DUViMOS: Development of a MATLAB-Based Real-Time Vibration Monitoring and Active Control Graphical User Interface for Screw Compressors with Predictive Maintenance Capabilities

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Abstract

Effective vibration management in industrial screw compressors requires more than periodic measurement and operator judgement. A dependable monitoring system must convert component-level vibration values into warning limits, protective decisions, and maintenance priorities. This study presents DUViMOS (Daniel Umanah Vibration Monitoring System), a MATLAB-based graphical user interface developed for vibration monitoring, threshold classification, active-vibration-control trigger logic, shutdown decision support, and predictive-maintenance trending in an oil-injected rotary screw compressor. The system covers ten monitored locations across the compressor-motor assembly: rotor, casing, four bearing positions, two gear positions, and two damper positions. Thresholds were organized using a three-level rule: normal operation below 70% of the component design limit, warning and AVC-trigger action from 70% to below 90%, and protective shutdown action at or above 90%. In this paper, real-time capability refers to the GUI response immediately after a monitoring value is entered; autonomous real-time sensing and actuator execution require plant-side hardware integration. The software and control-logic layer was validated using seven GUI monitoring passes and five command-line test sessions. The validation runs confirmed consistent classification of normal, warning, and shutdown states, preservation of historical trends, and correct shutdown response when the motor-foot damper channel exceeded its limit. Five-month field vibration measurements from the Ingersoll Rand R110i compressor, obtained with an SKF Microlog Analyser, were used to contextualize the operating ranges and to identify motor-foot support asymmetry as a critical monitoring concern. The framework provides a threshold-based software basis for component-level compressor vibration monitoring and later integration with sensor and actuator hardware.

Keywords: DUViMOS; MATLAB GUI; vibration monitoring; active vibration control; screw compressor; predictive maintenance; software-in-the-loop validation; threshold-based control; Ingersoll Rand R110i; IntelliSys.

Nomenclature

Symbol	Meaning	Unit
v_i	Measured vibration velocity for monitored location i	in/s

L_i	Component design limit or failure-limit reference	in/s
W_i	Warning threshold for monitored location i	in/s
S_i	Protective shutdown threshold for monitored location i	in/s
M_i	Remaining vibration margin relative to the design limit	%
AVC	Active Vibration Control	-

1. Introduction

Industrial rotary screw compressors are essential assets in manufacturing, oil and gas processing, refrigeration, pneumatic services, and HVAC plants. Because these machines often operate continuously, unnoticed deterioration in a bearing, gear, rotor support, damper, or mounting condition can lead to efficiency loss, abnormal noise, rising vibration, and avoidable downtime. Screw-compressor performance and reliability depend on the interaction among rotor geometry, casing stiffness, bearing condition, lubrication, support alignment, and machine installation [1,2]. Vibration monitoring is therefore a central diagnostic method because changes in vibration velocity, spectra, and trends provide early evidence of imbalance, looseness, misalignment, bearing defects, and gear-related faults [3-5].

In practical compressor maintenance, the main challenge is converting vibration measurements into timely component-level action. Many plants still depend on periodic portable measurements, spreadsheet records, and operator interpretation. That practice can reveal a problem after inspection, but it does not always give operators a clear threshold-based response while the machine is being monitored. Condition-based and predictive-maintenance studies show that maintenance decisions are stronger when raw measurements are joined with trend evidence, alarm rules, and consistent decision logic [6-8].

The Ingersoll Rand R110i compressor considered in this work is equipped with the IntelliSys control interface. The interface supports general operational monitoring, alarm history, and machine status visualization. It does not, in the investigated configuration, provide an auditable component-level vibration channel list, threshold logic for the selected vibration points, or a software trigger prepared for component-specific active vibration control. General vibration standards and condition-monitoring procedures provide an accepted basis for measurement discipline, but plant-specific software is still needed when the aim is channel-by-channel interpretation for a particular compressor installation [9,10].

DUViMOS was developed to provide this channel-level monitoring and decision layer. It is a MATLAB-based graphical user interface that accepts vibration velocity readings for ten compressor-motor locations, classifies each reading against defined thresholds, updates comparative and trend plots, issues a component-specific AVC trigger message, and places the system in a shutdown state when the protective limit is exceeded. MATLAB was selected because it provides an integrated environment for engineering prototyping, interface design, matrix-based data handling, and later integration with measured data streams [11]. The AVC function in this work is a software-level trigger and decision output; physical active vibration control requires actuator hardware, driver electronics, safety relays, and plant commissioning [12,13].

