The ontology called "Information for Prognostic and Health Management (PHM)" needs data from the Fault Diagnosis and Data Collection techniques, which interact in conjunction with Manufacturing Items, specifically with rotating mechanical Components, (according studies are the most likely to failure). In this work, the hierarchy of Manufacturing Items is considered through a bottom-up approach: Component, Machine and Equipment.

# To begin this study, data and information related queries are performed to identify: the component hierarchy, required functions, identification nomenclature, item specifications, and other information to ensure the correct identification of the component being analyzed.

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

PREFIX owl: <http://www.w3.org/2002/07/owl#>

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>

PREFIX utfpr: <http://www.semanticweb.org/david/ontologies/2016/untitled-ontology-286#>

## What are the main rotating mechanical components (Component) of a given mechanical machine? (In alphabetical order)

SELECT ?Component

WHERE {?Component rdfs:subClassOf utfpr:Component }

ORDER BY ?Component

|  |
| --- |
| **Component** |
| utfpr:Bearing |
| utfpr:Component |
| utfpr:Coupling |
| utfpr:GlandPacking |
| utfpr:Impeller |
| utfpr:JournalBearing |
| utfpr:Lubricant |
| utfpr:MechanicalSeal |
| utfpr:RollingBearing |
| utfpr:Seals |
| utfpr:Shaft |

## Considering that the intance to be analyzed is Component\_1, having a given ID, i. e., "6306\_C3". What is the Component\_1 to be analysed?

SELECT ?Component

WHERE {?Component utfpr:hasID "6306\_C3"^^xsd:string }

**OTHER WAY:**

SELECT ?Component

WHERE {?Component utfpr:hasID "6306\_C3" }

**OTHER WAY:**

SELECT ?Component

WHERE {?Component utfpr:hasID ?valor

FILTER (?valor="6306\_C3") }

|  |
| --- |
| **Component** |
| RollingBearing\_1 |

## Which Machine\_1 does the Component\_1 belong to?

SELECT ?Component ?OfMachine

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:isPartOf ?OfMachine }

|  |  |
| --- | --- |
| **Component** | **OfMachine** |
| utfpr:RollingBearing\_1 | utfpr:Pump\_1 |

## What is the specification of Machine\_1?

SELECT ?Component ?OfMachine ?TypeOfPump

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:isPartOf ?OfMachine.

?OfMachine utfpr:hasSpecification ?TypeOfPump }

|  |  |  |
| --- | --- | --- |
| **Component** | **OfMachine** | **TypeOfPump** |
| utfpr:RollingBearing\_1 | utfpr:Pump\_1 | Is a Centrifugal Pump ^^xsd:string |

## Which Equipment\_1 does the Component\_1 Machine\_1 belong to?

SELECT ?Component ?OfMachine ?TypeOfPump ?OfEquipment

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:isPartOf ?OfMachine.

?OfMachine utfpr:hasSpecification ?TypeOfPump;

utfpr:isPartOf ?OfEquipment}

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **OfMachine** | **TypeOfPump** | **OfEquipment** |
| utfpr:RollingBearing\_1 | utfpr:CentrifugalPump\_1 | Is a Centrifugal Pump ^^xsd:string | utfpr:MachineWithSeparateDriver\_1 |

## What is the specification of Equipment\_1?

SELECT ?Component ?OfMachine ?TypeOfPump ?OfEquipment ?TypeOfEquipment

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:isPartOf ?OfMachine.

?OfMachine utfpr:hasSpecification ?TypeOfPump;

utfpr:isPartOf ?OfEquipment.

?OfEquipment utfpr:hasSpecificatio ?TypeOfEquipment }

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **OfMachine** | **TypeOfPump** | **OfEquipment** | **TypeOfEquipment** |
| utfpr:RollingBearing\_1 | utfpr:Pump\_1 | Is a Centrifufal Pump^^xsd:string | utfpr:MachineWithSeparateDriver\_1 | Is a centrifugal pump for water supplies, with separate driver^^xsd:string |

## What is Machine\_1 ID?

SELECT ?Component ?OfMachine ?MachineID

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:isPartOf ?OfMachine.

?OfMachine utfpr:hasID ?MachineID}

|  |  |  |
| --- | --- | --- |
| **Component** | **OfMachine** | **MachineID** |
| utfpr:RollingBearing\_1 | utfpr:Pump\_1 | BOM0225^^xsd:string |

## What is Equipment\_1 ID?

SELECT ?Component ?OfMachine ?MachineID ?OfEquipment ?EquipmentID

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:isPartOf ?OfMachine.

?OfMachine utfpr:hasID ?MachineID;

utfpr:isPartOf ?OfEquipment.

?OfEquipment utfpr:hasID ?EquipmentID }

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **OfMachine** | **MachineID** | **OfEquipment** | **EquipmentID** |
| utfpr:RollingBearing\_1 | utfpr:Pump\_1 | BOM0225^^xsd:string | utfpr:MachineWithSeparateDriver\_1 | ES240BOM0225^^xsd:string |

## What is the Required Function of Equipment\_1?

SELECT ?Equipment ?EquipmentFunction

WHERE { ?Equipment utfpr:hasID "ES240BOM0225";

utfpr:hasFunction ?EquipmentFunction }

|  |  |
| --- | --- |
| **Equipment** | **EquipmentFunction** |
| utfpr:MachineWithSeparateDriver\_1 | Water treatment in a given sector of a particular company^^xsd:string |

## What is the Required Function of Machine\_1?

SELECT ?Machine ?MachineFunction

WHERE { ?Machine utfpr:hasID "BOM0225";

utfpr:hasFunction ?MachineFunction }

|  |  |
| --- | --- |
| **Machine** | **MachineFunction** |
| utfpr:Pump\_1 | Water transport from A to B, at a given flow rate, in m^3/h^^xsd:string |

## What is the Required Function of Component\_1?

SELECT ?Component ?ComponentFunction

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasFunction ?ComponentFunction }

|  |  |
| --- | --- |
| **Component** | **ComponentFunction** |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string |

## What are the required functions of: Component\_1, Machine\_1 and Equipment\_1?

SELECT ?Component ?ComponentFunction ?Machine ?MachineFunction ?Equipment ?EquipmentFunction

WHERE {?Component utfpr:hasID "6306\_C3"^^xsd:string;

utfpr:hasFunction ?ComponentFunction;

utfpr:isPartOf ?Machine.

?Machine utfpr:hasFunction ?MachineFunction;

utfpr:isPartOf ?Equipment.

