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Research Paper

EFFECT OF LUBE OIL TEMPERATURE ON TURBINE SHAFT VIBRATION

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The new generation of condition monitoring and diagnostics system plays an important role in efficient functioning of power plants. Most rotating machine defects can be detected by such a system much before a dangerous situation occurs. It allows the efficient use of stationary on-line continuous monitoring system for condition monitoring and diagnostics as well. Now a days real time monitoring reduces breakdowns to a large extent. We can conduct it with help of sensors and analyzers with software. T.S.I includes various velocity transducers, accelerometers and LVDT's with suitable automation and software for proper human interaction. By the help of real time monitoring we can assure continuous power supply without any catastrophic failure. The object of this paper is to identify influence of lube oil temperature on turbine shaft vibration at turbo generator at unit-6 (195 MW), Kota super thermal power station by measuring vibration amplitude and analyzing problem with help of Matlab.

Keywords: Lube oil temperature, Turbine shaft displacement, Axial shift, HPT, IPT, LPT

INTRODUCTION

The Lubricating oil system performs three basic functions:

1. It reduces friction between rotating and fixed elements of the turbine and generator such as occur in the journal bearings and thrust bearings.
2. This reduces wear, reduces heat and improves efficiency.
3. It removes heat from the bearings.

This heat may either be generated by friction within the bearing or by conduction along the shaft from the turbines. In mechanical hydraulic governing systems, it is used as a hydraulic pressure fluid. In these governing systems, lubricating oil is used for both the pilot oil and power oil systems.

Working

Figure is a schematic diagram of a typical lubricating oil system. The lubricating oil system is basically very simple. The majority

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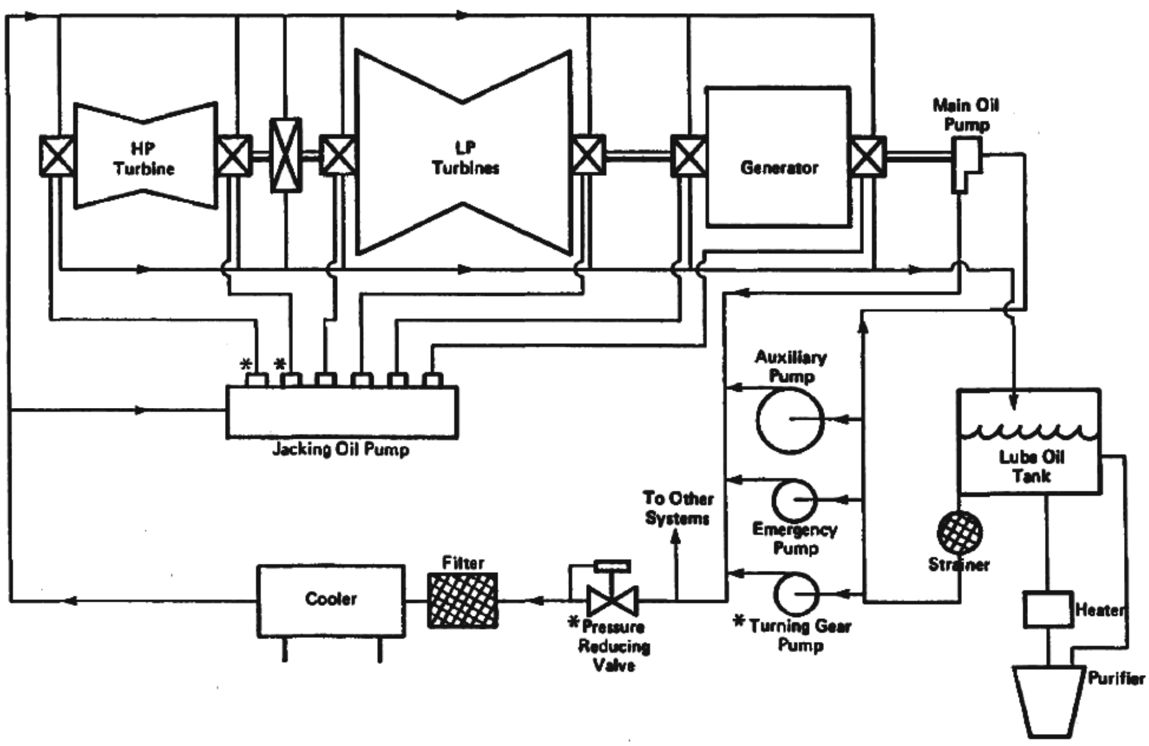
of the lubricating oil is held in a lube oil tank or lube oil sump. The tank has a capacity of between 4 and 10 cubic meters depending on the size of the unit. The lube oil pumps take suction from this tank and discharge the oil at high pressure (typically at a gauge pressure of from 500 to 1000 KPa). The oil mayor may not pass through a strainer prior to entering the pump. From the lube oil pump discharge piping, the majority of the lube oil is sent to the bearings. A small portion of the oil is sent to the control oil system where it is used for pilot oil and power oil. The control oil is at lube oil pump discharge pressure so that the required force to operate the control valves can be achieved with as small a piston as possible (Figure 1).