The contribution of this paper is threefold. First, it presents a component-level monitoring architecture for an industrial screw compressor rather than a single global machine alarm. Second, it links field vibration experience, finite-element-informed component limits, and threshold-based decision rules in one software workflow. Third, it validates the same logic through both a GUI and a command-line programme, giving an auditable basis for operator training and future software-in-the-loop or hardware-in-the-loop testing. This contribution is consistent with the broader movement from passive vibration reduction toward hybrid monitoring and cyber-physical maintenance support [14-16].

2. Background and Related Work

2.1. Vibration monitoring in rotating machinery

Vibration-based condition monitoring has long been used to evaluate rotating machinery condition because imbalance, misalignment, looseness, bearing defects, gear-mesh irregularities, and support flexibility usually introduce measurable changes in vibration response. Modern practice evaluates vibration in the time domain, the frequency domain, and, where operating conditions vary, in time-frequency representations. For fixed-speed compressor applications, RMS velocity trending and spectral inspection remain valuable because they are straightforward to interpret and can be compared with machine-class guidelines and plant-specific alarm limits [3-5,17].

The older ISO 2372 severity classification is treated here only as historical background because that standard has been withdrawn and superseded through the ISO 10816 and ISO 20816 series [18]. ISO 20816-1:2016 provides general guidance for measuring and evaluating vibration on rotating and non-rotating parts of complete machines, while ISO 20816-3:2022 addresses industrial machinery above 15 kW and operating from 120 r/min to 30 000 r/min [9,10]. DUViMOS does not replace those standards. It uses component-specific software thresholds for the investigated compressor and leaves final industrial alarm settings to be confirmed against the applicable standard, manufacturer guidance, and plant baseline data.

2.2. Passive, active, and hybrid vibration control

Passive vibration control reduces transmitted vibration through mounts, dampers, stiffness changes, isolation pads, and material damping. It is dependable and requires no controller, but it cannot adapt to changing excitation or progressive component deterioration. Active vibration control adds a sensing, decision, and actuation path so that a counteracting or corrective action can be commanded when vibration reaches a defined level [12-14]. Hybrid control combines these two ideas: passive elements reduce vibration physically, while monitoring and decision logic determine when corrective action or shutdown is needed.

DUViMOS follows this hybrid philosophy at the software level. Polyurethane dampers and mechanical supports remain the passive vibration-control components, while the GUI supplies a monitoring and decision layer. In this study, the AVC command is implemented as a component-specific software trigger. Industrial deployment requires an actuator, power driver, data-acquisition channel, safety relay, and commissioning tests before the system can be classified as a physically implemented closed-loop AVC platform. This boundary is maintained throughout the paper.

2.3. MATLAB GUI platforms for engineering monitoring systems

MATLAB remains suitable for engineering monitoring prototypes because numerical processing, plotting, matrix handling, and interface design can be developed in one environment. A GUI also allows operators to interpret values without reading the underlying code. In DUViMOS, callback routines read the ten input channels, update a history matrix, compare each value with its threshold, display the highest severity condition, and refresh the comparative and trend plots. This structure is compatible with later data-acquisition integration because the manual input layer can be replaced by measured sensor streams while leaving the threshold engine largely unchanged [11].

2.4. Predictive-maintenance relevance

Predictive maintenance depends on the ability to observe deterioration before failure. A single vibration reading captures the current condition, whereas a trend indicates deterioration, stability, or recovery. DUViMOS therefore records each monitoring pass and plots the history of the monitored locations so that gradual growth, recurring warning states, and response after corrective action can be observed. This aligns with condition-based maintenance practice, where diagnostic value comes from combining measurement, trend interpretation, and timely intervention rather than from alarm thresholds alone [6-8,16].

3. DUViMOS Design and Development

3.1. Compressor context and monitoring need

The investigated machine is an oil-injected Ingersoll Rand R110i screw compressor. Field inspections showed that general compressor status information alone was not sufficient for component-level vibration management. Ten locations were therefore selected for DUViMOS monitoring: rotor, casing, compressor-drive-end bearing, compressor-non-drive-end bearing, motor-drive-end bearing, motor-non-drive-end bearing, compressor-drive-end gear, motor-drive-end gear, compressor-foot damper, and motor-foot damper.

Figure 1. Ingersoll Rand R110i screw compressor used as the application platform for DUViMOS development.

3.2. Threshold derivation and control rules

For each monitored location, a component design limit was adopted from the material and modal-analysis stage of the compressor vibration study and then checked against the field-measurement context. The modal/material stage supplied conservative reference limits for the software logic by linking component response, material behaviour, and observed operating ranges; the values are not presented as direct ISO severity limits. In this paper, L_i is therefore the conservative velocity reference adopted for software decision testing after comparison with the observed healthy operating range, rather than a direct ISO acceptance limit or a measured fracture velocity. The design limit was treated as a protective software reference, not as permission to keep the compressor running up to failure. The warning and shutdown limits were placed below the design-limit reference. In industrial implementation, these values require checking against machine speed, foundation stiffness, component material, baseline vibration, manufacturer guidance, and the applicable ISO 20816 evaluation class.

$$W_i = 0.70 L_i \quad (1)$$

Equation (1). Warning threshold for monitored component i.

$$S_i = 0.90 L_i \quad (2)$$

Equation (2). Protective shutdown threshold for monitored component i.