?Equipment utfpr:hasFunction ?EquipmentFunction }

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Component** | **ComponentFunction** | **Machine** | **MachineFunction** | **Equipment** | **EquipmentFunction** |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Pump\_1 | Water transport from A to B, at a given flow rate, in m^3/h^^xsd:string | utfpr:MachineWithSeparateDriver\_1 | Water treatment in a given sector of a particular company^^xsd:string |

## What are the Machines that make up the Equipment\_1?

SELECT ?EquipmentMachine

WHERE { ?EquipmentMachine utfpr:isPartOf utfpr:MachineWithSeparateDriver\_1 }

|  |
| --- |
| **EquipmentMachine** |
| CentrifugalPump\_1 |
| ElectricMotor\_1 |

## What is the required function of Machine\_1, its ID and which Equipment does it belong to?

SELECT ?Required\_Function ?ID ?Belonging\_to

WHERE { utfpr:Pump\_1 utfpr:hasFunction ?Required\_Function;

utfpr:hasID ?ID;

utfpr:isPartOf ?Belonging\_to}

|  |  |  |
| --- | --- | --- |
| **Required\_Function** | **ID** | **Belonging\_to** |
| Water transport from A to B, at a given flow rate, in m^3/h^^xsd:string | BOM0225^^xsd:string | utfpr:MachineWithSeparateDriver\_1 |

## What are the main Rotating Components of Macnhine\_1, which can be monitored?

SELECT ?Components

WHERE {?Components utfpr:isPartOf utfpr:Pump\_1}

ORDER BY ?Components

|  |
| --- |
| **Components** |
| RollingBearing\_1 |
| Coupling\_1 |
| Impeller\_1 |
| Lubricant\_1 |
| MechanicalSeal\_1 |
| Shaft\_1 |

## What is the required function, ID, and which Machine belongs the Component\_1?

SELECT ?Required\_Function ?ID ?Belonging\_to

WHERE { utfpr:RollingBearing\_1 utfpr:hasFunction ?Required\_Function;

utfpr:hasID ?ID;

utfpr:isPartOf ?Belonging\_to}

|  |  |  |
| --- | --- | --- |
| **Required\_Function** | **ID** | **Belonging\_to** |
| Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | 6306\_C3^^xsd:string | utfpr:Pump\_1 |

## Finally, to identify the mechanical item to be analyzed and start with FMSA, we need to know.

## What are the main features of the Component\_1?

SELECT ?Component ?ComponentID ?TypeOfComponent ?OfMachine ?ComponentFunction

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasID ?ComponentID;

utfpr:hasSpecification ?TypeOfComponent;

utfpr:isPartOf ?OfMachine;

utfpr:hasFunction ?ComponentFunction }

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **ComponentID** | **TypeOfComponent** | **Ofmachine** | **ComponentFunction** |
| utfpr:RollingBearing\_1 | 6306\_C3^^xsd:string | Single row deep groove ball bearings^^xsd:string | utfpr:Pump\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string |

# Identified the Component\_1 and mainly its Required Function for the Machine / Equipment, now, is carried out the Fault Diagnosis of said Component\_1 (e. g., RollingBearing\_1) using the Failure Mode Symptoms Analysis (FMSA) technique. Thus, the following queries are performed from the Fault Diagnostics, which is a kind of database, collected from interviews, technical and scientifics bibliographic references and historical of real systems.

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

PREFIX owl: <http://www.w3.org/2002/07/owl#>

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>

PREFIX utfpr: <http://www.semanticweb.org/david/ontologies/2016/untitled-ontology-286#>

## What are the Component\_1 Failure Modes?

SELECT ?Component ?RequiredFunction ?FailureMode

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasFunction ?RequiredFunction

utfpr:hasMode ?FailureMode}

|  |  |  |
| --- | --- | --- |
| **Component** | **RequiredFunction** | **FailureMode** |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 |

## What are the Potential Cause of each Failure Mode identified in the Component\_1?

SELECT ?Component ?RequiredFunction ?FailureMode ?FailureCause

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasFunction ?RequiredFunction;

utfpr:hasMode ?FailureMode.

?FailureMode utfpr:hasCause ?PotencialCause.

?PotencialCause utfpr:isCausedBy ?FailureCause }

ORDER BY ?FailureMode

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **RequiredFunction** | **FailureMode** | **FailureCause** |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Angular misalignment of shaft due to mounting incorrect^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Parallel misalignment of shaft due to mounting incorrect^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to interference fit above of specified^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to lack of free side for dilation^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue due to fastening bolt loose^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to excessive tightening on the sides of the bearing^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Bolt specification with lower yield strength than required^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Loose bearing due to fracture in thread of bolt^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Incorrect tightening due to lack of tools^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to excessive amount of lubricant (swirling)^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to poor sealing that contaminates the lubricant (forming blistering)^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear of parts due to poor sealing that contaminates the lubricant with abrasive particles^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear due to lack of tightening of parts (looseness)^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to low lubricant level^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to incorrect lubricant specification^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Pitting corrosion due to contamination of the lubricant^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to vibration of bearing housing^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to lack tightening on the bearing sides (looseness)^^xsd:string |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to load above projected capacity^^xsd:string |

**OTHER WAY:**

SELECT ?TypeOfComponent ?RequiredFunction ?FailureMode ?FailureCause

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasSpecification ?TypeOfComponent;

utfpr:hasFunction ?RequiredFunction;

utfpr:hasMode ?FailureMode.

?FailureMode utfpr:hasCause ?PotencialCause.

?PotencialCause utfpr:isCausedBy ?FailureCause }

ORDER BY ?FailureMode

|  |  |  |  |
| --- | --- | --- | --- |
| **TypeOfComponent** | **RequiredFunction** | **FailureMode** | **FailureCause** |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Angular misalignment of shaft due to mounting incorrect^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Parallel misalignment of shaft due to mounting incorrect^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to interference fit above of specified^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to lack of free side for dilation^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue due to fastening bolt loose^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to excessive tightening on the sides of the bearing^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Bolt specification with lower yield strength than required^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Loose bearing due to fracture in thread of bolt^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Incorrect tightening due to lack of tools^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to excessive amount of lubricant (swirling)^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to poor sealing that contaminates the lubricant (forming blistering)^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear of parts due to poor sealing that contaminates the lubricant with abrasive particles^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear due to lack of tightening of parts (looseness)^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to low lubricant level^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to incorrect lubricant specification^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Pitting corrosion due to contamination of the lubricant^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to vibration of bearing housing^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to lack tightening on the bearing sides (looseness)^^xsd:string |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to load above projected capacity^^xsd:string |

## What are the Effects of Component\_1 Failure Mode?

SELECT ?Component ?Failure ?Cause ?Effect

WHERE {?Component utfpr:hasCode "6306\_C3"xsd:string;

utfpr:hasMode ?Failure.

?Failure utfpr:hasCause ?Cause;

utfpr:hasEffect ?Effect}

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **TypeOfComponent** | **RequiredFunction** | **FailureMode** | **IsCausesBy** | **Effect** |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Angular misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Overheat\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Parallel misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Overheat\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to interference fit above of specified^^xsd:string | utfpr:OperationImpaired\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to lack of free side for dilation^^xsd:string | utfpr:OperationImpaired\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue due to fastening bolt loose^^xsd:string | utfpr:OperationImpaired\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:OperationImpaired\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to excessive tightening on the sides of the bearing^^xsd:string | utfpr:OperationImpaired\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string | utfpr:OperationImpaired\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Bolt specification with lower yield strength than required^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Loose bearing due to fracture in thread of bolt^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Incorrect tightening due to lack of tools^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to excessive amount of lubricant (swirling)^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to poor sealing that contaminates the lubricant (forming blistering)^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear of parts due to poor sealing that contaminates the lubricant with abrasive particles^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear due to lack of tightening of parts (looseness)^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to low lubricant level^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to incorrect lubricant specification^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Pitting corrosion due to contamination of the lubricant^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to vibration of bearing housing^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to lack tightening on the bearing sides (looseness)^^xsd:string | utfpr:Sound\_1 |
| Single row deep groove ball bearings^^xsd:string | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to load above projected capacity^^xsd:string | utfpr:Sound\_1 |

## What is the severity (SEV) of each Effect of Component\_1, that affect a given production process?

SELECT ?Component ?FailureMode ?FailureCause ?Effect ?SEV

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasMode ?FailureMode.