[*Force* = (*Pressure*) × (*Area*)]

The larger the pressure, the smaller is the required area of the piston. With a small piston area, the volume of oil in the operators is small. This allows for faster response time as it requires less time for oil to move in and out of the operators of the valves. The required oil pressure to the bearings is much lower than that required in the control oil system [100 to 275 KPa(g) is typical]. A higher pressure is not only unnecessary but would require more complicated bearing seals to keep the oil from leaking out of the bearings. For this reason, the lube oil is passed through a pressure reducing valve prior to going to the bearings. On those turbine units with separate hydraulic systems for steam control valve operation, the lube oil pump discharge pressure is only as high as that required by

Figure 1: Lube Oil System for Turbo-Generator



Source: Schuelke (1984)

the bearings. The temperature of the oil flowing to the bearings must be carefully controlled. Coolers are installed in the line to keep the bearing oil at a sufficiently low temperature to properly cool the bearing. However, if the oil is too cool, its viscosity will be high enough to prevent proper oil flow to the bearings. The oil temperature out of the coolers is adjusted to be within a fairly narrow band (43° to 48 °C is typical). The oil flows through full flow filters prior to distribution to the bearings. These filters remove any solid contaminants in the oil which might score the bearings. After passing through the bearing, the oil flows through a drain header back to the lube oil tank.

Main Oil Pump

The main oil pump is the one that delivers all the oil requirements for the turbine-generator at high pressure during normal operation. It is direct-driven from the turbine shaft and may be located at either the turbine or generator end of the shaft. For small units, the main oil pump is generally a gear pump. For large units, a gear pump may not be able to deliver the required quantity of oil at the desired pressure and in this case, a centrifugal type pump is used but it is still driven by the turbine shaft. Because the centrifugal pump is not self priming, large units with centrifugal main oil pumps are equipped with lube oil driven booster pump to keep the main oil pump primed. Because the main lube oil pump is an attached pump, it runs at turbine shaft speed. During startup and shutdown, the main oil pump is not turning fast enough to deliver the required pressure or flow. The speed at which the main oil pump becomes able to handle the lube oil requirements is generally around 90-95% of operating speed.

Auxiliary Oil Pump

The auxiliary oil pump has two functions:

1. It operates during startup and shutdown when the turbine shaft is not rotating fast enough for the main oil pump to deliver the required pressure and flow.
2. It acts as a standby lube oil pump in the event of a main oil pump failure.

The auxiliary lube oil pump is a full flow and full pressure pump which will completely meet the turbine and generator oil needs. In the event of a main lube oil pump failure, the auxiliary oil pump is capable of supplying all bearing and control oil needs to allow continued full power operation. The auxiliary lube oil pump is started and stopped automatically by a pressure switch in the discharge piping of the main oil pump. The auxiliary oil pump is normally driven by a Class IV ac electric motor.

Emergency Oil Pump

The time required for a turbine to run down from operating speed to a stop is typically from 20 to 45 minutes. If the bearings did not receive lubrication during this period, they would rapidly overheat and be destroyed. A turbine trip coupled with a loss of ac power would result in bearing damage during turbine coast down unless the turbine is provided with a source of bearing lubrication. There is no way a modern large turbine generator is protected against a complete loss of lubricating oil at operating speed. The only method of protection is to provide a sufficient number of alternate power supply lube oil pumps to insure all lube oil flow is not lost. The auxiliary lube oil pump is normally backed up with a Class I dc emergency lube oil pump. This pump is automatically started from a pressure switch in the lube oil supply header to the bearings. The emergency lube oil pump is not a full flow or full pressure pump and will not supply the lube oil requirements for continued power operation. It is essentially a coast down pump. The emergency lube oil pump generally puts out insufficient pressure to keep the emergency stop valves and governor steam valves open. Thus a loss of the main and auxiliary lube oil pumps will result in a turbine trip.

Turning Gear Oil Pump

Some generating stations have a reduced capacity Class III ac motor driven lube oil pump for use when the turbine is on the turning gear. In those stations without this turning gear oil pump, the emergency oil pump is used to provide the reduced flow required when the turbine is on the turning gear.

