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Turbine Compressor Vibration Analysis and Rotor Movement Evaluation by Shaft Center Line Method (The Case History Related to Main Turbine Compressor of an Olefin Plant in Iran Oil Industries)

Omid A. Zargar

***Abstract*—**Vibration monitoring methods of most critical equipment like main turbine and compressors always plays important role in preventive maintenance and management consideration in big industrial plants. There are a number of traditional methods like monitoring the overall vibration data from Bently Nevada panel and the *time wave form* (TWF) or *fast Fourier transform* (FFT) monitoring. Besides, Shaft centerline monitoring method developed too much in recent years. There are a number of arguments both in favor of and against this method between people who work in preventive maintenance and condition monitoring systems (vibration analysts). In this paper basic principal of Turbine compressor vibration analysis and rotor movement evaluation by shaft centerline method discussed in details through a case history. This case history is related to main turbine compressor of an olefin plant in Iran oil industry. In addition, some common mistakes that may occur by vibration analyst during the process discussed in details. It is worthy to know that, these mistakes may one of the reasons that sometimes this method seems to be not effective. Furthermore, recent patent and innovation in shaft position and movement evaluation are discussed in this paper.

***Keywords*—**Shaft centerline position, attitude angle, journal bearing, sleeve bearing, tilting pad, steam turbine, main compressor, multistage compressor, condition monitoring, non-contact probe.

I. INTRODUCTION

A. The Importance of Shaft Centerline Position

THE turbine or compressor shafts usually located in journal bearings. The center of the bearing always is in same position because bearing consider as a stationary part after installation but shaft centerline moving in a vertical position. Before beginning the startup process for compressor and warming up the steam turbine, the shaft centerline is below the bearing centerline that calls sleep condition of the main shaft (Fig. 1).

After starting the oil pump of the compressor, this centrifugal pump starts to injecting oil to the bearing and the huge shaft of compressor beginning to moving upward gradually. The new shaft centerline moves over bearing center line in a vertical line (shown in Fig. 2).

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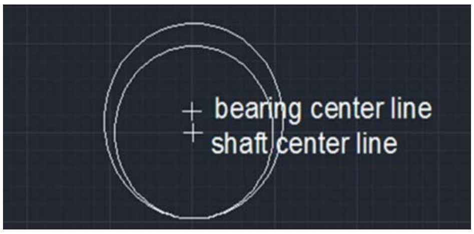

Fig. 1 Bearing center line and shaft center line position in shaft sleep condition

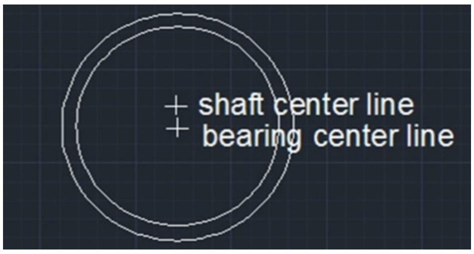

Fig. 2 Bearing center line and shaft center line position before operation

The shaft centerline is always over the bearing center line during the turbo compressor operation. The shaft centerline will change its position during operation. First, the process of changing in shaft center line monitoring is discussed.

The case bearing or housing bearing for most critical equipment is usually thick and the piezoelectric or velocity contact type vibration probes cannot representing the real shaft vibration because of damping phenomena. The traditional condition monitoring systems for most critical equipment like steam turbine, gas turbine and multi stage compressors were based on journal bearing temperature monitoring [1].

B. Technical Considerations

Nowadays the condition monitoring system of these types of machines is usually non-contact type. A typical none contact probe is shown in Fig. 3. Two non-contact probes install with 45 degree over the main shaft are shown in Fig. 5. The installation group calibrates the distance of the probes with shaft due to the material of shaft and probe sensitivity and length of the cables. The probe sensitivity for our non-contact probe is 200 mV/mils called scale factor. It means the probe translate each mils with 200 mV. One mil is unit of distance equal to 25.4 micron usually used in maintenance and mV is equal of 0.001 Volt [2].

Fig. 3 Non-contact type probe with 200 mv/mils sensitivity [2]

The working principle behind eddy current sensors has been shown Fig. 4. It is based on the fact that the coil in the sensor head generates an alternating magnetic field whose field lines emerge from the sensor plane, pass through the object and then close again. The measurement field (alternating magnetic field) generates eddy currents in the electrically conductive object, leading to a loss in joules.

These eddy current losses in the object increase as the distance to the object decreases. On the input side of the sensor coil, the eddy current losses are reflected in a change in the complex input impedance, which is measured and evaluated. An output signal proportional to the distance is formed, such as 0 ... 10 V or 4 ... 20 mA. That all will be translated to micrometer peak to peak [3].