?FailureMode utfpr:hasCause ?Cause.

?Cause utfpr:isCausedBy ?FailureCause.

?FailureMode utfpr:hasEffect ?Effect.

?Effect utfpr:hasSEV ?SEV }

ORDER BY ?SEV

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **FailureMode** | **FailureCause** | **Effect** | **SEV** |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Bolt specification with lower yield strength than required^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Loose bearing due to fracture in thread of bolt^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Incorrect tightening due to lack of tools^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Fretting wear due to excessive amount of lubricant (swirling)^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Fretting wear due to poor sealing that contaminates the lubricant (forming blistering)^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Wear of parts due to poor sealing that contaminates the lubricant with abrasive particles^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Wear due to lack of tightening of parts (looseness)^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Adhesive wear due to low lubricant level^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Adhesive wear due to incorrect lubricant specification^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Pitting corrosion due to contamination of the lubricant^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Fretting wear due to vibration of bearing housing^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Fretting wear due to lack tightening on the bearing sides (looseness)^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Wear\_1 | Adhesive wear due to load above projected capacity^^xsd:string | utfpr:Sound\_1 | 2 |
| utfpr:RollingBearing\_1 | utfpr:Deformation\_1 | Angular misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Overheat\_1 | 3 |
| utfpr:RollingBearing\_1 | utfpr:Deformation\_1 | Parallel misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Overheat\_1 | 3 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Ductile crack due to interference fit above of specified^^xsd:string | utfpr:OperationImpaired\_1 | 4 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Ductile crack due to lack of free side for dilation^^xsd:string | utfpr:OperationImpaired\_1 | 4 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Fatigue due to fastening bolt loose^^xsd:string | utfpr:OperationImpaired\_1 | 4 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:OperationImpaired\_1 | 4 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Ductile crack due to excessive tightening on the sides of the bearing^^xsd:string | utfpr:OperationImpaired\_1 | 4 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string | utfpr:OperationImpaired\_1 | 4 |

## What are the Symptoms of each Potential Cause of Component\_1?

SELECT ?Component ?ComponentFunction ?FailureMode ?FailureCause ?Symptom

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasFunction ?ComponentFunction;

utfpr:hasMode ?FailureMode.

?FailureMode utfpr:hasCause ?PotencialCause.

?PotencialCause utfpr:isCausedBy ?FailureCause;

utfpr:hasSymptom ?Symptom }

ORDER BY ?FailureMode

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **ComponentFunction** | **FailureMode** | **FailureCause** | **Symptom** |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Angular misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Vibration\_10 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Parallel misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Vibration\_11 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to interference fit above of specified^^xsd:string | utfpr:Temperature\_3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to lack of free side for dilation^^xsd:string | utfpr:Temperature\_4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue due to fastening bolt loose^^xsd:string | utfpr:Vibration\_15 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:Temperature\_2 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:Vibration\_13 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to excessive tightening on the sides of the bearing^^xsd:string | utfpr:Vibration\_14 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string | utfpr:Vibration\_12 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Bolt specification with lower yield strength than required^^xsd:string | utfpr:Vibration\_9 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Loose bearing due to fracture in thread of bolt^^xsd:string | utfpr:Vibration\_7 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Incorrect tightening due to lack of tools^^xsd:string | utfpr:Vibration\_8 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to excessive amount of lubricant (swirling)^^xsd:string | utfpr:Vibration\_4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to poor sealing that contaminates the lubricant (forming blistering)^^xsd:string | utfpr:LubricantProperty\_2 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear of parts due to poor sealing that contaminates the lubricant with abrasive particles^^xsd:string | utfpr:LubricantProperty\_3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear due to lack of tightening of parts (looseness)^^xsd:string | utfpr:Vibration\_5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to low lubricant level^^xsd:string | utfpr:Temperature\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to incorrect lubricant specification^^xsd:string | utfpr:LubricantProperty\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Pitting corrosion due to contamination of the lubricant^^xsd:string | utfpr:Vibration\_6 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to vibration of bearing housing^^xsd:string | utfpr:Vibration\_3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to lack tightening on the bearing sides (looseness)^^xsd:string | utfpr:Vibration\_2 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to load above projected capacity^^xsd:string | utfpr:Vibration\_1 |

## What is the symptom more efficient to assist in the elaboration of Diagnostics of a given Component\_1, according its weight (DGN)?

SELECT ?Component ?ComponentFunction ?FailureMode ?FailureCause ?Symptom ?DGN

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasFunction ?ComponentFunction;

utfpr:hasMode ?FailureMode.

?FailureMode utfpr:hasCause ?PotencialCause.

?PotencialCause utfpr:isCausedBy ?FailureCause;

utfpr:hasSymptom ?Symptom.

?Symptom utfpr:hasDGN ?DGN }

ORDER BY ?FailureMode

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Component** | **ComponentFunction** | **FailureMode** | **FailureCause** | **Symptom** | **DGN** |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Angular misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Vibration\_10 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Parallel misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Vibration\_11 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to interference fit above of specified^^xsd:string | utfpr:Temperature\_3 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to lack of free side for dilation^^xsd:string | utfpr:Temperature\_4 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue due to fastening bolt loose^^xsd:string | utfpr:Vibration\_15 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:Temperature\_2 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:Vibration\_13 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to excessive tightening on the sides of the bearing^^xsd:string | utfpr:Vibration\_14 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string | utfpr:Vibration\_12 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Bolt specification with lower yield strength than required^^xsd:string | utfpr:Vibration\_9 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Loose bearing due to fracture in thread of bolt^^xsd:string | utfpr:Vibration\_7 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Incorrect tightening due to lack of tools^^xsd:string | utfpr:Vibration\_8 | 4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to excessive amount of lubricant (swirling)^^xsd:string | utfpr:Vibration\_4 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to poor sealing that contaminates the lubricant (forming blistering)^^xsd:string | utfpr:LubricantProperty\_2 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear of parts due to poor sealing that contaminates the lubricant with abrasive particles^^xsd:string | utfpr:LubricantProperty\_3 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear due to lack of tightening of parts (looseness)^^xsd:string | utfpr:Vibration\_5 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to low lubricant level^^xsd:string | utfpr:Temperature\_1 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to incorrect lubricant specification^^xsd:string | utfpr:LubricantProperty\_1 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Pitting corrosion due to contamination of the lubricant^^xsd:string | utfpr:Vibration\_6 | 4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to vibration of bearing housing^^xsd:string | utfpr:Vibration\_3 | 4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to lack tightening on the bearing sides (looseness)^^xsd:string | utfpr:Vibration\_2 | 4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to load above projected capacity^^xsd:string | utfpr:Vibration\_1 | 5 |

## According to the Symptoms found for the Component\_1, what are the most effective monitoring techniques to be employed?

SELECT ?Component ?ComponentFunction ?FailureMode ?FailureCause ?Symptom ?Technique

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasFunction ?ComponentFunction;

utfpr:hasMode ?FailureMode.

?FailureMode utfpr:hasCause ?PotencialCause.

?PotencialCause utfpr:isCausedBy ?FailureCause;

utfpr:hasSymptom ?Symptom.