Jacking Oil Pump

This pump is generally used only for large turbine-generators, and then only during the period when the shaft is rotated by the turning gear. When the heavy turbine-generator shaft is at rest, it will squeeze the oil film from under the shaft at the bearings. If the shaft is then rotated, there will be metal to metal rubbing until the oil can work its way underneath. When the unit is rotated on the turning gear, the shaft is not rotating fast enough to keep a good "oil wedge" between the shaft and the bearing surface. This condition can also lead to metal-to-metal contact. To avoid this situation, the jacking oil pump injects oil at high pressure (around 6.9 MPa) into the bearing at the bottom of the shaft. This tends to lift or jack the shaft a few hundredths of a millimeter off the bearing so that there will be no metal-to-metal contact. Once the turbine speed has increased above turning gear speed, the rotation of the shaft will keep an oil wedge under the shaft and the jacking oil pump is no longer required. The jacking oil pump will normally run whenever the turning gear is running and will shutdown when the turning gear is shutdown. The jacking oil pump may take suction either from the oil line supplying the bearings, as shown in Figure 1, or directly from the oil tank. In either case, however, a lubricating oil pump is started. This is because the jacking oil pump does not supply all the bearings, notably the exciter bearings and thrust bearings, and these bearings would receive no oil flow without the auxiliary oil pump. In addition, since the flow from the jacking oil pump is quite small, it may not provide sufficient oil flow to cool the bearings it does supply. The jacking oil pump is generally a reciprocating plunger type pump and supplies the bearings through individual lines from the pump to each bearing.

Oil Purification System

During operation, the lubricating oil becomes contaminated with a variety of undesirable impurities:

- Water which most likely enters the system during shutdown from humidity in the air. Fibers which come from the gasket material used to seal joints in the system.
- Sludge which results from the breakdown of the oil into longer chain molecules and results in a thickening of the oil.

- Organic compounds which result from a slow reaction between the oil, oxygen and the metal piping.
- Metal fragments which come from wear products in the bearings and lube oil pumps.

Under normal operating conditions, none of these contaminants builds up rapidly in the oil, but the amount of contamination required to render lube oil totally unsuitable for use is quite small. Not only do these contaminants destroy the lubricating properties of the oil and accelerate corrosion, but they can act as grit within the bearings to cause bearing wear and unevenness. The insoluble impurities can be removed with filters, but the soluble impurities are only removed by centrifuging. The majority of the oil purification is accomplished with a centrifugal purifier. The purifier normally operates at about 15,000 rpm. Since the sludge, water, fibers and other impurities are denser than the oil; they are thrown to the outside and removed from the oil. The impurities normally are collected in the bottom of the purifier and must be removed at regular intervals. The oil may be heated before it enters the purifier since this lowers the viscosity and improves the separation of impurities from the oil, also water may be deliberately added to the oil before the purifier, to dissolve impurities. All the water, of course, is centrifuged from the oil before it is returned to the system. Centrifuges of sufficient capacity to purify all the oil in the system once every 6-10 hours, are normally installed. While the turbine is operating, the purifier is run virtually continuously to purify the oil. The purifier is also normally run prior to startup to purify the oil and warm it to near operating temperature.

OBSERVATIONS

My observations are related to measure effect of various parameters on vibration of turbo generator at unit-6 at Kota Super Thermal Power Station (KSTPS). As we have discussed above that there are various kind of vibrations in turbo-generator but I have observed that displacements are excessive in shafts as compare to bearings because at bearings, due to lubrication and cooling, horizontal as well as vertical displacement reduces considerably. I have observed that during period of February 2012 to May 2012, many times maximum displacement of shaft at horizontal and vertical direction was higher than its designated safe value of 200 microns. To analyze that we took readings regarding shaft vibrations and lube oil temperature surrounding to that particular peak value and analyze them in matlab to find effect of each parameter on shaft displacement and shaft (Figure 2).

Types of Bearings

- Number-1, 3, 4, 5, 6, 7 are Radial Journal Bearings.
- Number-2 is Thrust Bearing and Radial Journal Bearing.

Shaft vibration measurement conducted at eight places with four parameters as shown in Table 1.

