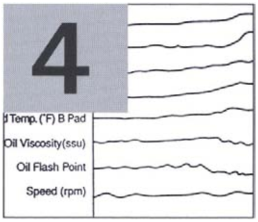

Optimizing CCM and PDM

(Component condition monitoring and predictive maintenance)

- The major machinery components
- Component condition monitoring
- Predictive maintenance (PDM) techniques

The major machinery components

Think of all the machinery that you have been associated with and ask ... What are the major components and systems that are common to all types of rotating equipment?

Figure 4.1 presents the major component classifications for any type of machinery:

- Pumps
- Steam turbines
- Compressors
- Motors
- Gas turbines
- Fans
- Etc.

Major machinery components and systems

- Rotor
- Radial bearing
- Thrust bearing
- Seal
- Auxiliary systems

Figure 4.1 Major machinery components and systems

Regardless of the type of machinery, monitor these components and you will know the total condition of the machine.

Component condition monitoring

As previously stated, component and system functions must first be defined and the normal values for each component listed. These facts are presented in Figure 4.2.

Component and system functions

- Define the function of each affected component
- Define the system in which each affected component operates
- List the normal parameters for each affected component and system component

Figure 4.2 Component and system functions

Once the function of each component is defined, each major machinery component can be monitored as shown in Figure 4.3.

Component condition monitoring

- **Define** each major component
- **List** condition monitoring parameters
- **Obtain** baseline data
- **Trend** data
- **Establish** threshold limits

Figure 4.3 Component condition monitoring

Baseline

Having defined all condition parameters that must be monitored, the next step in a condition monitoring exercise is to obtain baseline information. It is important to obtain baseline information as soon as physically possible after start-up of equipment. However, operations should be consulted to confirm when the unit is operating at rated or lined out conditions. Obtaining baseline information without conferring with operations is not suggested since mis-information could be obtained and thus lead to erroneous conclusions in predictive maintenance. Figure 4.4 states the basics of a baseline condition.

Base line condition

If you don't know where you started, you do not know where you are going!

Figure 4.4 Base line condition

It is amazing to us how many times baseline conditions are ignored. Please remember Figure 4.4 and make it a practice to obtain baseline conditions as soon as possible after start-up.

Trending

Trending is simply the practice of monitoring parameter condition with time. Trending begins with baseline condition and will continue until equipment shutdown. In modern day thought, it is often conjectured that trending must be performed by micro-processors and sophisticated control systems. This is not necessary! Effective trending can be obtained by periodic manual observation of equipment or using equipment available to us in the plant which will include DCS systems, etc. The important fact is to obtain the baseline and trends of data on a periodic basis. When trending data, threshold points should also be defined for each parameter that is trended. This means that when the parameter pre-established value is exceeded action must be taken regarding problem analysis. Setting threshold values a standard percentage above normal value is recommended. Typically values are on the order of 25–30% above baseline values. However, these values must be defined for each component based on experience. Figure 4.5 presents trending data for a hydrodynamic journal bearing. All of the parameters noted in Figure 4.5 should be monitored to define the condition of this journal bearing.

