SENSEYE PREDICTIVE MAINTENANCE

Best Practices in Condition Monitoring for Multi-Axis Equipment

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Executive Summary

As sophisticated and complex machines, multi-axis robots experience complex failure modes, which can prove challenging when it comes to condition monitoring. But, by using separate measures for the major components that comprise each robot axis, and by capturing data when the robot is in a known consistent state, it's possible to deploy "asset-agnostic" automated condition monitoring at scale across robot fleets to detect abnormal behavior and spot the early signs of potential failure – thereby reducing unplanned downtime.

Introduction

Senseye Predictive Maintenance has successfully deployed Predictive Maintenance capability with clients operating global production sites in a variety of industries. A key enabler is our data-driven approach that allows clients to benefit from economies of scale – a single solution capable of monitoring a wide range of asset types using existing condition monitoring data.

Assets we encounter regularly include motors, pumps, conveyors, lifters, presses and multi-axis robot arms. Multi-axis robots in particular pose some interesting challenges from a condition monitoring perspective; this white paper provides guidance and best practice based on our practical experience gained in this field.

Deployment approach

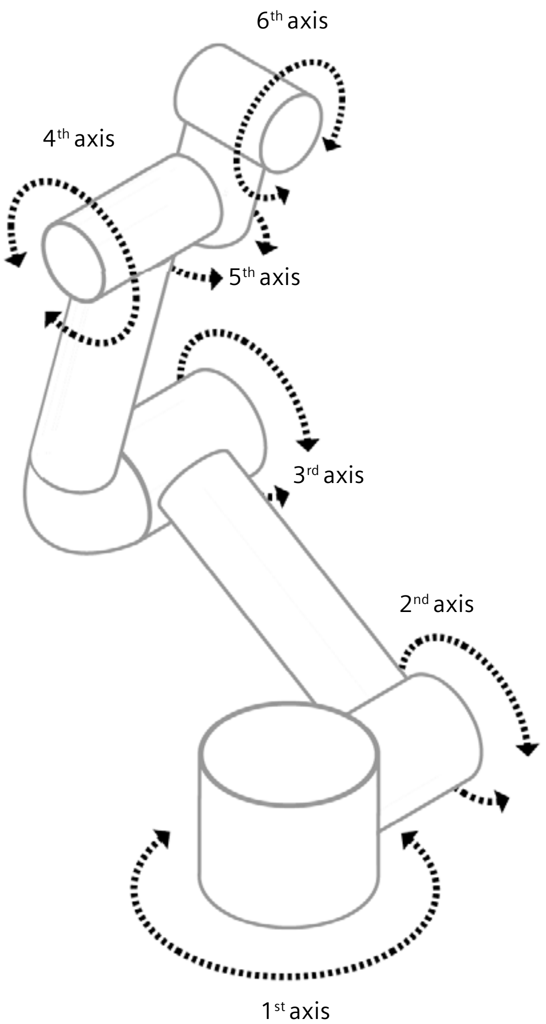
A typical Senseye Predictive Maintenance deployment targets asset types that will achieve a rapid return on investment. This may be driven by an objective to reduce unplanned downtime – detecting issues before they lead to a functional failure – or a need to reduce the costs associated with scheduled preventative maintenance. In both instances, Senseye Predictive Maintenance makes use of condition monitoring data available for each asset.

Condition monitoring data is obtained from controllers (PLCs), factory historians, or other data platforms operated by the client. Installation of dedicated sensor hardware is an option if there is no existing condition monitoring data although, in many cases, this is not required.

Robot controllers – the dedicated devices that execute predefined programs to control robot movement – typically expose real-time data including motor current and torque for each axis. In our experience this data can be used for condition monitoring purposes – there is little benefit retro-fitting additional hardware such as vibration sensors or accelerometers.

Despite access to torque and current data being relatively straightforward, however, there are some issues to overcome in relation to how this data is acquired and prepared.

Robot data acquisition

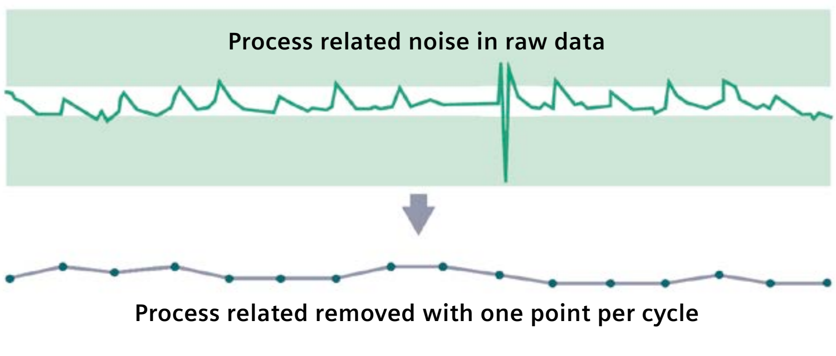


Multi-axis robot arms are sophisticated machines consisting of powerful servo motors, reduction gearboxes, and different tooling or end effectors for handling, welding, or other tasks. They are subjected to significant stresses based on payload, operating speed, and environmental conditions. These factors combined can result in complex failure modes.

