Analyzing Imbalance in a 24 MW Steam Turbine

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ABSTRACT

Imbalance in critical rotary equipment is one of the most important factors, which should be controlled to prevent great damages. In this case study we are discussing about a 24 MW steam turbine, which drives a propane compressor. The radial vibration on the DE side of the turbine was growing gradually to a high level close to the alarm's value. Using FFTs, time signals, orbit diagrams, and phase measurement led us to believe that the rotor became imbalanced. After tripping and disassembling the turbine, we found out, some blades of the impulse stage of HP section got broken. Changing the rotor with the spare one, and repair the damaged rotor, worked out. It was concluded that using the vibration analysis technique is an effective method to find critical rotating equipment's faults at the earliest levels. And performing the essential correcting tasks to prevent secondary damages and specially decrease of production.

1. INTRODUCTION

Vibration analysis technique is an effective method to find critical rotating equipment's faults such as imbalance, which is one of the most common defects of machinery that can be so destructive. Trending online values and gathering FFTs; phase measurements; time waveforms and orbit diagrams can help us to determine the faults to prevent secondary damages and specially production decrease at the earliest level even if the machine is very big or sophisticated.

2. IMBALANCE

Condition that exists in a rotor when vibration force or motion imparted to its bearings as result of centrifugal forces(1). Vibration due to unbalance of a rotor is probably the most common machinery defect. It is luckily also very easy to detect and rectify. It may also be defined as the uneven distribution of mass about a rotor's rotating centerline. There are two new terminologies used; one is rotating centerline and the other is geometric centerline. The rotating centerline is defined as the axis about which the rotor would rotate if not constrained by its bearings (also called the principle inertia axis or PIA). The geometric centerline (GCL) is the physical centerline of the rotor. When the two centerlines are coincident, then the rotor will be in a state of balance. When they are apart, the rotor will be unbalanced. There are three types of unbalance that can be encountered on machines, and these are:

1. Static unbalance (PIA and GCL are parallel)
2. Couple unbalance (PIA and GCL intersect in the center)
3. Dynamic unbalance (PIA and GCL do not touch or coincide)(2)

3. DESCRIPTION OF THE PROBLEM

The turbine that mentioned is driver of the refrigerant compressor (propane) which is for Morvarid petrochemical complex-the 5th olefin –in Iran that feeds MehrPC (HDPE) plant. This turbine actually plays the Heart role for the plant.

3.1. Technical Information(3)

Model: Siemens SST-600	Shaft Diameter at bearing DE: 250 mm
Power: 24 MW	Shafter Diameter at bearing NDE: 200 mm
Min speed: 3530 rpm	Inlet steam pressure: 40 bar
Rated speed: 4633 rpm	Inlet steam temperature: 392°C
Trip speed: 5096 rpm	Outlet steam pressure: -0.8 bar
First critical speed: 2890 rpm	Admission pressure: 5 bar
Second critical speed: 7566 rpm	Admission Temperature 180°C
Bearing DE: RKS05-5* 50-BETA=.5L.B.P.	Vibration alarm's value: 150 µm
Bearing NDE: RKS-08-4* 60-BETA=.5L.B.P.	Vibration Trip's value: 194 µm

Figure 1. Turbo Compressor

In 14 Jan 2011, radial vibration values on turbine DE bearing increased a little. Then data acquisition from online monitoring system began to gather FFTs for precise analyzing. Visit the bearing in early August 2011 assure us that it could not be the source of high vibration level.

Figure 2. Not severe pitting (permissible clearance)

Gathering FFTs; time waveforms; orbits and phase values, led us to believe that, rotor might have imbalance or bent shaft defect. Meantime we discovered that X507 was the most important and variable value.