?Symptom utfpr:isDetectedWith ?Technique }

ORDER BY ?FailureMode

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Component** | **ComponentFunction** | **FailureMode** | **FailureCause** | **Symptom** | **Technique** |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Angular misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Vibration\_10 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Parallel misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Vibration\_11 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to interference fit above of specified^^xsd:string | utfpr:Temperature\_3 | utfpr:InfraredThermography |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to lack of free side for dilation^^xsd:string | utfpr:Temperature\_4 | utfpr:InfraredThermography |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue due to fastening bolt loose^^xsd:string | utfpr:Vibration\_15 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:Temperature\_2 | utfpr:InfraredThermography |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:Vibration\_13 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to excessive tightening on the sides of the bearing^^xsd:string | utfpr:Vibration\_14 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string | utfpr:Vibration\_12 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Bolt specification with lower yield strength than required^^xsd:string | utfpr:Vibration\_9 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Loose bearing due to fracture in thread of bolt^^xsd:string | utfpr:Vibration\_7 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Loose bearing due to fracture in thread of bolt^^xsd:string | utfpr:Vibration\_7 | utfpr:VisulInspection\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Incorrect tightening due to lack of tools^^xsd:string | utfpr:Vibration\_8 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to excessive amount of lubricant (swirling)^^xsd:string | utfpr:Vibration\_4 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to poor sealing that contaminates the lubricant (forming blistering)^^xsd:string | utfpr:LubricantProperty\_2 | utfpr:OilAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear of parts due to poor sealing that contaminates the lubricant with abrasive particles^^xsd:string | utfpr:LubricantProperty\_3 | utfpr:OilAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear due to lack of tightening of parts (looseness)^^xsd:string | utfpr:Vibration\_5 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to low lubricant level^^xsd:string | utfpr:Temperature\_1 | utfpr:InfraredThermography |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to incorrect lubricant specification^^xsd:string | utfpr:LubricantProperty\_1 | utfpr:OilAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Pitting corrosion due to contamination of the lubricant^^xsd:string | utfpr:Vibration\_6 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to vibration of bearing housing^^xsd:string | utfpr:Vibration\_3 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to lack tightening on the bearing sides (looseness)^^xsd:string | utfpr:Vibration\_2 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to load above projected capacity^^xsd:string | utfpr:Vibration\_1 | utfpr:VibrationAnalysis\_1 |

## According to the Symptoms linked to each Potential Cause, what is the most efficient Monitoring Technique according its detectability (DET)?

SELECT ?Component ?ComponentFunction ?FailureMode ?FailureCause ?Symptom ?Technique ?DET

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasFunction ?ComponentFunction;

utfpr:hasMode ?FailureMode.

?FailureMode utfpr:hasCause ?PotencialCause.

?PotencialCause utfpr:isCausedBy ?FailureCause;

utfpr:hasSymptom ?Symptom.

?Symptom utfpr:isDetectedWith ?Technique;

utfpr:hasDET ?DET }

ORDER BY ?FailureMode

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Component** | **ComponentFunction** | **FailureMode** | **FailureCause** | **Symptom** | **Technique** | **DET** |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Angular misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Vibration\_10 | utfpr:VibrationAnalysis\_1 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Deformation\_1 | Parallel misalignment of shaft due to mounting incorrect^^xsd:string | utfpr:Vibration\_11 | utfpr:VibrationAnalysis\_1 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to interference fit above of specified^^xsd:string | utfpr:Temperature\_3 | utfpr:InfraredThermography | 4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to lack of free side for dilation^^xsd:string | utfpr:Temperature\_4 | utfpr:InfraredThermography | 4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue due to fastening bolt loose^^xsd:string | utfpr:Vibration\_15 | utfpr:VibrationAnalysis\_1 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:Temperature\_2 | utfpr:InfraredThermography | 4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:Vibration\_13 | utfpr:VibrationAnalysis\_1 | 4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Ductile crack due to excessive tightening on the sides of the bearing^^xsd:string | utfpr:Vibration\_14 | utfpr:VibrationAnalysis\_1 | 4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Fracture\_1 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string | utfpr:Vibration\_12 | utfpr:VibrationAnalysis\_1 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Bolt specification with lower yield strength than required^^xsd:string | utfpr:Vibration\_9 | utfpr:VibrationAnalysis\_1 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Loose bearing due to fracture in thread of bolt^^xsd:string | utfpr:Vibration\_7 | utfpr:VibrationAnalysis\_1 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Loose bearing due to fracture in thread of bolt^^xsd:string | utfpr:Vibration\_7 | utfpr:VisulInspection\_1 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Incorrect tightening due to lack of tools^^xsd:string | utfpr:Vibration\_8 | utfpr:VibrationAnalysis\_1 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to excessive amount of lubricant (swirling)^^xsd:string | utfpr:Vibration\_4 | utfpr:VibrationAnalysis\_1 | 4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to poor sealing that contaminates the lubricant (forming blistering)^^xsd:string | utfpr:LubricantProperty\_2 | utfpr:OilAnalysis\_1 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear of parts due to poor sealing that contaminates the lubricant with abrasive particles^^xsd:string | utfpr:LubricantProperty\_3 | utfpr:OilAnalysis\_1 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Wear due to lack of tightening of parts (looseness)^^xsd:string | utfpr:Vibration\_5 | utfpr:VibrationAnalysis\_1 | 3 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to low lubricant level^^xsd:string | utfpr:Temperature\_1 | utfpr:InfraredThermography | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to incorrect lubricant specification^^xsd:string | utfpr:LubricantProperty\_1 | utfpr:OilAnalysis\_1 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Pitting corrosion due to contamination of the lubricant^^xsd:string | utfpr:Vibration\_6 | utfpr:VibrationAnalysis\_1 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to vibration of bearing housing^^xsd:string | utfpr:Vibration\_3 | utfpr:VibrationAnalysis\_1 | 5 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Fretting wear due to lack tightening on the bearing sides (looseness)^^xsd:string | utfpr:Vibration\_2 | utfpr:VibrationAnalysis\_1 | 4 |
| utfpr:RollingBearing\_1 | Support and allows the shaft rotates without friction, at a given rpm^^xsd:string | utfpr:Wear\_1 | Adhesive wear due to load above projected capacity^^xsd:string | utfpr:Vibration\_1 | utfpr:VibrationAnalysis\_1 | 5 |

## According to our research, between SEV, DGN and DET. The most relevant is SEV. So, what is the highest SEV value of Component\_1?

SELECT ?Component ?FailureMode ?FailureCause ?Effect ?Symptom ?Technique ?SEV

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasMode ?FailureMode.

?FailureMode utfpr:hasCause ?PotencialCause;

utfpr:hasEffect ?Effect.

?PotencialCause utfpr:isCausedBy ?FailureCause;

utfpr:hasSymptom ?Symptom.

?Symptom utfpr:isDetectedWith ?Technique.

?Effect utfpr:hasSEV ?SEV;

utfpr:hasSEV "4"}

OTHER WAY:

SELECT ?Component ?FailureMode ?FailureCause ?Effect ?Symptom ?Technique ?SEV

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasMode ?FailureMode.

?FailureMode utfpr:hasCause ?PotencialCause;

utfpr:hasEffect ?Effect.

?PotencialCause utfpr:isCausedBy ?FailureCause;

utfpr:hasSymptom ?Symptom.

?Symptom utfpr:isDetectedWith ?Technique.

?Effect utfpr:hasSEV ?SEV.