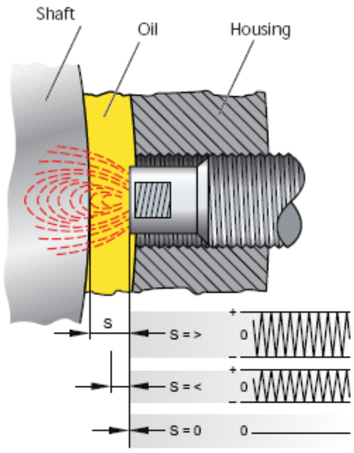

Fig. 4 Measuring principle of an eddy current sensor and definition of direction of movement

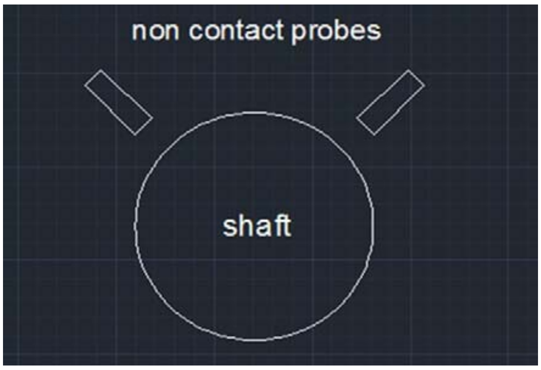

Fig. 5 Bently Nevada non-contact probes that are located with 45˚

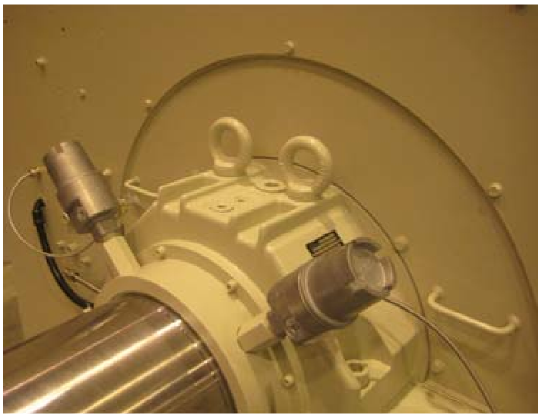

Fig. 6 Typical Bently Nevada connections are located with 45˚ [4]

Beside this monitoring system, A Multi-Probe Setup for the Measurement of Angular Vibrations in a Rotating Shaft recently introduced to measuring the angular vibrations of a rotating shafts that is effective for monitoring the torsional vibrations in huge turbo machines and compressors. The cogwheel shape can be very irregular, for example the “geared wheel” is represented by some bolts mounted on a joint in the shaft.

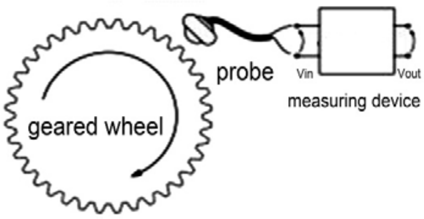

Fig. 7 Measurement of Angular Vibrations in a Rotating Shaft

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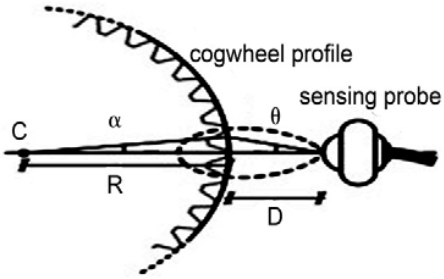

Fig. 8 Experimental set up parameter

By using related formulations, modeling and calibration, a theoretical description is proposed the probe output signal, as a function of the angular vibrations and the cogwheel shape [5].

In addition, Shaft Power and Performance Meter recently developed and consider as new patent in mechanical engineering. This system is self-supervision by using redundant vibrating string transducers that detached from shaft and fixed to clamp rings, which allows easy dismounting. The principal of this method is based on Wireless data and power transmission between shaft and transmission unit [6].

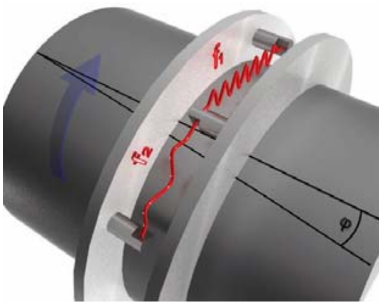

Fig. 9 Principle sensor arrangement

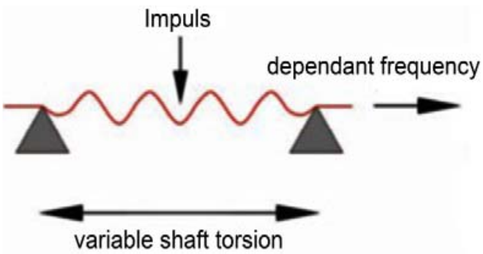

Fig. 10 Vibrating string measuring principle

Fig. 11 Vibrating string transducer MDS 31

If X and Y axis are introduced in the direction of the noncontact probes then the final circle with the center of shaft center line is evaluated just before operation (due to the machinery installation) and the radial of distance between shaft center and bearing center. This circle called *allowable circle*. The shaft center line always should be inside the allowable circle otherwise the touch will accrue between shaft and bearing because of geometry considerations. The shaft center line position has a direction with the center of this circle. This line has a degree with axis Y that called *attitude angle*. Attitude angle should be less than 20° and not more than 50° in optimal operations [7].