Table 1. Vibration level DE bearing

Date	X507	Date	Y507
02-Apr-11	8	02-Apr-11	8
03-Apr-11	15	03-Apr-11	16
02-May-11	7.5	02-May-11	8
03-May-11	22	03-May-11	13
12-Aug-11	28	12-Aug-11	18
13-Aug-11	45	13-Aug-11	53
26-Sep-11	43	26-Sep-11	54
27-Sep-11	61	27-Sep-11	54
12-Oct-11	71.5	12-Oct-11	52
30-Oct-11	91	30-Oct-11	76
21-Nov-11	105	21-Nov-11	82

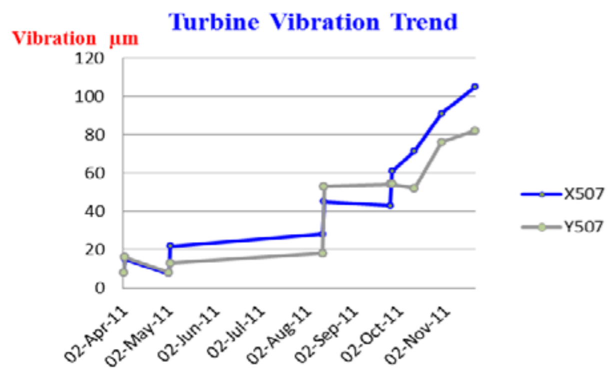

Figure 3.Vibration trend DE bearing

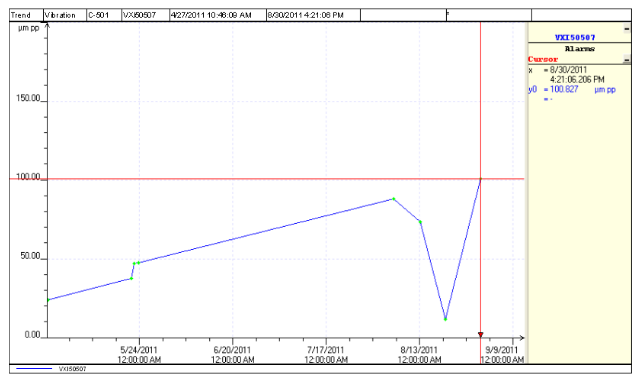

Figure 4. Vibration X507

Comp. Values	X506	Y506	X505	Y505
VIB	3.9	6.1	17	15.5
PHASE	317	68	280	11

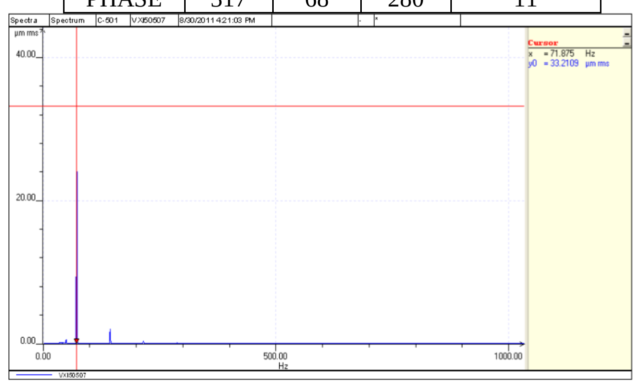

Figure 5. X507 FFT (Obviously 1*rpm excited)

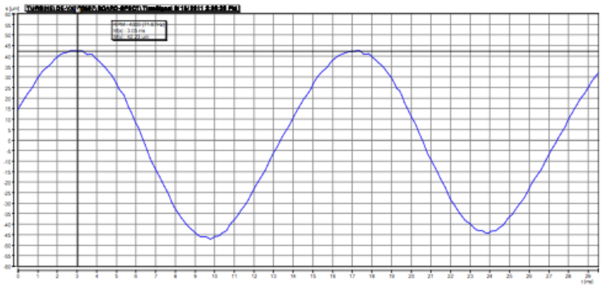

Figure 6. X507 Time Waveform (Absolute Sinusoidal)

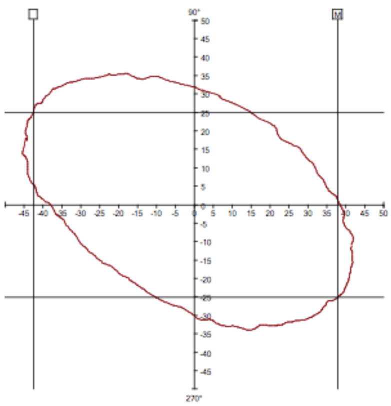

Figure 7. X507 Orbit diagram (Absolute Elliptical)