Typically, robots are configured to perform one or more different programs. For example, a welding robot in an automotive body shop may handle several different body styles each with a separate program. This variability introduces a further challenge to automated condition monitoring systems, as a high level of "process noise" is often present in raw sensor values. An example would be welding tip stick, which can be experienced during spot welding, resulting in the need for excessive force to break the robot free and continue to the next operation.

Process noise and other variability can be reduced by sampling data values at a consistent point in the operating cycle. These samples are stored in a factory historian or other data store where further pre-processing can be applied if necessary. For example, say we are interested in the hourly maximum motor current for each axis. The robot controller is configured to sample motor current every minute and these values are stored in a local database. The hourly maxima can then be calculated 'on the fly' or stored as discrete values by pre-processing the samples.

The example below illustrates a single point representing each cycle derived from raw data. This data was obtained from a welding robot and the pronounced spike is due to a welding tip stick incident.



Recommendations

Condition monitoring data for robots should satisfy these requirements:

- Separate measures for the major components that comprise each robot axis; typically motors and gearboxes or reducers
- Data captured when the robot is in a known consistent state. For example, on completion of each operating cycle as the robot arm returns to the home position

Firstly, establish what raw data is available from the robot controller/PLC and the capabilities of the controller in terms of data acquisition. Are separate values provided for each component and axis? Can these values be sampled at a consistent point in the operating program?

Based on our experience of deploying Senseye Predictive Maintenance across robot fleets from various manufacturers, we recommend torque and/or motor current measurements as most appropriate for condition monitoring purposes. Some robot manufacturers report disturbance torque; this is the difference between the torque due to gravity – when the arm is at rest – and the torque when the arm is moving. Disturbance reacts to increased friction due to mechanical wear or other degradation, and these changes are often detectable early in the component failure lifecycle.

Motor temperature can also be useful; however, this is typically a late indicator of failure.

Measurement	Unit
Torque for each axis	**Max/Min Disturbance**
Torque for each axis	**RMS Disturbance**
Motor temp for each axis	**Degrees C/F**
Tooling force	**Closing Torque**

Example Benefits
Getting Maintenance Credits from Predictive Maintenance

As part of a Condition-Based Maintenance (CBM) regime, lubrication analysis is often carried out on a scheduled basis to detect signs of abnormal wear and degradation in mechanical components such as gearboxes. With a large fleet of multiaxis robots, the costs associated with lubrication analysis can quickly become prohibitive.

Senseye Predictive Maintenance has helped clients realize significant cost savings by reducing the volume and frequency of lubrication analysis. After learning the normal behavior of each robot, Senseye Predictive Maintenance automatically monitors data from the fleet and notifies maintenance staff of outliers or deviations from the norm.

Lubrication analysis can then be targeted at specific assets when it is required rather than carrying it out on a scheduled basis. Enabling the removal of the preventative maintenance lubrication analysis check then results in a credit to the maintenance regime.

Additional benefits can be achieved if information on historic failures is available. Maintenance records provide details of the affected asset, the part(s) replaced, and when this work was carried out. Analysis of condition monitoring data leading up to a failure allows a model of the failure to be constructed without human intervention. Senseye Predictive Maintenance maintains a library of such models and allows them to be shared across fleets, automatically detecting the signature of a potential failure before it occurs.

Other Approaches

Robot equipment vendors may offer condition monitoring or Predictive Maintenance software as an additional subscription or license fee per asset. This approach is appealing from a procurement and supplier management perspective but there are several limitations worth highlighting.

Firstly, vendor solutions may not be compatible with other types of asset. If you are investing in a comprehensive site-wide Predictive Maintenance initiative, you will need to procure and manage multiple systems to provide full coverage across all types of asset.

In contrast, Senseye Predictive Maintenance is ‘asset-agnostic’, enabling you to benefit from Predictive Maintenance using a single solution.

A further limitation with some solutions is the approach used to detect and report potential issues. Rather than utilizing condition monitoring data, it is common to simply count the number of completed operating cycles and trigger an advisory message when a threshold is exceeded. This approach takes no account of the actual condition of the equipment and may result in over-maintenance or – worse – a missed failure resulting in unplanned downtime.

Summary

1. Multi-axis robots are complex machines that experience complex failure modes

2. Automated condition monitoring can be deployed at scale across robot fleets to detect abnormal behavior and spot the early signs of potential failure

3. Robot controllers/PLCs can be used to sample torque and current at consistent points in the operating cycle, creating usable condition monitoring data

4. Systems such as Senseye Predictive Maintenance are 'asset-agnostic', enabling Predictive Maintenance to scale to all asset types.

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