The shaft center line position calculated with following formula [8]:

Center line position = Gap (from Bently Nevada monitoring system) - Gap initial (installation time)/scale factor (1)

Gaps usually are in volt and scale factor is in mv/mils then the units should always be converted to volt/mils.

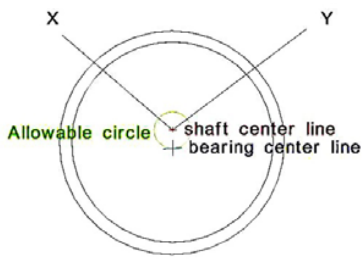

Fig. 12 Allowable circle position

The common mistakes usually occurred when the voltages gathered from probes by installation or machinery group members. The numbers must be accurate enough with 0.01 volt otherwise it will be made the geometry method useless and caused unreliable conclusion [9]. The method has some appendixes. One of them is *Er* number that introduced as the following formula:

Er=the center line displacement to shaft center/radial bearing clearance (2)

The center line displacement to shaft center is calculated by geometric method from the mentioned circles. Besides, the radial bearing clearances are installed by machinery group. *Er* is always between 0 and 1 if *Er* is more than 0.7 the bearing mechanical system is stable otherwise the bearing system probably unstable and closer monitoring should be performed for turbine and compressor [10].

Moreover, the stability of the system is a function of *Er*, RPM of the main shaft and clearance of the bearing [11].

C. Recent Patents and Innovations

One of the new patent and innovation in shaft vibration analysis is Short time amplitude frequency spectrum array for section shaft vibration analysis for mechanical rotor. A short-term spectrum array for mechanic rotor single section shaft vibration analysis called short-term amplitude frequency spectrum array, manufacturing comprising steps of: (1) reading an x signal sequence and y signal sequence in two vertical directions from a section of a rotary shaft collected synchronously; (2) dividing the x signal sequence and y signal sequence according to a certain time delay D and short-term window length L, dividing a group of short-term signal sequence; (3) processing Fourier transformation individually for each pair of two directional short-term signals; (4) solving Fourier levels individually; (5) synthesizing an ellipse by two directional Fourier components of each frequency for each pair of Fourier level; (6) calculating size of major semi axis of the synthesized ellipse, that is shaft vibration component amplitude of each frequency; (7) obtaining short-term amplitude frequency spectrum in the cross section for each pair of two short-term signals, using frequency or order as a transverse axis and shaft vibration amplitude as a vertical axis; (8) arranging short-term amplitude frequency spectrum of each time cross along time axis to obtain short-term amplitude frequency spectrum array [12].

In addition, bearing assemblies including proximity probes for monitoring relative position and vibration of rotating shaft are discussed in [13].

Non-contact probes applications and techniques are recently developed. Methods of measuring copper impurities on a silicon surface are investigated. In certain embodiments, copper is electrically activated by ultra-violet illumination of the surface at room temperature. Activation can enhance the copper contribution to surface recombination and to surface voltage, which are measured in a noncontact manner using an ac-surface photo voltage and a vibrating Kelvin-probe, respectively. Differential measurements before and after activation enable the separations of the copper impurities from other surface contaminants [14].

In addition, a new type of ultra-precision non-contact three-dimensional probing system based on a spherical capacitive plate has a probe which comprises a spherical probing head, a stylus pipe, an active shielding pipe, a signal conducting rod, an insulating element, a stylus holder and a probe body. The stylus pipe, the active shielding pipe and the signal conducting rod are coaxially assembled, and they are insulated against each other with the insulating element. The spherical probing head is mounted at one end of the insulating element, and it has a spherical capacitive plate over its surface. The capacitive signal coming from the spherical capacitive plate is outputted through the signal-conducting rod. The active shielding pipe is driven by the signal converting and processing circuit of the probing system to maintain equipotential with the signal-conducting rod and so the influence of parasitic capacitance and spatial electromagnetic interference can be eliminated [15].

Besides, new techniques developed a system for warming up a steam turbine includes a gas turbine and a controller operably connected to the gas turbine. The controller is programmed to receive a plurality of measured input signals and control the gas turbine to produce an exhaust having a desired energy. A first measured input signal is reflective of a measured operating parameter of the gas turbine and a second measured input signal is reflective of an operating parameter of the steam turbine. A method for warming up a steam turbine includes sending a plurality of measured input signals to a controller, wherein a first measured input signal reflects a measured operating parameter of a gas turbine and a second measured input signal reflects an operating parameter of the steam turbine. The method further includes controlling the gas turbine based on the plurality of measured input signals and producing an exhaust from the gas turbine, wherein the exhaust has a desired energy [16].