The remaining vibration margin was calculated to support maintenance interpretation:

$$M_i = ((L_i - v_i) / L_i) \times 100\% \quad (3)$$

Equation (3). Remaining margin relative to the design limit. The status classification was implemented with the following rule:

$$\text{Status}_i = \begin{cases} \text{Normal}, & v_i < W_i \\ \text{Warning + AVC trigger}, & W_i \le v_i < S_i \\ \text{Shutdown}, & v_i \ge S_i \end{cases} \quad (4)$$

Equation (4). Threshold-based status rule applied to each monitoring location.

Table 1. Component-specific thresholds used in the DUViMOS monitoring logic.

Component/location	Parameter	Warning W_i (in/s)	Shutdown S_i (in/s)	Design limit L_i (in/s)
Rotor	Vibration velocity	0.525	0.675	0.750
Casing	Vibration velocity	0.595	0.765	0.850
Bearing - CDE	Vibration velocity	0.455	0.585	0.650
Bearing - CNDE	Vibration velocity	0.455	0.585	0.650
Bearing - MDE	Vibration velocity	0.455	0.585	0.650
Bearing - MNDE	Vibration velocity	0.455	0.585	0.650
Gears - CDE	Vibration velocity	0.518	0.666	0.740
Gears - MDE	Vibration velocity	0.518	0.666	0.740
Dampers - CF	Vibration velocity	0.126	0.162	0.180
Dampers - MF	Vibration velocity	0.126	0.162	0.180

3.3. Software architecture

The architecture separates the operator interface, threshold engine, decision logic, control-trigger output, and visualization layer. This separation improves maintainability and prevents the validated software logic from being confused with hardware functions that are not yet installed. The input layer is modular, so it may be substituted with a sensor-acquisition interface that passes the same vibration variables to the threshold engine.

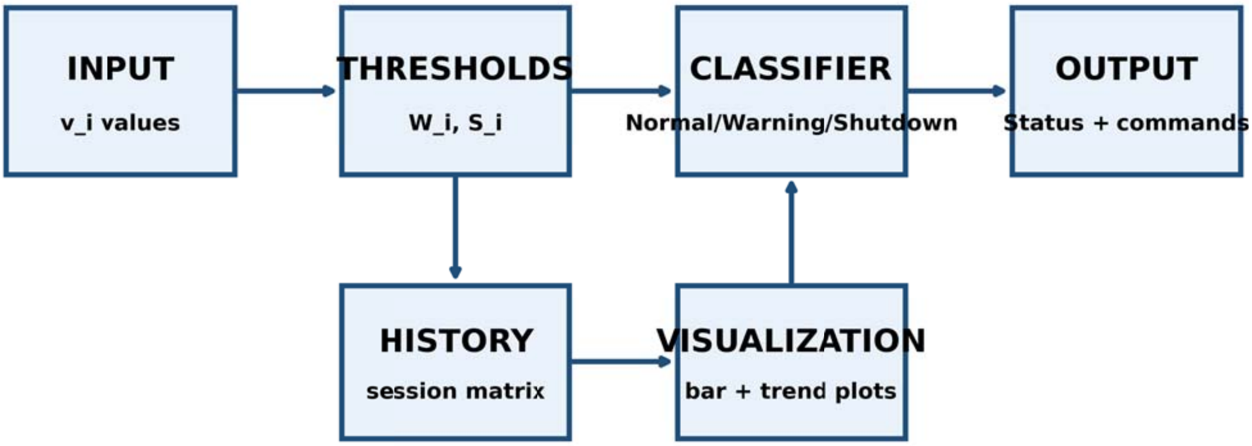

Figure 2. DUViMOS software architecture and information flow.

The GUI contains an input section for the ten vibration channels, a comparative bar-chart section for the current monitoring pass, a historical trend section for all passes within the active session, a status indicator, and session-control buttons. The Start Monitoring button runs one complete pass. The Reset button clears the session history only after the operator acknowledges the shutdown or warning context.

3.4. Monitoring algorithm

The main callback function follows a fixed sequence so that every monitoring pass is reproducible. The values are first read from the input controls, then appended to the history matrix. DUViMOS then plots the current values against the shutdown thresholds, redraws the trend chart, classifies every component, displays the highest severity level, and locks further monitoring when the shutdown condition is reached. This deterministic sequence makes the software-in-the-loop test repeatable and auditable.