ANALYSIS AND RESULT

Analysis of observed data has performed with help of analyzing software MATLAB (Figures

Figure 2: Vibration Measurement at Given Shaft Locations

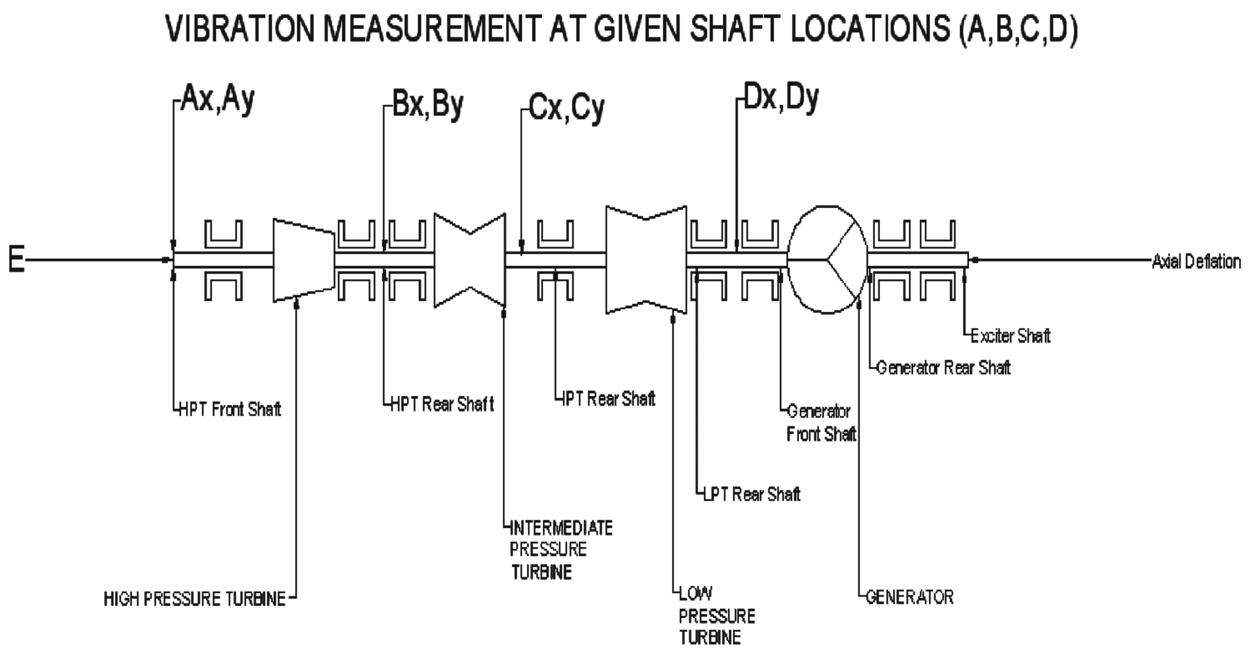
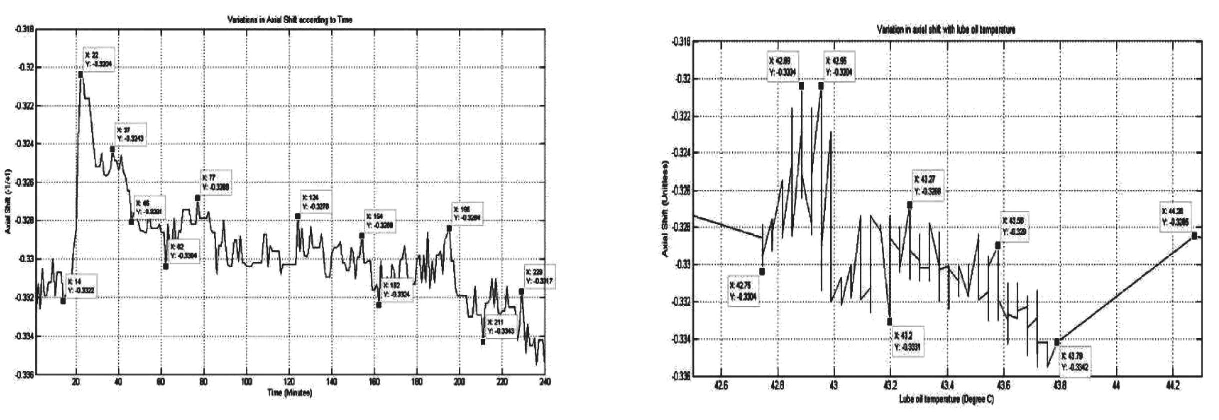


Table 1: Designated Safe Values of Various Parameters During Running Condition of Turbo Generator

S. No.	Abbreviation	Parameter	Unit
1.	Shaft Displacement	200 Microns	300 Microns
2.	Bearing Pedestal Displacement	50 Microns	120 Microns
3.	Axial Shift	(+/-) 0.5	(+/-) 1
4.	Lube Oil Temperature at Aft Cooler	43 °C	45 °C