Furthermore, an active non-contact probe card developed recently. This technique is provided an active non-contact probe card including a carrier, a support base, a piezoelectric material layer, an active sensor array chip and a control circuit. The support base is disposed on the carrier. The piezoelectric material layer is connected with the support base. The position of the active sensor array chip with respect to the carrier is determined according to the thicknesses of the support base and the thicknesses of the piezoelectric material layer. A control circuit provides a control voltage to the piezoelectric material layer to control the thickness of the piezoelectric material layer, so as to adjust the position of the active sensor array chip with respect to the carrier [17].

Moreover, short time two-dimension holographic spectrum or mechanical rotating shaft vibration analysis developed for rotary equipment. This method can successfully evaluated changes in main shafts vibrational directions. A short-term spectrum array for mechanic rotor single section shaft vibration analysis called short-term two-dimensional holograph array, manufacturing comprising steps of: (1) reading an x signal sequence and y signal sequence in two vertical directions from a section of a rotary shaft collected synchronously; (2) dividing the x signal sequence and y signal sequence according to a certain time delay D and short-term window length L, dividing a group of short term signal sequence; (3) synthesizing a short-term two dimensional holograph in a frequency domain with a pair of two directional short-term signal sequences with same time cross; (4) arranging synthesized short-term two-dimensional holograph along time shaft, arranging according to time sequence intercepted according to short-term signal sequence. The short-term two-dimensional holograph array not only reacts to dynamic change of amplitude of shaft vibration component along time, but also reacts to features that vibration directions change dynamically, being a tool for depth analysis of stable operation of mechanic rotary shaft [18].

Start up and shut down times considered as one of the most challenging periods in vibration monitoring and maintenance activities. Amplitude spectrum array waterfall plot for shaft vibration analysis of starting-stopping process considered as one of the innovative techniques and methods in this area. The invention relates to an amplitude spectrum array waterfall plot for shaft vibration analysis of starting-stopping process of equipment. A making method of the waterfall plot comprises three steps: (1) reading a pair of vibration displacement signal arrays, for example an x signal array and a y signal array of a rotating shaft in the process of starting or stopping; (2) evaluating a synthesized amplitude spectrum of the x signal array and the y signal array at each rotation speed; and (3) arranging the synthesized amplitude spectrum in rising speed or reducing speed sequence into an array plot which is the made amplitude spectrum array waterfall plot. Any amplitude on the waterfall plot made by the method can represent the true amplitude of the corresponding shaft vibration component in a bearing cross section; the shape of the waterfall plot is only involved with the starting and stopping process and has no relation with the installation position of a sensor; and the invention is convenient for understanding the characteristics of machine states [19].

Multi-range non-contact probe is also considered as a new patent in this area. Multi-range non-contact probe could provide approximate range-finding measurement functions in addition to more precise structured light measurement functions. The probe is compatible with a probe control interface, which allows advanced measuring capabilities and functions to be used with a probe head system that provides a limited number of wired connections. A laser beam of the probe is directed along a first optical path during a first period for providing structured light measurement functions and is directed along a second optical path for a second time period for providing range finding functions.

A single beam modification element having at least first and second portions with different types of optical characteristics is moved to output the laser beam from the first portion along the first optical path and then to output the laser beam from the second portion along the second optical path. These characteristics are the main advantages of multi-range non-contact probe compared with traditional techniques [20].

Besides, non-contact focused, ultrasonic probe vibration measuring, gauging, condition monitoring considered as one of the innovations that could successfully applied in industrial robotics as well as preventive maintenance. Method and apparatus for vibration measurement, gauging, condition monitoring and 5 feedback control of robots, using one or more ultrasonic probes that are non-contact and form a focused beam. The ultrasonic is driven by a pulse-receiver controlled by a computer. The probe has a substantially spherical transducer surface that forms the focused beam within a gas or a liquid. Diameter of the probe determines the size of the beam, which can be chosen to satisfy a particular application. The focused beam has acoustic depth of field, which is the furthest distance from the probe to a surface that can return a measurable echo to a pulse emitted by the probe [21].

In addition, the signal decomposition techniques and methods considered as one of the most challenging concepts in vibration measuring and preventive maintenance. The resolution of graphs increased too much in recent years. The filtering ability of data collectors also developed too much. Therefore the quality of vibration analysis of rotary equipment increased. Nowadays, more successful vibration analysis and fault diagnosis cases are performed by engineers in industrial plants. The reliability of condition monitoring systems increased too much in recent years [22].