FILTER (?SEV = 4 )}

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Component** | **FailureMode** | **FailureCause** | **Effect** | **Symptom** | **Techniqye** | **SEV** |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Ductile crack due to interference fit above of specified^^xsd:string | utfpr:OperationImpaired\_1 | utfpr:Temperature\_3 | utfpr:InfraredThermography | 4 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Ductile crack due to lack of free side for dilation^^xsd:string | utfpr:OperationImpaired\_1 | utfpr:Temperature\_4 | utfpr:InfraredThermography | 4 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Fatigue due to fastening bolt loose^^xsd:string | utfpr:OperationImpaired\_1 | utfpr:Vibration\_15 | utfpr:VibrationAnalysis\_1 | 4 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:OperationImpaired\_1 | utfpr:Temperature\_2 | utfpr:InfraredThermography | 4 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string | utfpr:OperationImpaired\_1 | utfpr:Vibration\_13 | utfpr:VibrationAnalysis\_1 | 4 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Ductile crack due to excessive tightening on the sides of the bearing^^xsd:string | utfpr:OperationImpaired\_1 | utfpr:Vibration\_14 | utfpr:VibrationAnalysis\_1 | 4 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string | utfpr:OperationImpaired\_1 | utfpr:Vibration\_12 | utfpr:VibrationAnalysis\_1 | 4 |

## After filtering the Failure Modes by SEV. What are the Failure Modes with highest DGN?

SELECT ?Component ?FailureMode ?FailureCause ?Effect ?SEV ?Symptom ?DGN ?Technique

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasMode ?FailureMode.

?FailureMode utfpr:hasCause ?PotencialCause;

utfpr:hasEffect ?Effect.

?PotencialCause utfpr:isCausedBy ?FailureCause;

utfpr:hasSymptom ?Symptom.

?Symptom utfpr:isDetectedWith ?Technique;

utfpr:hasDGN ?DGN.

?Effect utfpr:hasSEV ?SEV.

FILTER (?SEV = 4 )

FILTER (?DGN = 5 )}

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Componente** | **FailureMode** | **FailureCause** | **Effect** | **SEV** | **Symptom** | **DGN** | **Technique** |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Fatigue due to fastening bolt loose^^xsd:string | utfpr:OperationImpaired\_1 | 4 | utfpr:Vibration\_15 | 5 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string | utfpr:OperationImpaired\_1 | 4 | utfpr:Vibration\_12 | 5 | utfpr:VibrationAnalysis\_1 |

## What are the Failure Modes with highest SEV, DGN and DET?

SELECT ?Component ?FailureMode ?FailureCause ?Effect ?SEV ?Symptom ?DGN ?Technique ?DET

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasMode ?FailureMode.

?FailureMode utfpr:hasCause ?PotencialCause;

utfpr:hasEffect ?Effect.

?PotencialCause utfpr:isCausedBy ?FailureCause;

utfpr:hasSymptom ?Symptom.

?Symptom utfpr:isDetectedWith ?Technique;

utfpr:hasDGN ?DGN;

utfpr:hasDET ?DET.

?Effect utfpr:hasSEV ?SEV.

FILTER (?SEV = 4 )

FILTER (?DGN = 5 )

FILTER (?DET = 5 ) }

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Componente** | **FailureMode** | **FailureCause** | **Effect** | **SEV** | **Symptom** | **DGN** | **Technique** | **DET** |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Fatigue due to fastening bolt loose^^xsd:string | utfpr:OperationImpaired\_1 | 4 | utfpr:Vibration\_15 | 5 | utfpr:VibrationAnalysis\_1 | 5 |
| utfpr:RollingBearing\_1 | utfpr:Fracture\_1 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string | utfpr:OperationImpaired\_1 | 4 | utfpr:Vibration\_12 | 5 | utfpr:VibrationAnalysis\_1 | 5 |

# After identifying the most relevant SEV, DGN and DET of Component\_1, using the FMSA technique. Now, using vibration analysis as the most adequate monitoring technique, queries are made to know which data collector should be used, what magnitude, location to be measured and what are its zone boundaries, according to the recommendation of international standards.

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

PREFIX owl: <http://www.w3.org/2002/07/owl#>

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>

PREFIX utfpr: <http://www.semanticweb.org/david/ontologies/2016/untitled-ontology-286#>

## What is the Component\_1 with ID 6306\_C3?

SELECT ?Component

WHERE {?Component utfpr:hasID "6306\_C3" }

|  |
| --- |
| **Component** |
| utfpr:RollingBearing\_1 |

## Using SWRL rules, can be created constraints within data and object properties. Following is created the transitive constraint.

## **NOTE:** Pellet reasoner should be started.

*Component(?C1) ^ FailureMode(?FM1) ^ PotentialCause(?PC1) ^ hasMode(?C1, ?FM1) ^ hasCause(?FM1, ?PC1) -> hasCause(?C1, ?PC1)*

### Now, what is the Potential Cause of Component\_1?

SELECT ?Component ?PotencialCause ?FailureCause

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasCause ?PotencialCause.

?PotencialCause utfpr:isCausedBy ?FailureCause}

ORDER BY ?PotencialCause

|  |  |  |
| --- | --- | --- |
| **Component** | **PotencialCause** | **FailureCause** |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_1 | Adhesive wear due to load above projected capacity^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_10 | Pitting corrosion due to contamination of the lubricant^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_11 | Loose bearing due to fracture in thread of bolt^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_12 | Incorrect tightening due to lack of tools^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_13 | Bolt specification with lower yield strength than required^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_14 | Angular misalignment of shaft due to mounting incorrect^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_15 | Parallel misalignment of shaft due to mounting incorrect^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_16 | Fatigue in rolling bearing parts by housing misalignment^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_17 | Fatigue in bearing parts by mounting with high pressure between housing and bearing/shaft^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_18 | Ductile crack due to excessive tightening on the sides of the bearing^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_19 | Ductile crack due to interference fit above of specified^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_2 | Adhesive wear due to incorrect lubricant specification^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_20 | Ductile crack due to lack of free side for dilation^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_21 | Fatigue due to fastening bolt loose^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_3 | Adhesive wear due to low lubricant level^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_4 | Fretting wear due to lack tightening on the bearing sides (looseness)^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_5 | Fretting wear due to vibration of bearing housing^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_6 | Fretting wear due to poor sealing that contaminates the lubricant (forming blistering)^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_7 | Fretting wear due to excessive amount of lubricant (swirling)^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:PotencialCause\_8 | Wear due to lack of tightening of parts (looseness)^^xsd:string |

## Using SWRL rules, is created the following transitive constraint.

*Component(?C1) ^ PotentialCause(?PC1) ^ Symptom(?Sy1) ^ hasCause(?C1, ?PC1) ^ hasSymptom(?PC1, ?Sy1) -> hasSymptom(?C1, ?Sy1)*

### Now, What are the symptoms of failure causes of Component\_1?

SELECT ?Component ?Symptom

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:hasCause ?Cause.