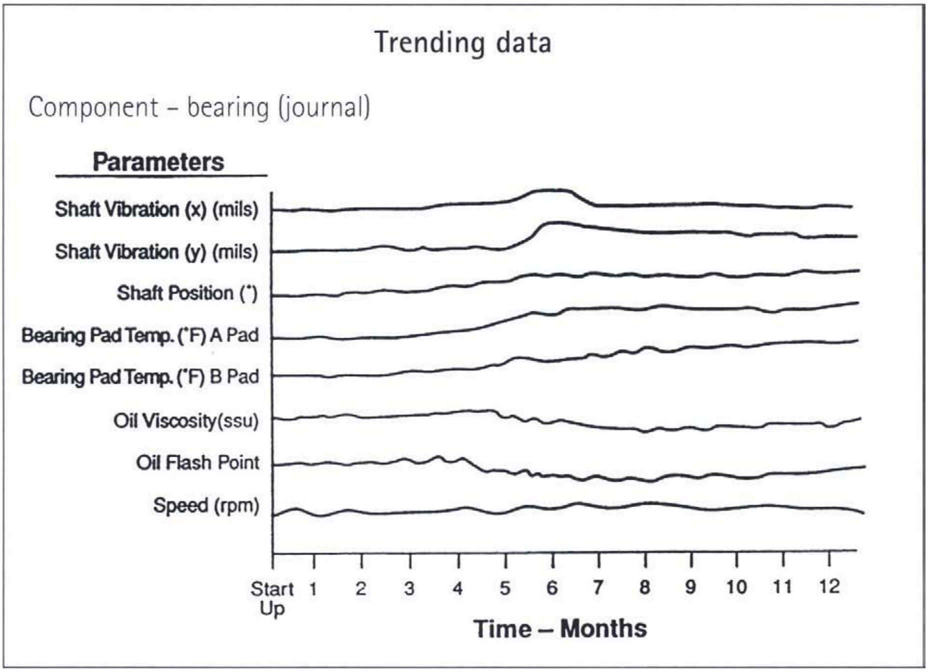

Figure 4.5 Trending data

Specific machinery component and system monitoring parameters and their limits

On the following pages is contained information concerning what parameters should be monitored for each major machinery component to determine its condition. In addition, typical limits are noted for each component.

These limits represent the approximate point at which action should be planned for maintenance. They are not intended to define shutdown values.

The rotor

Rotor condition defines the performance condition (energy and efficiency) of the machine. Figure 4.6 presents this value for a pump.

Pump performance monitoring

1. Take value at minimum flow (shut off discharge valve)
2. Measure:
   - P_1
   - P_2
   - Driver bhp
   - Specific gravity

   Where: P_1 and P_2 = psig, bhp = brake horsepower.
3. Calculate:

   A. head produced $\frac{ft\text{-}lb_f}{lbm} = \frac{\Delta P \times 2.311}{S.G.}$

   B. pump efficiency (%) $= \frac{hd \times gpm \times SG}{3960 \times bhp}$
4. Compare to previous value if > −10% perform maintenance

Figure 4.6 Pump performance monitoring

Radial bearings

Figures 4.7 and 4.8 present the facts concerning anti-friction and hydrodynamic (sleeve) radial or journal bearing condition monitoring.

Condition monitoring parameters and their alarm limits

Journal bearing (anti-friction)

Parameter	limits
1. Bearing housing vibration (peak)	.4 inch/sec (10 mm/sec)
2. Bearing housing temperature	180°F (85°C)
3. Lube oil viscosity	off spec 50%
4. Lube oil particle size	
■ non metallic	25 microns
■ metallic	any magnetic particle in the sump
5. Lube oil water content	below 200 ppm

Figure 4.7 Condition monitoring parameters and their alarm limits – Journal bearing (anti-friction)

Condition monitoring parameters and their alarm limits

Journal bearing (hydrodynamic)

Parameter	Limits
1. Radial vibration (peak to peak)	2.5 mils (60 microns)
2. Bearing pad temperature	220°F (108°C)
3. Radial shaft position*	>30° change and/or 30% position change
4. Lube oil supply temperature	140°F (60°C)
5. Lube oil drain temperature	190°F (90°C)
6. Lube oil viscosity	off spec 50%
7. Lube oil particle size	>25 microns
8. Lube oil water content	below 200 ppm

* Except for gearboxes where greater values are normal from unloaded to loaded

Figure 4.8 Condition monitoring parameters and their alarm limits – Journal bearing (hydrodynamic)

Thrust bearings

Figures 4.9 and 4.10 show condition parameters and their limits for anti-friction and hydrodynamic thrust bearings.

Condition monitoring parameters and their alarm limits

Thrust bearing (anti-friction)

Parameter	Limits
1. Bearing housing vibration (peak)	
■ radial	.4 in/sec (10 mm/sec)
■ axial	.3 in/sec (1 mm/sec)
2. Bearing housing temperature	185°F (85°C)
3. Lube oil viscosity	off spec 50%
4. Lube oil particle size	
■ non metallic	>25 microns
■ metallic	any magnetic particles with sump
5. Lube oil water content	below 200 ppm

Figure 4.9 Condition monitoring parameters and their alarm limits – Thrust bearing (anti-friction)

Condition monitoring parameters and their alarm limits

Thrust bearing (hydrodynamic)

Parameter	Limits
1. Axial displacement*	>15–20 mils (0.4–0.5 mm)
2. Thrust pad temperature	220°F (105°C)
3. Lube oil supply temperature	140°F (60°C)
4. Lube oil drain temperature	190°F (90°C)
5. Lube oil viscosity	off spec 50%
6. Lube oil particle size	>25 microns
7. Lube oil water content	below 200 ppm

* *and* thrust pad temperatures >220°F (105°C)

Figure 4.10 Condition monitoring parameters and their alarm limits – Thrust bearing (hydrodynamic)

Seals

Figure 4.11 presents condition parameters and their limits for a pump liquid mechanical seal.