Besides, wireless sensor networking developed in recent years. The wireless condition monitoring systems have great advantages comparative to previous portable systems. Firstly different maintenance groups could have high speed access to vibration information simultaneously and more effectively. Secondly these kinds of systems reduced the amount of errors especially in installation times. Finally, the monitoring systems applied with closer periods than conventional types. Furthermore, under web condition monitoring and fault diagnosis systems are developed for remote areas in recent years [23].

Optimized decision making for complex maintenance strategies like most critical equipment is also developed in recent years and has great economic advantages. The reliability centered maintenance (RCM) is based on stochastic evaluations in maintenance actions. RCM could significantly help the managers to make optimal decisions in critical times [24].

Unbalance and misalignment of most critical equipment couplings are considered as one of the most challenging concepts in preventive maintenance. The alignment of this kind of equipment has some kind of complexity and should be applied with special procedure according to machine technical documents. The unbalance of couplings also hard to diagnosed in conventional vibration analysis methods. Coupling unbalance and misalignment could be detected by measuring phase in both side of coupling (phase analysis). In this project all these activities measured accurately in both side of coupling that represented normal condition of both unbalance and misalignment. Nowadays several methods developed to simulate the coupling of most critical equipment motions. All these kind of techniques are based on vibration modal analysis [25].

The shaft crack represented by monitoring of coast down and run up characteristics when passing through resonance (critical speeds of turbine compressor). Both graphs based on phase diagrams in turbine shut down and startup. Different types of modeling systems are developed recently. These techniques mostly based on vibration modal analysis [26].

An environmental friendly palm-grease has already been formulated from modified RBDPO (Refined Bleach

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Deodorized Palm Oil) as base oil and lithium soap as thickener. Such palm-grease is dedicated for general application and or equipment working in areas like most critical equipment. Several conventional methods are applied for wear diagnosis in main shafts of most critical equipment. Some of them are based on impacts in Time wave form (TWF). There are too many impact shape signals in TWF because of the nature of turbine multistage compressors process condition. Then the real causes of impacts could be mechanical or related to process and it is sometimes hard to distinguish. Besides, rotor rub have usually truncated wave form symptoms same as mechanical looseness. In such cases, Sub harmonics 1/2, 1/3 … is dominated. Moreover, strong harmonic pattern caused by truncation could be appeared [27].

Some methods like an adaptive inverse dynamics control recently developed for detecting micro vibrations. This method is applied to control and suppress the micro vibrations of equipment. The piezoelectric layers are used as sensors and actuators. Micro-vibrations, generally defined as low amplitude vibrations at frequencies up to 1 kHz. These frequencies usually appeared in most critical equipment like turbine compressors [28].

The axial motion of the rotor can be evaluated by gap voltage analysis. Two axial none contact probes located at the end of turbine and compressor main shafts. The axial vibrations (micron peak to peak) and gap voltages should be equal to each other by 0.1 micron or 0.01 volt accurately otherwise the rotor is not in parallel condition. In addition, the turbine and compressor rotor motion should be reasonable by this method otherwise it could be misalignment of coupling or any mechanical abnormality in turbine and compressor [29].

The quality of steam in turbines is also considered as one of the important factors in vibration behavior. New generation of governors are equipped with electronic devices. These types of governors are increased the control and decrease the process problems in turbine compressor during operation [30].

The main process parameter in most critical equipment like inlet and out let pressure and temperature monitoring for both turbine and compressor are evaluated the condition of energy balance by thermodynamic laws (like first and second laws of thermodynamic). These techniques are applied in turbine compressor modeling systems [31]. In addition Abbreviations and Acronyms used in this paper are shown in table I.

TABLE I
ABBREVIATIONS AND ACRONYMS

Fast Fourier Transform	FFT
Time wave form	TWF
Bently Nevada connection	BNC
Condition monitoring	CM
Preventive maintenance	PM
Non drive end	NDE
Drive end	DE
Peak to peak	P-P

II. EXPERIMENTAL DETAILS

Main turbine compressor MPC-C-8001 working in 11000 RPM. This machine equipped with Bently Nevada 3500 series monitoring system. MPC-C-8001 is the heart of an olefin plant in Iran oil industry (Maron petrochemical company).

The overall vibrations are measured in micrometer peak-to-peak (P-P). The alert limit is 20 micron and the danger is 40. Then, less than 20 is good and between 20 and 40 is fair. Alarm lamp is appeared in BNC board in substation in fair conditions (alert). More than 40 is rough condition and compressor is automatically tripped to protect the rotary and stationary part of turbo compressor.

In addition, the vibration analysis methods for rotary equipment are discussed in [32]. Besides, some successful traditional vibration analysis case reports discussed in [32]-[35]. Furthermore, vibration values could be applied in rotor balancing evaluation for most critical equipment balancing process [36].

