0.80
Valid Extraction %	> 70%	50% - 70%	< 50%

8.7 Data Requirements

Metric	Minimum	Recommended	Optimal
Frequency Points	50	200	500+
Time Domain Samples	10,000	50,000+	300,000+
Number of Averages	10	50	100+
Coherence (mean)	0.80	0.90	0.95+

8.8 ML Auto-Configuration

The MLConfigSuggester analyzes impedance/stiffness results and automatically configures:

- Analyzer Mode: Foil Bearing vs General based on loss factor distribution (η range 0.05-0.6 → Foil Bearing)
- Sensitivity Level: 1-10 scale based on system type and data quality
- Frequency Range: Optimal range where coherence ≥ threshold
- Expected Anomaly Rate: Estimated from coherence dropout percentage
- Feature Selection: System-type specific features
- Isolation Forest Estimators: 50-200 based on sample count
- 50Hz Exclusion: Automatically excludes mains harmonics (50, 100, 150, 200, 250, 300 Hz)

8.9 Workflow Integration

Phase 3 (Impedance) Complete → Store $\gamma^2(f)$, $Z(f)$ for ML

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Phase 4 (Stiffness) Complete → Store $K(f)$, $\eta(f)$, $C(f)$ → Activate ML Tab

↓

ML Tab Activation → Auto-configure parameters based on system characterization

↓

Run ML Analysis → Detect anomalies, calculate health score

↓

Display Results → Dashboard with gauge, anomaly list, recommendations

↓

Export

8.10 Key ML Formulas

Formula	Description	Application
$\eta < 0.02$	Blocking detection threshold	Foil bearing critical check
$CV\% = \sigma/\mu \times 100$	Coefficient of variation	Stiffness stability
Isolation Score < -0.5	Outlier classification	Anomaly detection
$K \propto f^\alpha$, $\lvert\alpha\rvert > 0.5$	Unusual frequency dependence	Material behavior
Score = 100 - $\Sigma(w \times c)$	Health score calculation	Overall assessment
γ^2 dropout % = count($\gamma^2 < 0.9$)/n	Coherence quality	Measurement reliability

⚠ Critical Note for Foil Bearings: Blocking detection ($\eta < 0.02$) is a manufacturing-critical indicator. Low loss factor sustained across frequency bands suggests bump foil contact issues requiring immediate attention to preload adjustment, assembly tolerances, or surface conditions. The ML module will flag this with CRITICAL severity and recommend manufacturing review.

9. Summary Tables

9.1 All Analyses by Phase

Phase	Metrics (6)	Statistical (4-5)	Uncertainty (5)	Waterfall (4-5)
1. Initial	Force TD, Stats, PSD, Distribution, Cross-corr, Compliance	Signal Quality, Distribution, Stationarity, Coherence, Cross-corr	Combined, Time Sync, Coherence, SNR, Jitter	Stationarity, Coherence, 50Hz, SNR
2. Data Prep	F overlay, D overlay, Coherence, Spectrum, Summary, Compliance	Before/After, Coherence Improvement, Spectral, Signal Integrity	Combined, Processing, Coherence, Energy, Spectral	Before/After, Energy, Coherence Δ
3. Impedance	|Z|, φ, γ^2, Nyquist, Modal, Compliance	Coherence Stats, Modal Stats, Phase Linearity, THD, Resonance	Combined (ISO §7), Coherence, Phase, Modal, Band	Transfer Fn, Modal Track, Phase, Coherence
4. Stiffness	K(f), C(f), η(f), Phase, Distribution, Quality	Extraction Quality, Stiffness Dist, Damping, Freq Dependence	Combined, Stiffness, Damping, Loss Factor, Freq Model	Stiffness Map, Loss Factor, Extraction Quality

9.2 Waterfall Analysis Quick Reference

Phase	Primary Waterfall	Key Metric	Pass Criteria
1. Initial	Stationarity Map	RMS CV%	< 10%
1. Initial	Coherence Evolution	γ^2 min	> 0.9 temporal
2. Data Prep	Before/After	Energy ratio	0.5 - 1.5
2. Data Prep	Coherence Change	$\Delta\gamma^2$	≥ -0.05
3. Impedance	Transfer Function	CV%	< 20%
3. Impedance	Coherence Quality	Compliant %	> 90%
4. Stiffness	Stiffness Map	CV%	< 30%
4. Stiffness	Loss Factor	η range	0.05 - 0.5, no blocking

9.3 ML Analysis Quick Reference

Data Source	ML Analysis	Key Detections	Pass Criteria
Phase 3: Z(f), γ^2(f)	Coherence stability	Drops, harmonics	$\gamma^2 > 0.9$ stable
Phase 4: K(f), η(f)	Property analysis	Blocking, instability	η > 0.05, CV < 30%
Combined results	Health scoring	All anomalies	Score ≥ 85

Document prepared for SADAP GmbH foil bearing characterization per ISO 7626:2011
Version 3.0 - Complete Technical Datasheet with ML-Based Quality Assessment