Condition monitoring parameters and their alarm limits

Pump liquid mechanical seal

Parameter	Limits
1. Stuffing box pressure	<25 psig (175 kpa) **
2. Stuffing box temperature	Below boiling temperature for process liquid
3. Flush line temperature	+/– 20°F (10°C) from pump case temp
4. * Primary seal vent pressure (before orifice)	>10 psi (70 kpag)

* On tandem seal arrangements only

** Typical limit – there are exceptions (Sundyne Pumps)

Figure 4.11 Condition monitoring parameters and their alarm limits – Pump liquid mechanical seal

Auxiliary systems

Condition monitoring parameters and their alarm limits are defined in Figures 4.12 and 4.13 for lube and pump flush systems.

Condition monitoring parameters and their alarm limits

Lube oil systems

Parameters	Limits
1. Oil viscosity	off spec 50%
2. Lube oil water content	below 200 ppm
3. Auxiliary oil pump operating yes/no	operating
4. Bypass valve position (P.D. pumps)	change > 20%
5. Temperature control valve position	Closed, supply temperature > 130 55°C)
6. Filter ΔP	> 25 psid (170 kpag)
7. Lube oil supply valve position	change > +/–20%

Figure 4.12 Condition monitoring parameters and their alarm limits – Lube oil systems

Condition monitoring parameters and their alarm limits	
Pump seal flush (single seal, flush from discharge)	
Parameter	**Limits**
1. Flush line temperature	+/-20°F (+/-10°C) of pump case temperature
2. Seal chamber pressure	< 25 psi (175 kpa) above suction pressure

Figure 4.13 Condition monitoring parameters and their alarm limits – Pump seal flush

Figures 4.14, 4.15 and 4.16 present condition monitoring parameters and limits for dynamic compressor performance, liquid seals and seal oil systems. One final recommendation is presented in Figure 4.14.

Compressor performance condition monitoring

1. Calibrated: pressure and temperature gauges and flow meter
2. Know gas analysis and calculate k, z, m.w
3. Perform as close to rated speed and flow as possible
4. Relationships:

A. $$\frac{N-1}{N} = \frac{LN\frac{(T_2)}{(T_1)}}{LN\frac{(P_2)}{(P_1)}}$$

B. $$EFFICIENCY_{poly} = \frac{\frac{k-1}{k}}{\frac{n-1}{n}}$$

C. $$HEAD_{poly} = \left(\frac{Ft\text{-}lb_f}{Lb_m}\right) = \frac{1545}{MW} \times T_1 \times \frac{n}{n-1} \times Z_{aug} \times \left(\left(\frac{P_2}{P_1}\right)^{\frac{(n-1)}{n}} - 1\right)$$

5. Compare to previous value, if decreasing trend exists greater than 10%, inspect at first opportunity

Figure 4.14 Compressor performance condition monitoring

Condition monitoring parameters and their alarm limits

Compressor liquid seal

Parameter	Limits
1. Gas side seal oil/gas ΔP	
■ bushing	< 12 ft. (3.5m)
■ mechanical contact	< 20 psi (140 kpa)
2. Atmospheric bushing oil drain temperature	200°F (95°C)
3. Seal oil valve* position	> 25% position change
4. Gas side seal oil leakage	> 20 gpd per seal

* supply valve = + 25%
return valve = – 25%
Note this assumes compressor reference gas pressure stays constant

Figure 4.15 Condition monitoring parameters and their alarm limits – Compressor liquid seal

Condition monitoring parameters and their alarm limits

Compressor liquid seal oil systems

Parameters	Limits
1. Oil Viscosity	off spec 50%
2. Oil flash point	below 200°F (100°C)
3. Auxiliary oil pump operating yes/no	operating
4. Bypass valve position (P.D. Pumps)	change > 20%
5. Temperature control valve position	closed, supply temperature 130°F (55°C)
6. Filter ΔP	25 psid (170 kpag)
7. Seal oil valve position	change > 20% open (supply) > 20% closed (return)
8. Seal oil drainer condition	(Proper operation)
■ constant level (yes/no)	level should be observed
■ observed level (yes/no)	level should not be constant
■ time between drains	approximately 1 hour (depends on drainer volume)

Figure 4.16 Condition monitoring parameters and their alarm limits – Compressor liquid seal oil systems

Predictive maintenance (PDM) techniques

Now that the component condition monitoring parameters and their limits have been presented, predictive maintenance techniques must be used if typical condition limits are exceeded. The following chapter will address the techniques used for predictive maintenance analysis and root cause analysis techniques.