Fig. 13 Bently Nevada 3500 series machinery monitoring system

Fig. 14 MPC-C-8001

The overall vibration trends were not shown any considerable increase. The last data was almost constant with previous vibration measured during last 6 month. But the PM group reported some abnormal noise from drive end bearing of compressor (point number3). The last vibration data reported was as following.

TABLE II
VIBRATION DISPLACEMENT MICROMETER PEAK TO PEAK MPC-C-8001

MPC-C-8001	POINT 1-turbine NDE	POINT 2-turbine DE	POINT 3-compressor DE	POINT 4-compressor NDE
Horizontal	5.39	7.053	13.18	12.22
Vertical	9.29	13.94	11.58	7.48
axial	7.03	6.07	7.09	6.08

All of the traditional vibration analysis systems were constant. The phase almost showed same values in different position and directions. In addition, the axial movement analysis has shown nothing abnormal. The TWF and FFT analysis is only reliable in radial direction (horizontal or vertical). All TWF, FFT measured by easy viber data collector (VMI) and analyzed with spectra pro software was in the range of technical documents. The turbine side TWF is shown in Fig. 15.

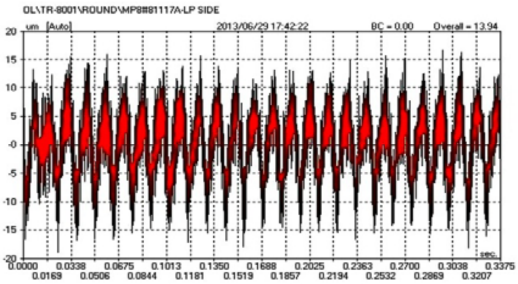

Fig. 15 TWF steam turbine low pressure side

The symmetry still existed in Fig. 15 also the carrier and high frequency ride wave (modulation) was like previous signals. These data all related to POINT 2-turbine DE in vertical position. The FFT also was same as previous signals.

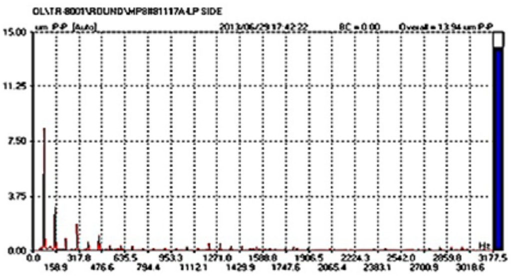

Fig. 16 FFT steam turbine low-pressure side

The compressor side TWF has shown some stronger impacts in bearing systems but the amplitude of impacts were not high enough for any recommendation (checking bearings in point 3). Point 4 was remained steady in shape of both TWF and FFT. In addition, the FFT forms were remained constant in all positions and directions. The first two diagrams related to point 3 horizontal direction was shown as following.

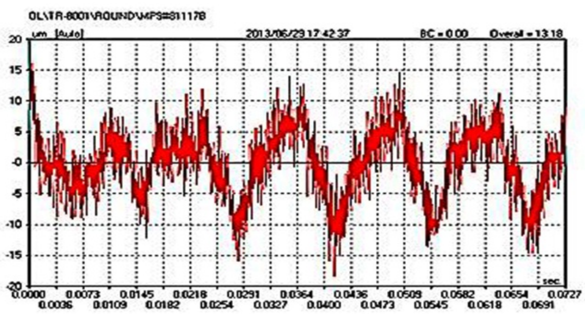

Fig. 17 TWF point 3 horizontal direction

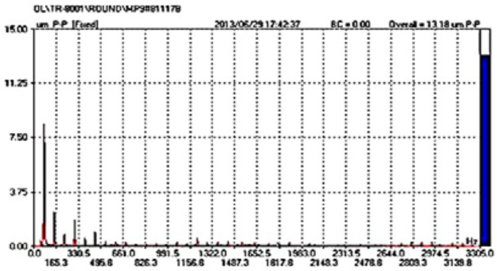

Fig. 18 FFT point 3 horizontal direction

Furthermore, the following two diagrams are related to point 3 vertical direction. The cursor is evaluated scales between time and amplitude.

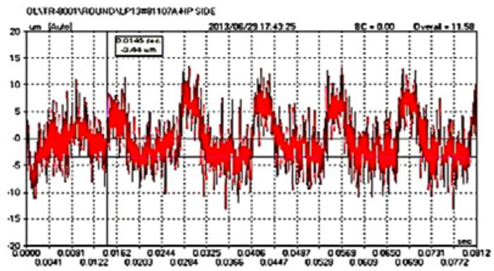

Fig. 19 TWF point 3 vertical direction

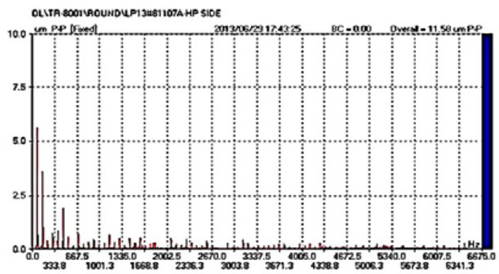

Fig. 20 FFT point 3 vertical direction

The traditional vibration analysis was shown nothing abnormal but the PM group were reported some abnormality (abnormal noise in point 3). Therefore, CM group decided to perform shaft centerline analysis in point 3 to ensure the machine healthy.