Figure 3: (a) Time-E; (b) W-E



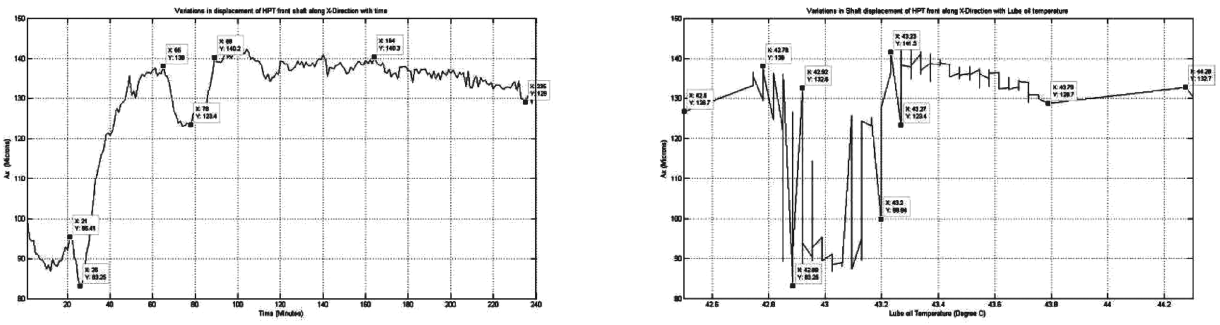
(a) (b)

3 to 13 and Table 2). By those programs we got two plots related to each parameter, i.e.,

1. Time vs. Parameter
2. Parameter vs. Shaft displacement

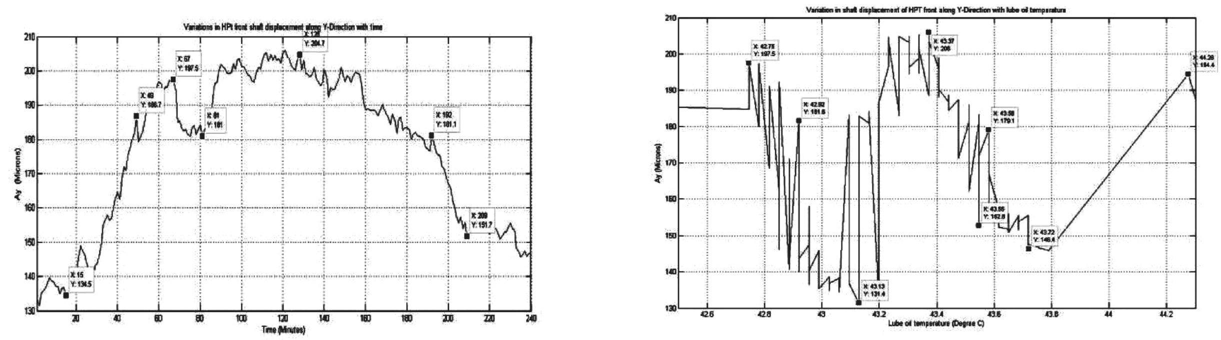
Maximum displacement has observed in HPT front shaft along Y direction.

Figure 4: (a) Time-Ax; (b) W-Ax



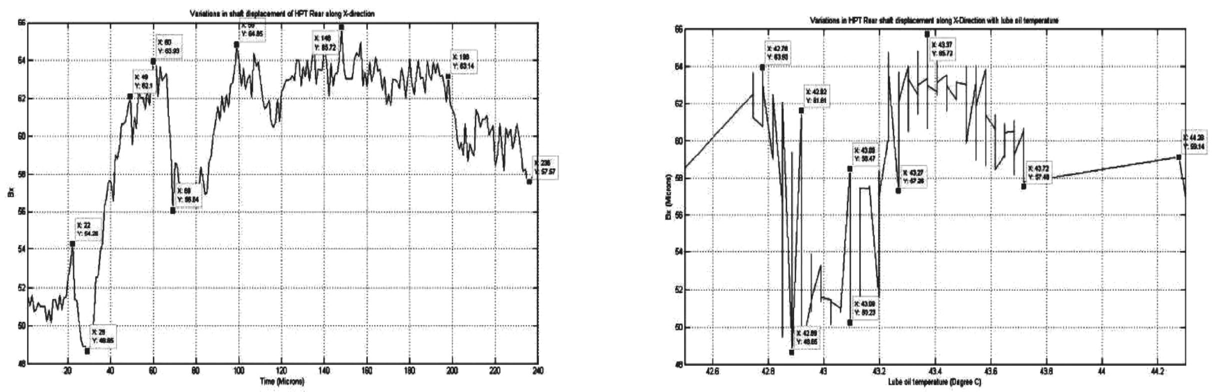
(a) (b)