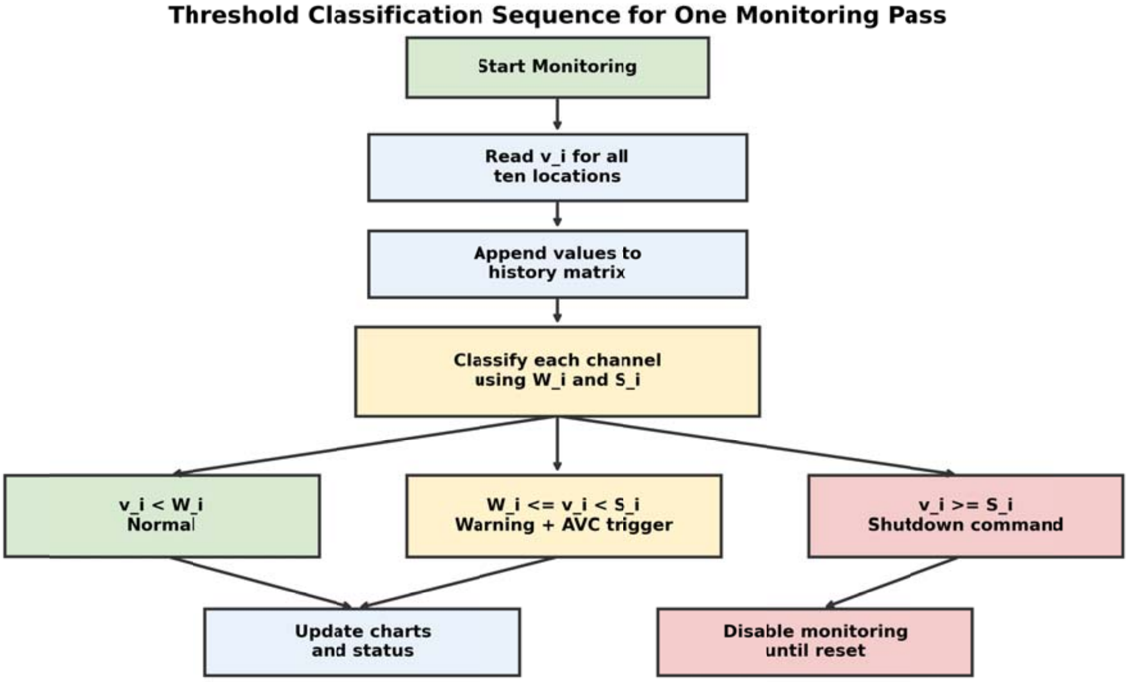

Figure 3. Threshold classification sequence used during one DUViMOS monitoring pass.

3.5. Functional comparison with IntelliSys

Table 2 shows that DUViMOS is not intended to replace the existing IntelliSys interface completely, but to extend its capability for component-level vibration monitoring. IntelliSys already provides general machine status and embedded machine-control functions, but in the investigated configuration it does not provide a detailed vibration-channel list, warning thresholds, component-specific vibration shutdown logic, AVC trigger logic, or editable vibration-monitoring parameters for the selected compressor locations. DUViMOS addresses these gaps by implementing ten vibration-monitoring locations, applying warning logic at 70% of the component limit, issuing software-level shutdown commands at 90% of the component limit, and providing component-specific AVC trigger messages. It also stores and plots historical vibration trends, which makes it more useful for predictive maintenance than a simple status display. However, the table also makes an important limitation clear: DUViMOS is still a software-in-the-loop system, so physical actuation requires additional sensor, actuator, driver, safety-interface, and plant-integration hardware before it can operate as a full closed-loop active vibration control system.

Table 2. Functional comparison between the existing interface context and DUViMOS.

Feature	IntelliSys interface	DUViMOS contribution
General machine status	Available	Available as contextual display
Component-level vibration channel list	Not available in the investigated configuration	Ten locations implemented
Warning threshold logic	Not implemented for the selected vibration channels	70% of component limit
Protective shutdown logic	No component-specific vibration shutdown was available for the monitored channels in the investigated configuration	Software-level command at 90% of component limit
AVC trigger logic	Not available	Component-specific software trigger
Historical vibration trend	Limited for this component-level use	Session trend stored and plotted
User configurability	Constrained by proprietary interface	Thresholds and labels editable in MATLAB
Hardware actuation	Embedded for machine control functions	Not implemented in the software-in-the-loop version; requires actuator and safety-

		interface integration

3.6. Interactive command-line programme

A command-line companion programme was developed to expose the same decision rules without the GUI. It prompts the operator for each vibration value, classifies each channel, and asks whether monitoring is to continue. The programme provides operator-training support by showing the complete decision sequence in text form. It also served as an independent check that the GUI logic and the command-line logic produced consistent responses for the same test scenario.