III. Results

The process condition of both turbine and compressor such as suction and discharge pressure and inlet and outlet temperature were remained constant. These values were remained in the range of turbine and compressor technical documents (according to the data trends in main board of olefin plant).

In addition, the quality of steam was acceptable and remained in the range of turbine documentation. Therefore, the problem of abnormal noise in point 3 should be mechanical rather than something related to the process.

Firstly, the shaft position data were calculated and replaced in Tables III to IX (based on the mentioned methodology).

Secondly, the shaft centerline position calculated based on technical data mentioned before. After that, the allowable circle is drawn with assist of the gap voltage data in last 34 days. Finally, Shaft centerline position MPC-C-8001 was drawn for point 3 (shown in Fig. 21).

TABLE III
SHAFT CENTERLINE POSITION DATA IN FINAL ALLOWABLE CIRCLE (PART 1)

date	27/05/2013	28/05/2013	29/05/2013	30/05/2013	31/05/2013
Y	O.9	1.2	1.2	1.4	1.8
X	-1.2	-1.2	-0.8	-0.6	-0.6

TABLE IV
SHAFT CENTERLINE POSITION DATA IN FINAL ALLOWABLE CIRCLE (PART 2)

date	01/06/2013	02/06/2013	03/06/2013	04/06/2013	05/06/2013
Y	2.2	2	1.8	1.5	1.8
X	-0.4	-1	-2.2	-1.5	-1.6

TABLE V
SHAFT CENTERLINE POSITION DATA IN FINAL ALLOWABLE CIRCLE (PART 3)

date	06/06/2013	07/06/2013	08/06/2013	09/06/2013	10/06/2013
Y	1.9	1.9	1.7	2.4	1.6
X	-1.8	-2	-2.2	-2.4	-2.8

TABLE VI
SHAFT CENTERLINE POSITION DATA IN FINAL ALLOWABLE CIRCLE (PART 4)

date	11/06/2013	12/06/2013	13/06/2013	14/06/2013	15/06/2013
Y	0.9	0.6	0.4	0.2	0.1
X	-3	-3.2	-3.6	-3.6	-3.5

TABLE VII
SHAFT CENTERLINE POSITION DATA IN FINAL ALLOWABLE CIRCLE (PART 5)

date	16/06/2013	17/06/2013	18/06/2013	19/06/2013	20/06/2013
Y	-0.1	-0.6	-1	-1.2	-1.2
X	-3.6	-3	-2.9	-3.5	-3.6

TABLE VIII
SHAFT CENTERLINE POSITION DATA IN FINAL ALLOWABLE CIRCLE (PART 6)

date	21/06/2013	22/06/2013	23/06/2013	24/06/2013	25/06/2013
Y	-1.4	-1.7	-1.9	-2	-2.2
X	-3.8	-3.9	-4.2	-4.2	-3.5

TABLE IX
SHAFT CENTERLINE POSITION DATA IN FINAL ALLOWABLE CIRCLE (PART 7)

date	26/06/2013	27/06/2013	28/06/2013	29/06/2013
Y	-2.5	-3.2	-4	-4.2
X	-2.5	-2.3	-2.5	-3

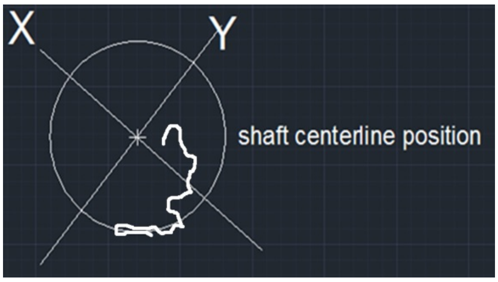

Fig. 21 Shaft centerline position MPC-C-8001

The shaft touched in the down half of the bearing as shown in Fig. 21. The bearing may be damaged in this location. Enough evidences are existed in present condition to predict this phenomenon (bad bearing).

Now, it is mandatory to recommend the bearing check in point 3 to maintenance section (machinery group). Besides, process managers should be planning to turn of the machine and change the process roles of this compressor to the spare compressor simultaneously (to continuing the Olefin production during maintenance activities).

The bearing housing in point three consist of a journal and a thrust bearing. The journal is sleeve type and the thrust is tilting pad. After checking the bearings system in point 3, the upper half was in good condition but the down half was touched and damaged seriously.

In addition, the main shaft touched and should be sent to metal spray. The bearing should change, replace and reinstall.