Figure 5: (a) Time-Ay; (b) W-Ay



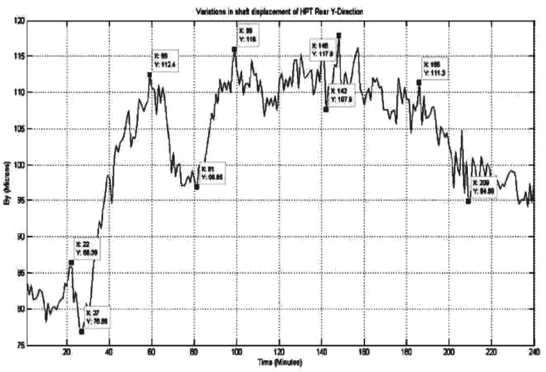
(a) (b)

Figure 6: (a) Time-Bx; (b) W-Bx

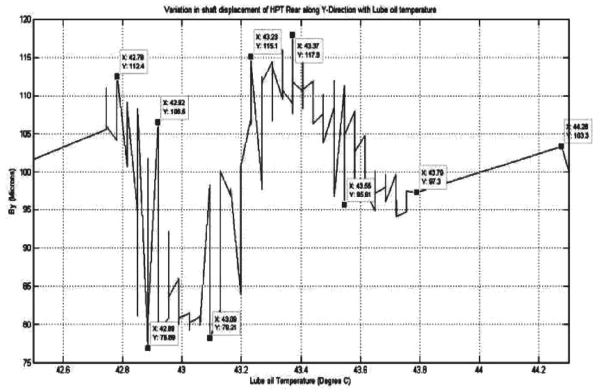


(a) (b)

Figure 7: (a) Time-By; (b) W-By

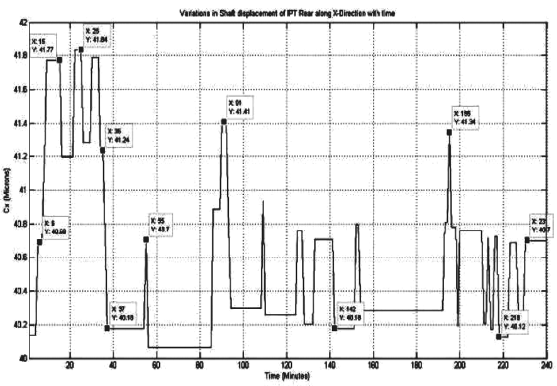


(a)

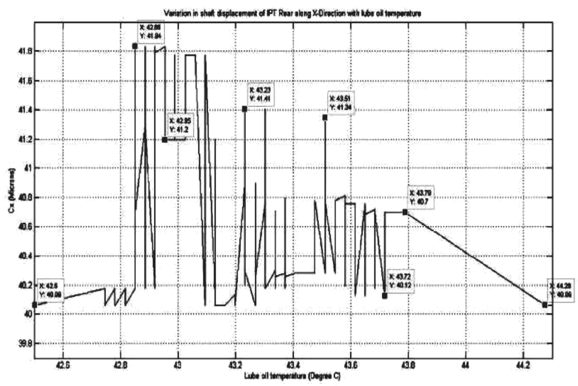


(b)

Figure 8: (a) Time-Cx; (b) W-Cx

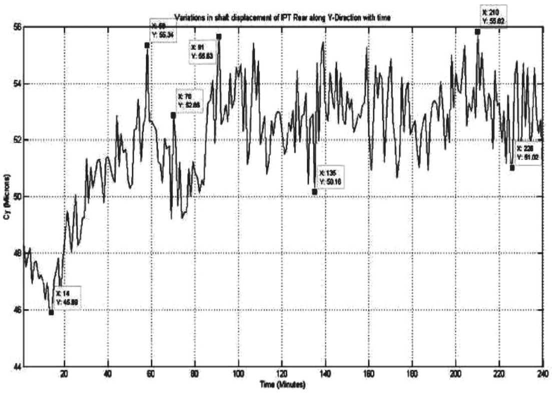


(a)

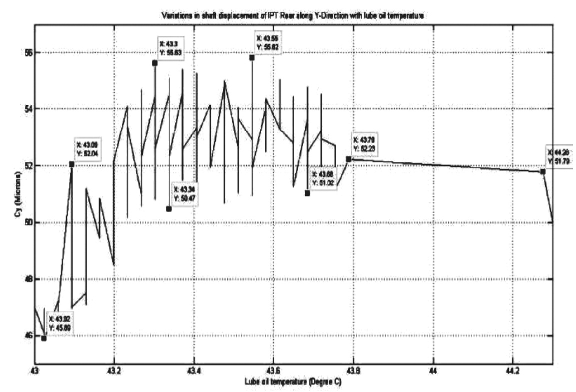


(b)