4. Results

4.1. Seven-pass GUI validation

DUViMOS was tested through seven monitoring passes in one MATLAB session. The input values were intentionally varied so that the validation exercised normal operation, warning-level response, repeated warning on bearing channels, damper warning, and final shutdown. The Reset button was not pressed during the validation run; therefore, the trend chart preserved the entire seven-pass history.

Table 3. Seven-pass functional validation summary.

Pass	Selected values (in/s)	Highest status	AVC trigger channel	Action
1	Rotor 0.20; Casing 0.23; Dampers_MF 0.132	Warning: 1 channel	Dampers_MF	Monitoring continues
2	Rotor 0.45; Casing 0.30; Dampers_MF 0.120	Warning: 2 channels	Bearing_CDE, Bearing_MNDE	Monitoring continues
3	Rotor 0.35; Casing 0.28; Dampers_MF 0.130	Warning: 2 channels	Bearing_CDE, Dampers_MF	Monitoring continues
4	Rotor 0.40; Casing 0.33; Dampers_MF 0.150	Warning: 1 channel	Dampers_MF	Monitoring continues
5	Rotor 0.36; Casing 0.32; Dampers_MF 0.160	Warning: 3 channels	Bearing_MDE, Dampers_CF, Dampers_MF	Monitoring continues
6	Rotor 0.45; Casing 0.36; Dampers_MF 0.150	Warning: 2 channels	Dampers_CF, Dampers_MF	Monitoring continues
7	Rotor 0.46; Casing 0.31; Dampers_MF 0.200	Shutdown: Dampers_MF	Not applicable after shutdown	Monitoring disabled pending reset

The seventh pass produced the intended protective response. The Dampers_MF value of 0.20 in/s was above both its protective shutdown threshold of 0.162 in/s and its design-limit reference of 0.18 in/s. DUViMOS therefore displayed the shutdown condition and disabled further monitoring until reset. The result confirms that the protective logic is sensitive to the most severe component state rather than to the average condition of the machine.

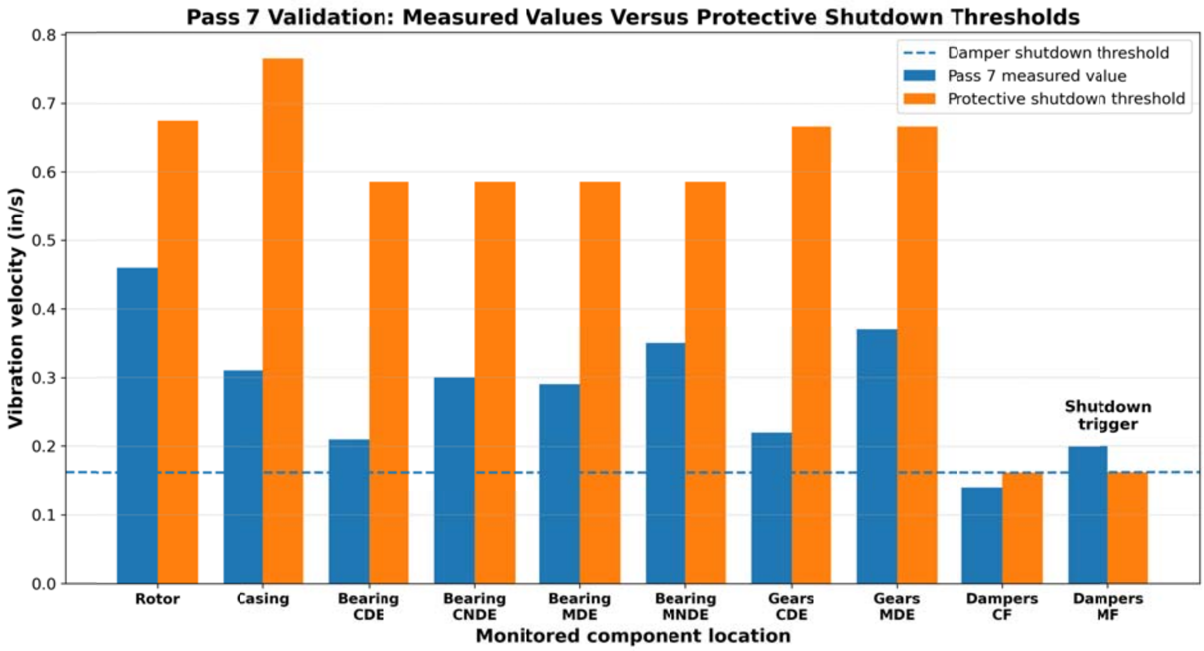

Figure 4. Pass 7 validation values compared with the protective shutdown thresholds.