The touched down half of bearing is shown in Fig. 22. Moreover, the up half of the bearing is shown in Fig. 23. Besides, the rotor and main shaft is shown in Fig. 24.

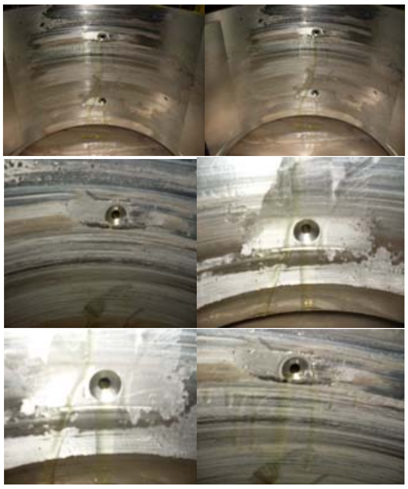

Fig. 22 Touched down half of the bearing point 3

Fig. 23 Up half of the bearing point 3

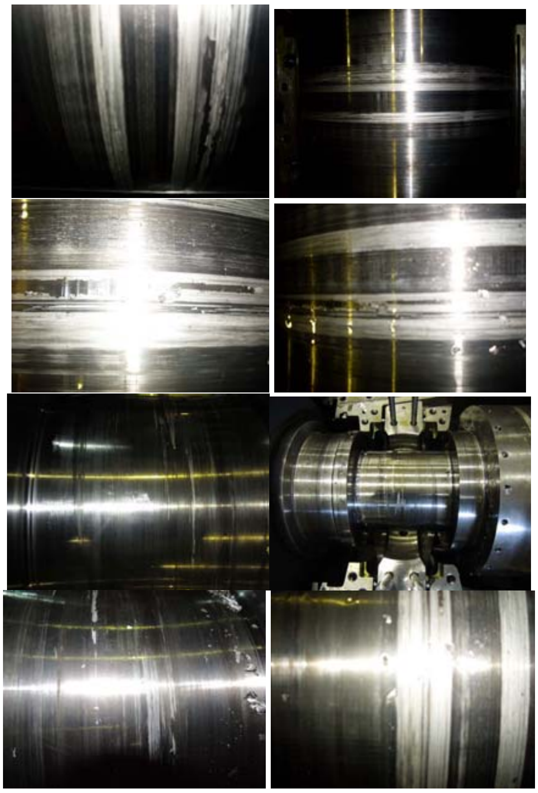

Fig. 24 Rotor and main shaft condition MPC-C-8001

IV. DISCUSSION

The bearing condition was terrible meanwhile all traditional signals like overall vibrations, BNC data, TWF, FFT, phase trends and gap voltages were shown nothing abnormal. These data were not shown any dramatic increase. Nevertheless, the shaft centerline monitoring method was provided enough evidences for suitable and on time recommendations.

This method caused successful fault prediction. If CM group did not perform shaft centerline monitoring, the alignment will faced serious problems in next step. The valuable turbine blades might have some touches or damages.

Furthermore; some damages might occurred in multi stage compressor parts. This would cause high economical maintenance and production costs for the factory (petrochemical zone). In addition, the plant might face an unexpected shut down for several hours. The process may have 4 to 5 hours high-pressure work to start up the spare compressor. Moreover, thousands of dollars wasted in these kinds of shutdowns (because of quit of the Olefin production).

In addition, Olefin is the base material for tens of other petrochemical companies in the petrochemical zone. These plants faced serious problems in production. Besides, petrochemical companies should pay some delay fines to the export ships that coming from far countries every hour.

All in all this 4 to 5 hours may costs thousands of dollars wasted in production. Beside this, mechanical part damages like turbine parts could waste large amount of time and money. All these evidences have shown the effectiveness of shaft centerline method for future applications.

V. CURRENT AND FUTURE DEVELOPMENT

The shaft centerline analysis performed successfully for main steam turbine multistage compressor MPC-C-8001 related to an Olefin plant in Iran oil industry (Maron petrochemical company) for point 3-compressor drive end bearing.

The traditional methods like overall trends of vibration displacement micrometer peak to peak (P-P) by Bently Nevada board in substation, phase trends, TWF and FFT monitoring did not indicated any dramatic increase and enough evidence to any machinery maintenance recommendation (for example checking the bearings).

The shaft center line analysis predicted the strong touch in down half of the bearing that was completely true. Besides the shaft center line method could predict the exact location of touches successfully.

After maintenance, the bearing changed, reinstalled and replaced. The main shaft was sent to metal spray work shop.

This successful analysis caused protecting potential unexpected shutdowns that might pose huge mechanical and production costs on the factory.

Therefore shaft centerline analysis could be effective if performed accurately and correctly on most critical equipment like main turbine compressors.

In conclusion, rotor movement evaluation by shaft centerline method considered as one of the most effective tools in predictive maintenance and condition monitoring systems. Besides, low vibration does not always indicate a healthy machine.

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