Figure 9: (a) Time-Cy; (b) W-Cy

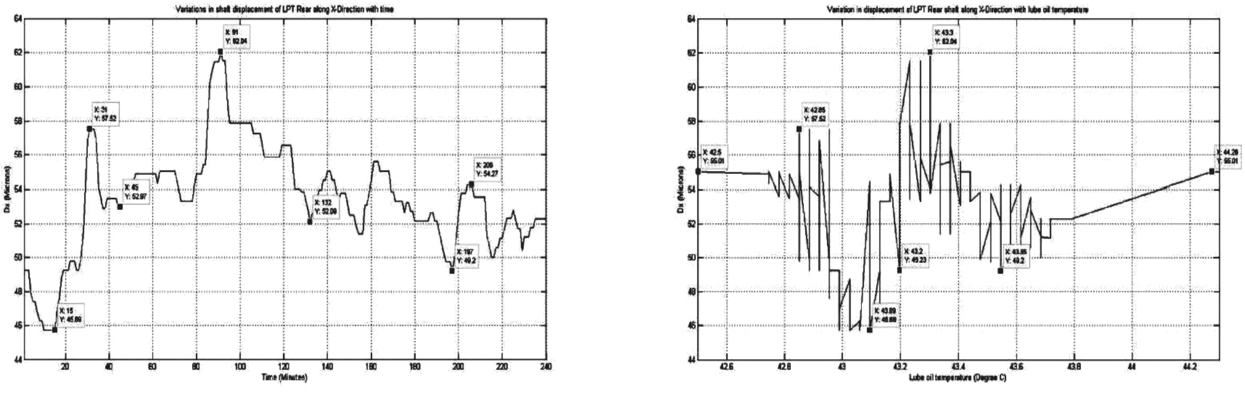


(a)



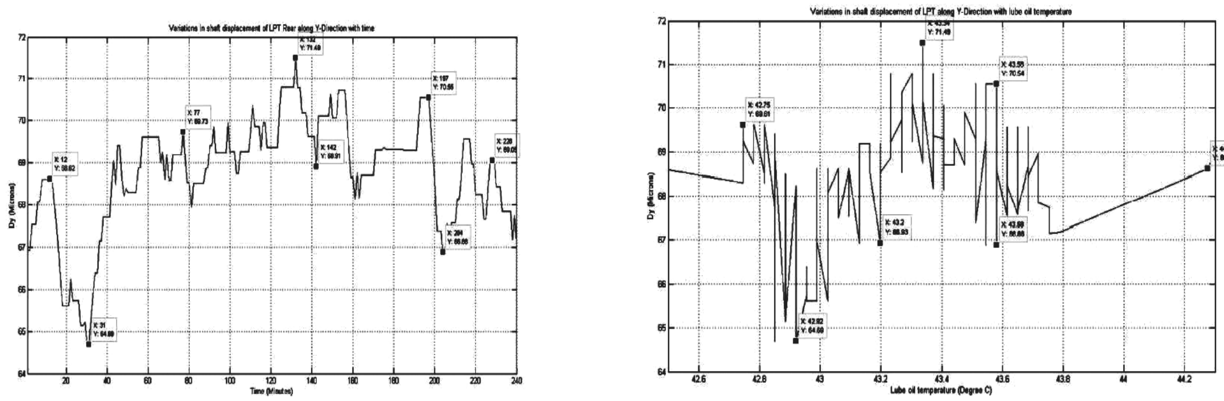
(b)

Figure 10: (a) Time-Dx; (b) W-Dx



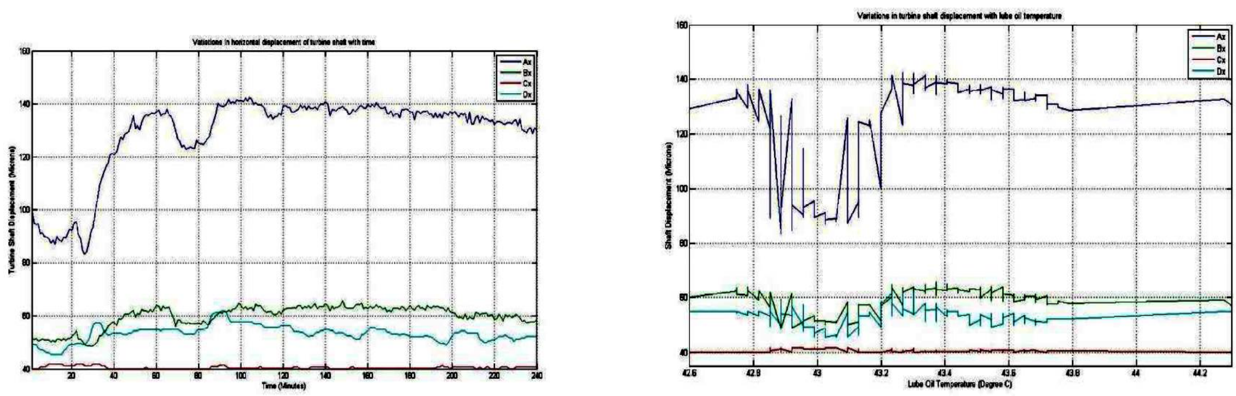
(a) (b)