?Cause utfpr:isCausedBy ?PotencialCause;

utfpr:hasSymptom ?Symptom}

ORDER BY ?Symptom

|  |  |
| --- | --- |
| **Component** | **Symptom** |
| utfpr:RollingBearing\_1 | utfpr:LubricantProperty\_1 |
| utfpr:RollingBearing\_1 | utfpr:LubricantProperty\_2 |
| utfpr:RollingBearing\_1 | utfpr:LubricantProperty\_3 |
| utfpr:RollingBearing\_1 | utfpr:Temperature\_1 |
| utfpr:RollingBearing\_1 | utfpr:Temperature\_2 |
| utfpr:RollingBearing\_1 | utfpr:Temperature\_3 |
| utfpr:RollingBearing\_1 | utfpr:Temperature\_4 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_1 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_10 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_11 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_12 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_13 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_14 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_15 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_2 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_3 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_4 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_5 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_6 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_7 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_8 |
| utfpr:RollingBearing\_1 | utfpr:Vibration\_9 |

## Using SWRL rules, is created the following transitive constraint.

*Component(?C1) ^ Symptom(?Sy1) ^ ConditionMonitoring(?Tch1) ^ hasSymptom(?C1, ?Sy1) ^ isDetectedWith(?Sy1, ?Tch1) -> isDetectedWith(?C1, ?Tch1)*

### Which are the Condition Monitoring techniques using in the Component \_1?

SELECT ?Component ?Technique

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:isDetectedWith ?Technique }

|  |  |
| --- | --- |
| **Component** | **Technique** |
| utfpr:RollingBearing\_1 | utfpr:OilAnalysis\_1 |
| utfpr:RollingBearing\_1 | utfpr:InfraredThermography\_1 |
| utfpr:RollingBearing\_1 | utfpr:VibrationAnalysis\_1 |
| utfpr:RollingBearing\_1 | utfpr:VisulInspection\_1 |

## In this study, is used the vibration analysis technique and the velocity like measurement magnitude.

## **Note: The choice of the monitoring technique to be used was made in item 2, because it is the most adequate to detect symptoms of Componente\_1. In addition, in the vibration analysis technique for Component\_1 could be used the magnitude velocity or acceleration. Among these two magnitudes only velocity has international Standard (in this study, the Standards are considered one specialist).**

## Then, using SWRL rules, is created the following transitive constraint.

*Component(?C1)^ConditionMonitoring(?Tch1)^Magnitude(?Mg1)^isDetectedWith(?C1, ?Tch1)^usedMagnitude(?Tch1, ?Mg1) ->usedMagnitude(?C1, ?Mg1)*

### What is the Magnitude used for Component \_1 Monitoring, and what is its Unit?

SELECT ?Component ?Magnitude ?Unit

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:usedMagnitude ?Magnitude.

?Magnitude utfpr:hasUnit ?Unit

FILTER (?Unit = "mm/s rms") }

|  |  |  |
| --- | --- | --- |
| **Component** | **Magnitude** | **Unit** |
| utfpr:RollingBearing\_1 | utfpr:RMS\_Velocity\_1 | mm/s rms^^xsd:string |

## Which collector is used in the selected monitoring technique??

SELECT ?Component ?Technique ?Magnitude ?Unit ?Transducer

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:isDetectedWith ?Technique.

?Technique utfpr:usedMagnitude ?Magnitude;

utfpr:useCollector ?Transducer.

?Magnitude utfpr:hasUnit ?Unit

FILTER (?Unit = "mm/s rms") }

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **Technique** | **Magnitude** | **Unit** | **Transducer** |
| utfpr:RollingBearing\_1 | utfpr:VibrationAnalysis\_1 | utfpr:RMS\_Velocity\_1 | mm/s rms^^xsd:string | utfpr:Accelerometer\_1 |

## What are the measurement points and its location ID that must be performed in the Component\_1, for the selected technique (Vibration analysis)?

SELECT ?Component ?Technique ?Magnitude ?Unit ?Transducer ?Measurement ?LocationID

WHERE {?Component utfpr:hasID "6306\_C3";

utfpr:isDetectedWith ?Technique;

utfpr:hasMeasurementPoint ?Measurement.

?Measurement utfpr:hasLocationID ?LocationID.

?Technique utfpr:usedMagnitude ?Magnitude;

utfpr:useCollector ?Transducer.

?Magnitude utfpr:hasUnit ?Unit

FILTER (?Unit = "mm/s rms") }

ORDER BY ?Measurement

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Component** | **Technique** | **Magnitude** | **Unit** | **Transducer** | **Measurement** | **LocationID** |
| utfpr:RollingBearing\_1 | utfpr:VibrationAnalysis\_1 | utfpr:RMS\_Velocity\_1 | mm/s rms^^xsd:string | utfpr:Accelerometer\_1 | utfpr:Measurement\_1 | BOM0225\_003\_AC\_180\_R\_N^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:VibrationAnalysis\_1 | utfpr:RMS\_Velocity\_1 | mm/s rms^^xsd:string | utfpr:Accelerometer\_1 | utfpr:Measurement\_2 | BOM0225\_003\_AC\_090\_R\_N^^xsd:string |
| utfpr:RollingBearing\_1 | utfpr:VibrationAnalysis\_1 | utfpr:RMS\_Velocity\_1 | mm/s rms^^xsd:string | utfpr:Accelerometer\_1 | utfpr:Measurement\_3 | BOM0225\_003\_AC\_315\_A\_N^^xsd:string |

## For the vibration analysis technique used in pump with separate driver, there are groups that limit the values collected as: Good, Satisfactory, Alert and Alarm. Which are these groups?

SELECT ?Group

WHERE {?Group rdfs:subClassOf utfpr:VibrationZoneBoundary }

ORDER BY ?Group

|  |
| --- |
| **Groups** |
| utfpr:Group1 |
| utfpr:Group2 |
| utfpr:Group3 |
| utfpr:Group4 |

## What are the Specifications contained in each of these Groups?

SELECT ?Group ?Specification

WHERE {?Group rdf:type utfpr:VibrationZoneBoundary;

utfpr:hasSpecification ?Specification }

ORDER BY ?Group

|  |  |
| --- | --- |
| **Group** | **Specification** |
| utfpr:Group1\_1 | Machines with rated power: 300 kW < P < 50 MW^^xsd:string |
| utfpr:Group1\_1 | Macines with shaft heigt H >= 315 mm^^xsd:string |
| utfpr:Group1\_1 | Is an electrical machine^^xsd:string |
| utfpr:Group2\_1 | Machines with rated power: 15 kw < P <= 300 kW^^xsd:string |
| utfpr:Group2\_1 | Is an electrical machine^^xsd:string |
| utfpr:Group2\_1 | Machines with shaft heigh 160 mm <= H < 315 mm^^xsd:string |
| utfpr:Group3\_1 | Machines with rated power: P > 15kW^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine with separate driver^^xsd:string |
| utfpr:Group4\_1 | Used in pump machine with integrated driver^^xsd:string |
| utfpr:Group4\_1 | Machines with rated power: P > 15kW^^xsd:string |
| utfpr:Group4\_1 | Used in pump machine^^xsd:string |

## Which of these groups is used in pump machine?

SELECT ?Group ?Specification

WHERE {?Group rdf:type utfpr:VibrationZoneBoundary;

utfpr:hasSpecification ?Specification

FILTER (?Specification="Used in pump machine") }

ORDER BY ?Group

|  |  |
| --- | --- |
| **Groups** | **Specification** |
| utfpr:Group3\_1 | Used in pump machine^^xsd:string |
| utfpr:Group4\_1 | Used in pump machine^^xsd:string |

## Otherwise. What are the groups that have among their specification, "used in pump machine"?

SELECT ?Group ?Specification

WHERE {?Group rdf:type utfpr:VibrationZoneBoundary;

utfpr:hasSpecification ?Specification;

utfpr:hasSpecification "Used in pump machine"}

ORDER BY ?Group

|  |  |
| --- | --- |
| **Groups** | **Specification** |
| utfpr:Group3\_1 | Machines with rated power: P > 15kW^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine with separate driver^^xsd:string |
| utfpr:Group4\_1 | Used in pump machine with integrated driver^^xsd:string |
| utfpr:Group4\_1 | Machines with rated power: P > 15kW^^xsd:string |
| utfpr:Group4\_1 | Used in pump machine^^xsd:string |

## We have to make more filters to find the right group. Which is the group that has within its specification - "Machines with rated power: P > 15kW"?