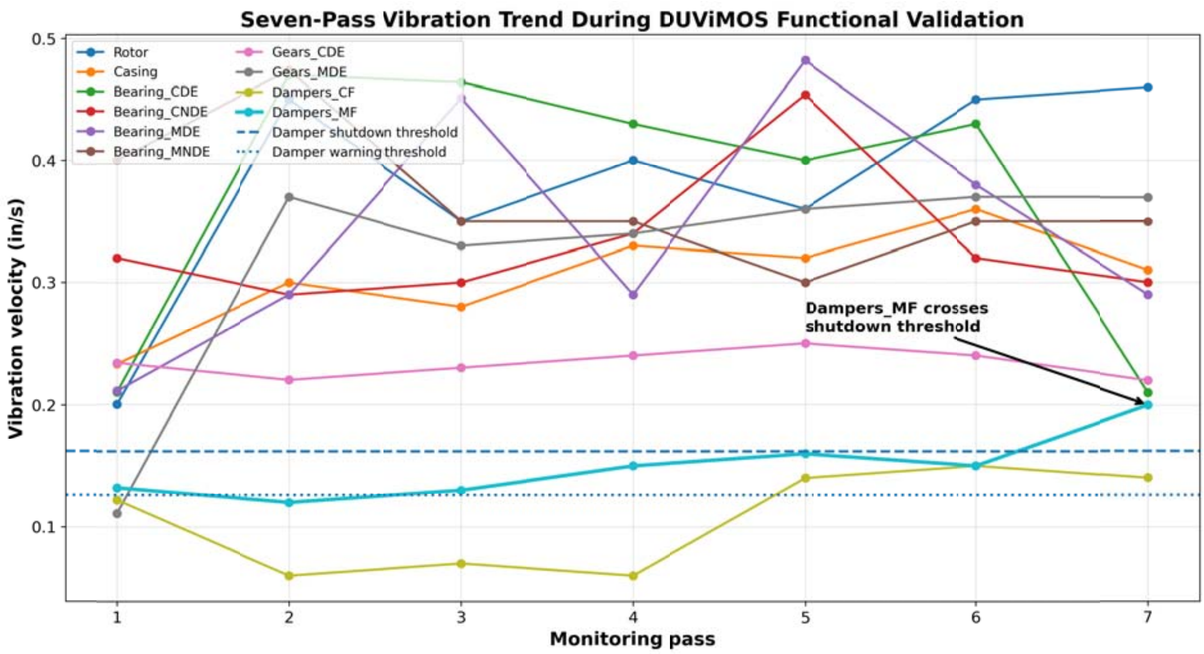

Figure 5. Seven-pass vibration trend generated during DUViMOS functional validation.

4.2. Alert behaviour and maintenance interpretation

The validation sequence showed three important behaviours. First, normal readings remained classified as safe, so the tool did not produce unnecessary alarms under low vibration values. Second, values within the warning band produced component-specific warning messages, allowing a maintenance engineer to focus on the affected channel rather than inspect the complete machine without component-level prioritisation. Third, a value at or above the shutdown threshold disabled further monitoring until reset, which prevents the interface from treating a critical state as a routine monitoring pass.The trend plot supports maintenance prioritisation by showing the direction and rate of vibration change. The Dampers_MF channel increased toward the final shutdown value across the session, so the historical plot showed a progressive rise before shutdown. In a plant monitoring routine, this type of channel-specific trend would support targeted inspection before the protective shutdown threshold is reached.

4.3. Command-line validation

The interactive command-line programme was validated through five sessions. Sessions 1 to 4 produced normal and warning-level outputs, while Session 5 triggered shutdown after a Dampers_MF input of 0.20 in/s. This confirmed that the threshold logic is not dependent on the GUI layout. The GUI and command-line programme therefore provide two interfaces to the same decision principle: one for visual monitoring and one for step-by-step operator training.

4.4. Field vibration context

Five months of field measurements were obtained with an SKF Microlog Analyser at the compressor drive end, compressor non-drive end, motor drive end, and motor non-drive end. The field readings were not used as a replacement for component design limits. They were used to establish the healthy operating context of the investigated installation and to identify abnormal locations that deserved closer engineering attention. The highest motor non-drive-end vertical readings were traced during inspection to looseness at the end-cover region rather than to a general failure of the compressor train.

Table 4. Field-measurement context used to interpret DUViMOS threshold settings.