Figure 11: (a) Time-Dy; (b) W-Dy



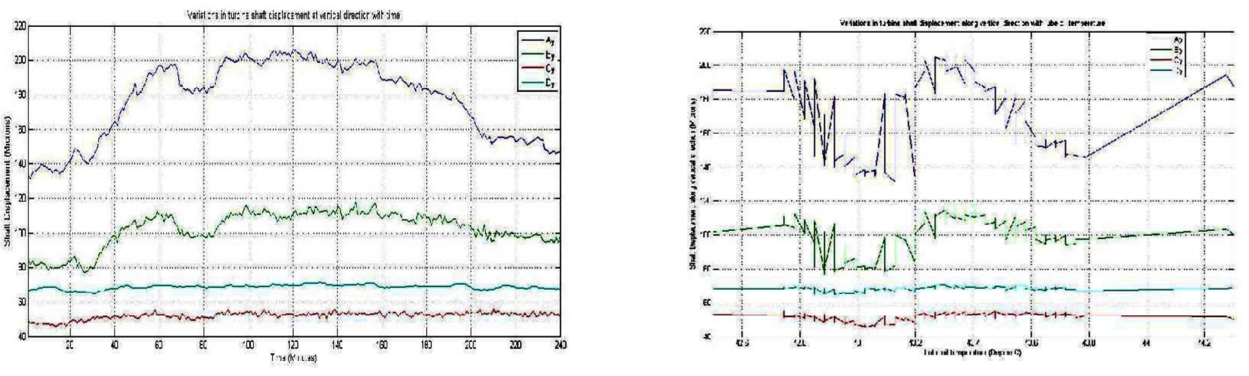
(a) (b)

Figure 12: (a) Time-Ax, Bx, Cx, Dx; (b) W-Ax, Bx, Cx, Dx



(a) (b)

Figure 13: (a) Time-Ay, By, Cy, Dy; (b) W-Ay, By, Cy, Dy



(a) (b)

Table 2: Results from Figures

S. No.	Abbreviations of Parameter	Maximum Value of Shaft Displacement	Corresponding Value of Lube Oil Temperature (°C)	Designated Safe Value of Parameter	Designated Safe Value of Lube Oil Temperature W (°C)
1.	E	–0.3204	42.95	–0.5	43
2.	Ax	141.5 Microns	43.23	200 Microns	43
3.	Ay	206 Microns	43.37	200 Microns	43
4.	Bx	65.72 Microns	43.37	200 Microns	43
5.	By	117.9 Microns	43.37	200 Microns	43
6.	Cx	42.85 Microns	41.84	200 Microns	43
7.	Cy	55.82 Microns	43.55	200 Microns	43
8.	Dx	62.04 Microns	43.30	200 Microns	43
9.	Dy	71.49 Microns	43.34	200 Microns	43

CONCLUSION

- In most of the cases, Turbine shaft displacements are maximum when lube oil temperature is higher than its designated safe value.
- Displacement of HPT front shaft at Y-direction (Ay) is maximum and it is also higher than its designated safe value.
- Corresponding value of lube oil temperature of Ay is also higher than its designated safe value.
- Value of turbine shaft displacements are as per following order:

Cx < Cy < Dx < Bx < Dy < By < Ax < Ay

It is due to bearing supports and cantilever situation of turbine shaft at some positions.

So finally we can make conclusion that displacement of turbine shaft increases when lube oil temperature is higher than its designated safe value.

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APPENDIX

Table: Abbreviations and Units of Various Parameters

S. No.	Abbreviation	Parameter	Unit
1.	Ax	HPT Front, Shaft Displacement along X Direction	Microns
2.	Ay	HPT Front, Shaft Displacement along Y Direction	Microns
3.	Bx	HPT Rear, Shaft Displacement along X Direction	Microns
4.	By	HPT Rear, Shaft Displacement along Y Direction	Microns
5.	Cx	IPT Rear, Shaft Displacement along X Direction	Microns
6.	Cy	IPT Rear, Shaft Displacement along Y Direction	Microns
7.	Dx	LPT Rear, Shaft Displacement along X Direction	Microns
8.	Dy	LPT Rear, Shaft Displacement along Y Direction	Microns
9.	W	Lube Oil Temperature Aft Cooler	°C
10.	E	Axial Shift	Unitless