SELECT ?Group ?Specification

WHERE {?Group rdf:type utfpr:VibrationZoneBoundary;

utfpr:hasSpecification ?Specification;

utfpr:hasSpecification "Used in pump machine";

utfpr:hasSpecification "Machines with rated power: P > 15kW"}

ORDER BY ?Group

|  |  |
| --- | --- |
| **Groups** | **Specification** |
| utfpr:Group3\_1 | Machines with rated power: P > 15kW^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine with separate driver^^xsd:string |
| utfpr:Group4\_1 | Used in pump machine with integrated driver^^xsd:string |
| utfpr:Group4\_1 | Machines with rated power: P > 15kW^^xsd:string |
| utfpr:Group4\_1 | Used in pump machine^^xsd:string |

## We have to make more filters to find the right group. Which is the group that has the specification “ Used in pump machine with separate driver (motor)”?

SELECT ?Group ?Specification

WHERE {?Group rdf:type utfpr:VibrationZoneBoundary;

utfpr:hasSpecification ?Specification;

utfpr:hasSpecification "Used in pump machine";

utfpr:hasSpecification "Machines with rated power: P > 15kW";

utfpr:hasSpecification "Used in pump machine with separate driver"}

ORDER BY ?Group

|  |  |
| --- | --- |
| **Groups** | **Specification** |
| utfpr:Group3\_1 | Machines with rated power: P > 15kW^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine with separate driver^^xsd:string |

## Now, we know that Group 3 meets Component\_1. So, what are the Group\_3 specifications?

SELECT ?Group ?Specification

WHERE {?Group rdf:type utfpr:Group3;

utfpr:hasSpecification ?Specification}

|  |  |
| --- | --- |
| **Group** | **Specification** |
| utfpr:Group3\_1 | Machines with rated power: P > 15kW^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine with separate driver^^xsd:string |

## According to ISO 10816-3 standard, for Group 3 the velocity (rms mm/s):

### > = 0 and <= 2.3 is within of good zone boundary, i.e. Good zone. For this constraint is created the rule:

*Group3(?Gp3) ^ hasZone(?Gp3, "Good") -> hasVelocity(?Gp3, "greater than or equal 0 and less than or equal 2.3")*

### > 2.3 and <= 4.5 is within of satisfactory zone boundary, i.e. Satisfactory zonne. For this constraint is created the rule:

*Group3(?Gp3) ^ hasZone(?Gp3, "Satisfactory") -> hasVelocity(?Gp3, "greater than 2.3 and less than or equal 4.5")*

### > 4.5 and <= 7.1 is within of alert zone boundar, i.e. Alert zone. For this constraint is created the rule:

Group3(?Gp3) ^ hasZone(?Gp3, "Alert") -> hasVelocity(?Gp3, "greater than 4.5 and less than or equal 7.1")

### > 7.1 is within of alarm zone boundary, i.e. Alarm zone. For this constraint is created the rule:

Group3(?Gp3) ^ hasZone(?Gp3, "Alarm") -> hasVelocity(?Gp3, "greater than 7.1")

## **After the SWRL rules have been made, we can perform the following queries:**

## Which are the velocity zone boundary, considered as "Good"?

Note: To obtain this query we must enter the value "Good" in hasZone Data Properties.

SELECT ?Group ?Specification ?ZoneBoundary ?Velocity

WHERE {?Group rdf:type utfpr:Group3;

utfpr:hasSpecification ?Specification;

utfpr:hasZone ?ZoneBoundary;

utfpr:hasVelocity ?Velocity }

|  |  |  |  |
| --- | --- | --- | --- |
| **Group** | **Specification** | **ZoneBoundary** | **Velocity** |
| utfpr:Group3\_1 | Machines with rated power: P > 15kW^^xsd:string | Good^^xsd:string | greater than or equal 0 and less than or equal 2.3^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine^^xsd:string | Good^^xsd:string | greater than or equal 0 and less than or equal 2.3^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine with separate driver^^xsd:string | Good^^xsd:string | greater than or equal 0 and less than or equal 2.3^^xsd:string |

## Which are the velocity zone boundary, considered as "Satisfactory"?

Note: To obtain this query we must enter the value "Satisfactory" in hasZone Data Properties.

SELECT ?Group ?Specification ?ZoneBoundary ?Velocity

WHERE {?Group rdf:type utfpr:Group3;

utfpr:hasSpecification ?Specification;

utfpr:hasZone ?ZoneBoundary;

utfpr:hasVelocity ?Velocity }

|  |  |  |  |
| --- | --- | --- | --- |
| **Group** | **Specification** | **ZoneBoundary** | **Velocity** |
| utfpr:Group3\_1 | Machines with rated power: P > 15kW^^xsd:string | Satisfactory^^xsd:string | greater than 2.3 and less than or equal 4.5^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine^^xsd:string | Satisfactory^^xsd:string | greater than 2.3 and less than or equal 4.5^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine with separate driver^^xsd:string | Satisfactory^^xsd:string | greater than 2.3 and less than or equal 4.5^^xsd:string |

## Which are the velocity zone boundary, considered as "Alert"?

Note: To obtain this query we must enter the value "Alert" in hasZone Data Properties.

SELECT ?Group ?Specification ?ZoneBoundary ?Velocity

WHERE {?Group rdf:type utfpr:Group3;

utfpr:hasSpecification ?Specification;

utfpr:hasZone ?ZoneBoundary;

utfpr:hasVelocity ?Velocity }

|  |  |  |  |
| --- | --- | --- | --- |
| **Group** | **Specification** | **ZoneBoundary** | **Velocity** |
| utfpr:Group3\_1 | Machines with rated power: P > 15kW^^xsd:string | Alert^^xsd:string | greater than 4.5 and less than or equal 7.1^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine^^xsd:string | Alert^^xsd:string | greater than 4.5 and less than or equal 7.1^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine with separate driver^^xsd:string | Alert^^xsd:string | greater than 4.5 and less than or equal 7.1^^xsd:string |

## Which are the velocity zone boundary, considered as "Alarm"?

Note: To obtain this query we must enter the value "Alarm" in hasZone Data Properties.