Table 1. Vibration & Phase Values in rated speed

Turbine Values	X507	Y507	X508	Y508
VIB	81.8	58.5	43.5	10.5
PHASE	357	113	302	24

3.2. Axial Phase Measurement

In order to identify the fault accurately; we should measure the phase difference between axial direction of DE and NDE bearing. Whereas we have DC process values with no raw signal in axial direction instead of axial vibration output in online monitoring system. Then we decided to measure synchronic time waveforms on the two bearings' housing as following:

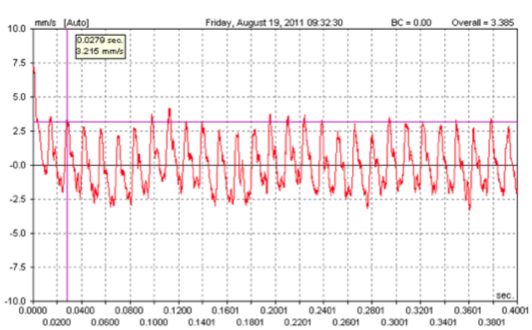

Figure 8. Turbine NDE Synchronous Time waveforms

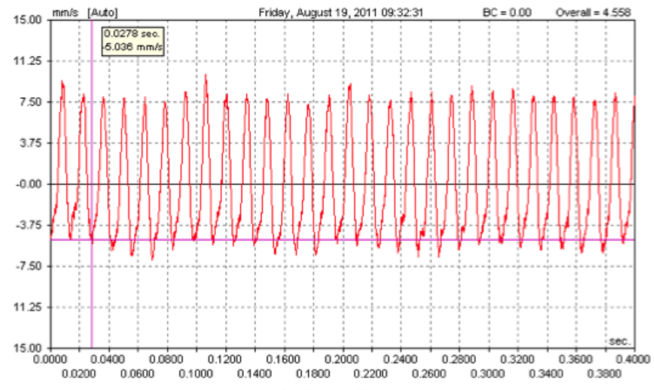

Figure 9. Turbine DE Synchronous Time waveforms (180° Phase difference)

As for 180-degree difference in axial measurement directions; the axial phase difference between turbine DE and NDE bearings is zero. That means the bent shaft theory is rejected. Accordingly imbalance was the final diagnosis. Eventually when vibration level on X507 was about 122 µm, turbine was tripped and disassembled so we saw that some blades of the impulse stage for HP section was broken.

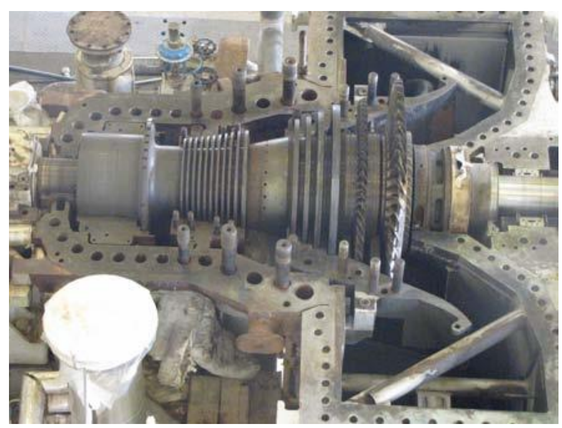

Figure 10. Turbine Disassembly

Figure 11. Hp Broken Blades (Full shot)

Figure 12. Hp broken blades (Detail shot)

By changing the rotor, the vibration levels lowered to near its initial values. And the damaged rotor was sent to shop for repairing.

4. CONCLUSION

However imbalance fault is a common defect, but we should consider that it can happen for any machine of any brand, any type at any time. Meantime we should be aware of this point, trend diagram is a key to recognize and solve problems, and we should not confine to alarm values in standard and manufacturer's recommendation. Finally it is necessary to mention that, axial phase measurement is a very important tool to understand the difference between imbalance and bent shaft.

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