Field location	Measured range (mm/s or RMS)	Approx. range (in/s)	DUViMOS comparison channel	Warning threshold (in/s)	Interpretation
Compressor drive end	1.905-4.318	0.075-0.170	Bearing/gears/rotor channels	0.455-0.525	Below warning range for these channels
Compressor non-drive end	1.950-3.600	0.077-0.142	Bearing/gears channels	0.455-0.518	Within healthy context for tested installation
Motor drive end	3.700-4.320	0.146-0.170	Bearing/gears channels	0.455-0.518	Below warning range for rotating channels
Motor non-drive end	14.0-31.75	0.551-1.250	Inspection flag	Not used as healthy baseline	Investigated as looseness/end-cover condition
Motor-foot damper	1.19-1.21 RMS	Not velocity-converted	Dampers_MF	0.126	Used to motivate closer damper-channel monitoring

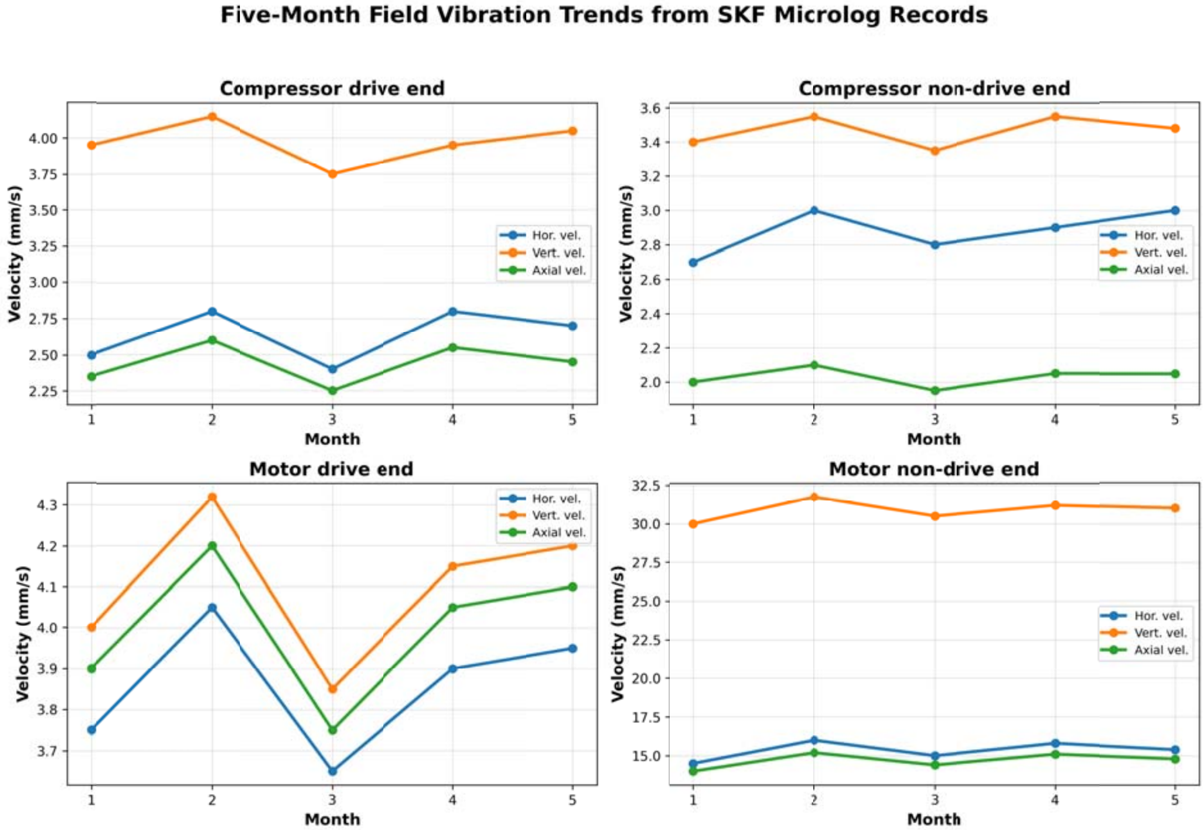

Figure 6. Five-month field vibration trends for the four measured machine locations, reconstructed from SKF Microlog measurement records.

The field data also explains the use of the motor-foot damper channel for evaluating the shutdown response. The machine installation showed asymmetry at the motor base: the left-hand side of the motor foot was less effectively supported than the right-hand side. The measured RMS values were close, but the unsupported side was consistently higher. This provided a physically meaningful monitoring point for assessing whether the DUViMOS trend output can reflect mounting-related vibration behaviour and the effect of later corrective support.