SELECT ?Group ?Specification ?ZoneBoundary ?Velocity

WHERE {?Group rdf:type utfpr:Group3;

utfpr:hasSpecification ?Specification;

utfpr:hasZone ?ZoneBoundary;

utfpr:hasVelocity ?Velocity }

|  |  |  |  |
| --- | --- | --- | --- |
| **Group** | **Specification** | **ZoneBoundary** | **Velocity** |
| utfpr:Group3\_1 | Machines with rated power: P > 15kW^^xsd:string | Alarm^^xsd:string | greater than 7.1^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine^^xsd:string | Alarm^^xsd:string | greater than 7.1^^xsd:string |
| utfpr:Group3\_1 | Used in pump machine with separate driver^^xsd:string | Alarm^^xsd:string | greater than 7.1^^xsd:string |

# After the component-related information queries, such as its diagnostic history, failure modes and most relevant monitoring technique. Beside, its measurement parameters of the selected technique, such as type of collector, measurement location, measurement magnitude and its acceptable and non-acceptable zone values. Now, data collection on the factory floor is simulated (with the "has current value"), making inferences to know the health of the component and providing warnings for decision making, such as the prognostics of a failure and scheduling its Condition Based Maintenance (CBM).

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

PREFIX owl: <http://www.w3.org/2002/07/owl#>

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>

PREFIX utfpr: <http://www.semanticweb.org/david/ontologies/2016/untitled-ontology-286#>

In order to be able to make the inferences in the measuring locations which have already been identified in item 3. Following, SWRL rules must be elaborated:

*VibrationMeasurement(?M1) ^ hasCurrentValue(?M1, ?A) ^ swrlb:greaterThanOrEqual(?A, 0) ^ swrlb:lessThanOrEqual(?A, 2.3) -> hasHealth(?M1, "Good")*

*VibrationMeasurement(?M1) ^ hasHealth(?M1, ?A) ^ swrlb:equal(?A, "Good") -> hasWarning(?M1, "Collect new data in 3 months")*

*VibrationMeasurement(?M1) ^ hasCurrentValue(?M1, ?B) ^ swrlb:greaterThan(?B, 2.3) ^ swrlb:lessThanOrEqual(?B, 4.5) -> hasHealth(?M1, "Satisfactory")*

*hasHealth(?M1, ?B) ^ VibrationMeasurement(?M1) ^ swrlb:equal(?B, "Satisfactory") -> hasWarning(?M1, "Collect new data in 1 months")*

*VibrationMeasurement(?M1) ^ hasCurrentValue(?M1, ?C) ^ swrlb:greaterThan(?C, 4.5) ^ swrlb:lessThanOrEqual(?C, 7.1) -> hasHealth(?M1, "Alert")*

*hasHealth(?M1, ?C) ^ swrlb:equal(?C, "Alert") ^ VibrationMeasurement(?M1) -> hasWarning(?M1, "Schedule Condition-based Maintenance")*

*VibrationMeasurement(?M1) ^ hasCurrentValue(?M1, ?D) ^ swrlb:greaterThan(?D, 7.1) -> hasHealth(?M1, "Alarm")*

*hasHealth(?M1, ?D) ^ swrlb:equal(?D, "Alarm") ^ VibrationMeasurement(?M1) -> hasWarning(?M1, "Turn off equipment")*

## When we perform the collection of data in the measurement location 1 that has ID “BOM0225\_003\_AC\_180\_R\_N”. E.g., if the value collected is 2.1, what is the health of the Component\_1 and its warning message?

SELECT ?Component ?MeasurementPoint ?Health ?WarningMessage

WHERE {?Component utfpr:hasID"6306\_C3";

utfpr:hasMeasurementPoint ?MeasurementPoint.

?MeasurementPoint utfpr:hasLocationID "BOM0225\_003\_AC\_180\_R\_N";

utfpr:hasCurrentValue "2.1";

utfpr:hasHealth ?Health;

utfpr:hasWarning ?WarningMessage }

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **MeasurementPoint** | **HealthMessage** | **WarningMessage** |
| utfpr:RollingBearing\_1 | utfpr:Measurement\_1 | Good^^xsd:string | Collect new data in 3 months^^xsd:string |

## When we perform the collection of data in the measurement location 1 that has ID “BOM0225\_003\_AC\_180\_R\_N”. E.g., if the value collected is 2.31, what is the health of the Component\_1 and its warning message?

SELECT ?Component ?MeasurementPoint ?Health ?WarningMessage

WHERE {?Component utfpr:hasID"6306\_C3";

utfpr:hasMeasurementPoint ?MeasurementPoint.

?MeasurementPoint utfpr:hasLocationID "BOM0225\_003\_AC\_180\_R\_N";

utfpr:hasCurrentValue "2.31";

utfpr:hasHealth ?Health;

utfpr:hasWarning ?WarningMessage }

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **MeasurementPoint** | **HealthMessage** | **WarningMessage** |
| utfpr:RollingBearing\_1 | utfpr:Measurement\_1 | Satisfactory^^xsd:string | Collect new data in 1 months^^xsd:string |

## When we perform the collection of data in the measurement location 1 that has ID “BOM0225\_003\_AC\_180\_R\_N”. E.g., if the value collected is 7.1, what is the health of the Component\_1 and its warning message?

SELECT ?Component ?MeasurementPoint ?Health ?WarningMessage

WHERE {?Component utfpr:hasID"6306\_C3";

utfpr:hasMeasurementPoint ?MeasurementPoint.

?MeasurementPoint utfpr:hasLocationID "BOM0225\_003\_AC\_180\_R\_N";

utfpr:hasCurrentValue "7.1";

utfpr:hasHealth ?Health;

utfpr:hasWarning ?WarningMessage }

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **MeasurementPoint** | **HealthMessage** | **WarningMessage** |
| utfpr:RollingBearing\_1 | utfpr:Measurement\_1 | Alert^^xsd:string | Schedule Condition-based Maintenance^^xsd:string |

## When we perform the collection of data in the measurement location 1 that has ID “BOM0225\_003\_AC\_180\_R\_N”. E.g., if the value collected is 7.11, what is the health of the Component\_1 and its warning message?

SELECT ?Component ?MeasurementPoint ?Health ?WarningMessage

WHERE {?Component utfpr:hasID"6306\_C3";

utfpr:hasMeasurementPoint ?MeasurementPoint.

?MeasurementPoint utfpr:hasLocationID "BOM0225\_003\_AC\_180\_R\_N";

utfpr:hasCurrentValue "7.11";

utfpr:hasHealth ?Health;

utfpr:hasWarning ?WarningMessage }

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **MeasurementPoint** | **HealthMessage** | **WarningMessage** |
| utfpr:RollingBearing\_1 | utfpr:Measurement\_1 | Alarm^^xsd:string | Turn off equipment^^xsd:string |

## When we perform the collection of data in the measurement location 1 that has ID “BOM0225\_003\_AC\_180\_R\_N”. E.g., if the value collected is 5.1, what is the health of the Component\_1 and its warning message?

SELECT ?Component ?MeasurementPoint ?Health ?WarningMessage

WHERE {?Component utfpr:hasID"6306\_C3";

utfpr:hasMeasurementPoint ?MeasurementPoint.

?MeasurementPoint utfpr:hasLocationID "BOM0225\_003\_AC\_180\_R\_N";

utfpr:hasCurrentValue "5.1";

utfpr:hasHealth ?Health;

utfpr:hasWarning ?WarningMessage }

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **MeasurementPoint** | **HealthMessage** | **WarningMessage** |
| utfpr:RollingBearing\_1 | utfpr:Measurement\_1 | Alert^^xsd:string | Schedule Condition-based Maintenance^^xsd:string |

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SELECT DISTINCT ?tipo ?Component ?comentario

WHERE {?Component utfpr:hasCode "6306\_C3"xsd:string .

?Component rdf:type ?tipo .

?tipo rdfs:comment ?comentario

FILTER (langMatches(lang(?comentario), "en"))}