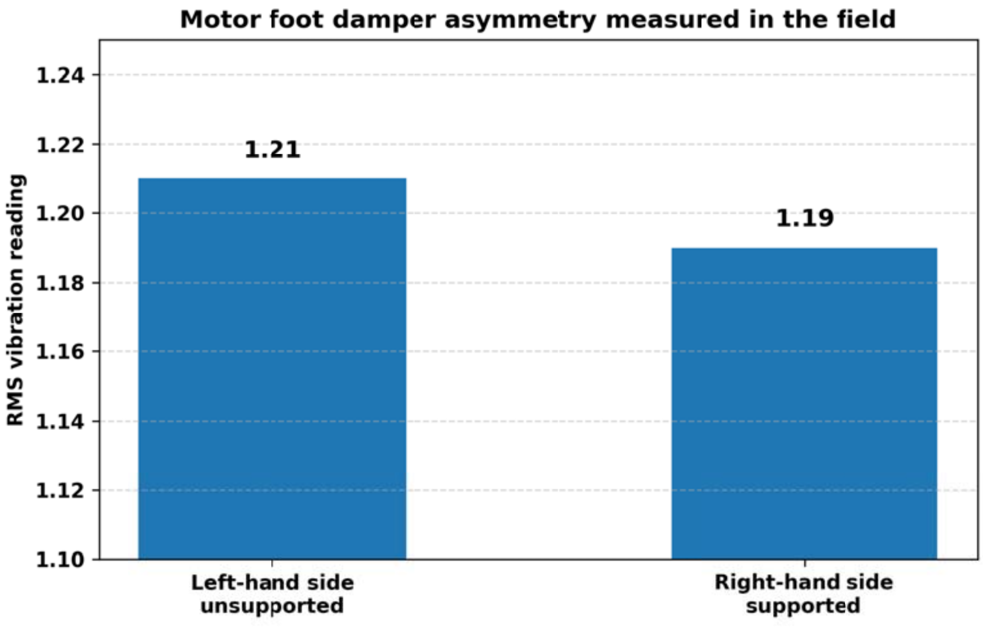

Figure 7. Motor-foot damper comparison showing the higher RMS reading on the less-supported side.

5. Discussion

5.1. Reliability of the software logic

The validation confirms that DUViMOS performs the intended software functions consistently. It reads the ten input channels, stores the session history, applies the same thresholds to every monitoring pass, updates the comparative and trend charts, identifies the highest severity level, and disables monitoring when the shutdown condition is reached. These are the essential functions required before a monitoring prototype can be connected to physical sensors or actuators.

DUViMOS provides a control-trigger layer, not a fully commissioned actuator system. This distinction is important because it defines the contribution precisely: the study validates the monitoring interface and decision algorithm, while complete sensor-controller-actuator validation remains a requirement for industrial active-control deployment.

5.2. Predictive-maintenance value

The historical trend chart extends the interface from alarm display to trend-based maintenance support. Maintenance planning improves when engineers can see whether vibration is stable, gradually increasing, or responding to corrective action. DUViMOS preserves the channel identity and trend direction needed for maintenance prioritisation by plotting every monitoring pass in the active session. The result is not a remaining-useful-life model, but it provides the structured trend evidence needed before remaining-useful-life modelling can be implemented.

5.3. Threshold choice and engineering caution

The threshold values are intentionally conservative because the shutdown threshold is set below the component design-limit reference. This is appropriate for protective logic, but it also means that threshold derivation must be auditable. For industrial deployment, the limits require review against measured baseline data, manufacturer guidance, machine class, speed, support condition, load, and safety requirements. Where possible, the threshold set can be updated after commissioning using statistically meaningful healthy-operation data.

5.4. Deployment pathway

Industrial deployment requires sensor integration on the ten monitored locations, followed by calibration under healthy operating conditions. Data validation, filtering, sampling-rate control, and signal-quality checks are deployment requirements before values are passed to the threshold engine. The AVC channel requires simulation testing and hardware-in-the-loop verification before any actuator is allowed to command the compressor. Before plant operation, all shutdown and actuator commands require fail-safe interlock verification.

6. Conclusion

This paper presented DUViMOS, a MATLAB-based graphical user interface for component-level vibration monitoring and active-control decision support in an industrial screw compressor. The present contribution is a validated software-in-the-loop monitoring and control-logic layer for threshold-based warning, shutdown decision support, historical trending, and later sensor-actuator integration. The implementation shows how compressor vibration readings can be converted into channel-specific decisions without overstating the present system as a commissioned closed-loop AVC installation.

The seven-pass GUI validation and five-session command-line validation confirmed that the threshold logic works consistently across normal, warning, and shutdown states. The final shutdown event was triggered by the motor-foot damper channel, which was physically meaningful because field inspection identified motor-foot support asymmetry. The figures and tables report the implemented monitoring logic, the field context, and the maintenance interpretation.

A fully instrumented DUViMOS deployment requires accelerometer acquisition, physical actuator interfacing, continuous operation testing, validated alarm limits, and fail-safe interlocks. These additions are necessary before the system can be classified as a physically implemented closed-loop AVC platform. Within the present scope, the work establishes a reproducible MATLAB-based monitoring and decision framework that can be adapted to similar compressor installations after machine-specific calibration.

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