Failure Analysis of a Cracked Gas Compressor

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***Abstract*—Cracked Gas Compressor (CGC) serves as the vital core of the Olefin plant. However, one of the leading companies in Indonesia, which employs CGC, faces the challenge of high vibration in both low-pressure (LP) and medium-pressure (MP) casings. This phenomenon is very important to overcome, because it may cause losses of thousands and even millions of dollars per day for the Company when there is a system failure. Vibration levels in MP casing have escalated from 13.8 µm to 39 µm, and LP compressor vibration has abruptly risen to 52 µm from 12 µm. Therefore, this study aimed to investigate the underlying causes of this high vibration in CGC. To analyze vibration issue, the Process Information (PI) and *System1* software were employed. The result showed that the fouling of the rotor was the primary source of vibration in MP casing, while mechanical damage to rotating parts was responsible for vibration in LP casing. It is recommended to implementation of wash oil injection to reduce fouling and utilization of water injection to reduce compressor discharge temperature.**

Keywords*—cracked gas compressor, failure analysis, vibration, system 1, olefin plant

I. INTRODUCTION

One of the largest industries in Indonesia, located in Cilegon, Banten, employs a Crack Gas Compressor (CGC) for the production of ethylene, propylene and butadiene gas. In 2015, companies expanded its production capacity from 600 KTA to 860 KTA (Kilo Tons per Annum). To achieve this increase, the crack gas compressor needed to be replaced with a higher capacity unit and be operated by 2016.

Compressor used is a double suction centrifugal type, comprising three casings, namely low pressure (LP), medium pressure (MP), and high pressure (HP), all driven by a steam turbine. The CGC is considered a critical piece of equipment and is equipped with *System1* for monitoring equipment conditions and performing problem analysis [1], [2].

In April 2017, vibration in MP casing increased from 13.8 µm to 39 µm, nearing the alarm threshold of 56 µm. Therefore, further analysis is required to both maintain and reduce vibration levels to ensure uninterrupted plant operations. A study conducted on the CGC in the ethylene plant focused on compressor fouling. Furthermore, it provided insights into the fouling process in CGC and proposed methods to control and mitigate fouling occurrence.

Before vibration in MP casing could be addressed, compressor tripped in November 2017 due to insufficient steam to drive the turbine. Upon restarting compressor, several findings related to vibration were observed. After compressor reached its normal operating speed of approximately 5200 rpm, LP casing vibration suddenly increased significantly from 9 µm to 52 µm.

Considering the criticality of CGC and the potential operational implications, further analysis of vibration increases in LP and MP casing is necessary. To facilitate this analysis, *System1* is used to collect some data in the form of the spectrum, orbit shaft, and centerline shaft, enabling a comprehensive understanding of the underlying issues [3], [4]. Additionally, data collected from operator logs and plant operation records from PI is compared to *System1* data for a more holistic analysis of the situation. Therefore, this research aims to identify and analyze the causes that lead to the failure of the CGC of the company. The current literature review on this topic that provided in the [5]–[9] are not sufficient to be used to evaluate the failure of the CGC.

II. METHODOLOGY

The methodology employed in this study was shown in Fig. 1. The first step involved conducting a comprehensive literature survey on vibration analysis, fouling problems, and mechanical issues in CGC. The literature was sourced from various outlets, such as training outcomes with manufacturers, e-books, or benchmarking conducted at other companies encountering similar problems. Subsequently, all relevant data pertaining to the encountered problem was gathered. This included process parameters during the occurrence of the problem, which was extracted from PI program. To aid in vibration analysis, data from *System1*, comprising spectra, orbits, and shaft centerline measurements, was utilized.

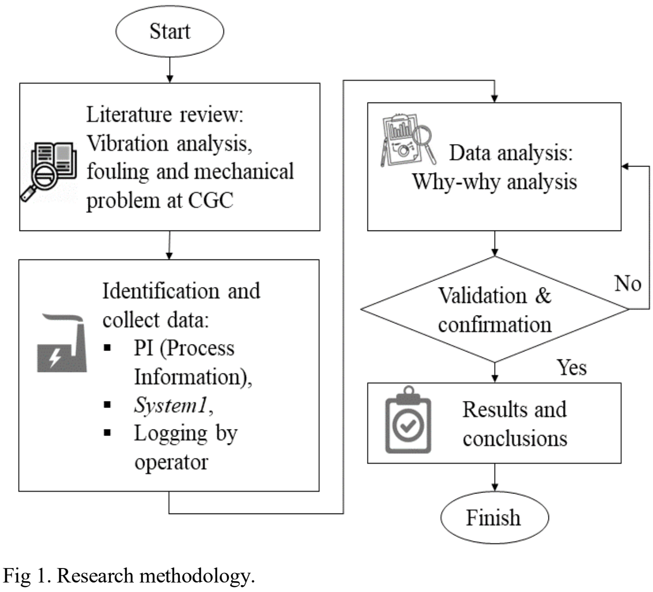

Fig 1. Research methodology.

Additionally, certain data not recorded in PI, such as wash oil injection flow, was sourced from the manual record of the operators, compiled in the CCR (Central Control Room). The data used in this study spanned the period from 2017 to 2018. Once all the data was amassed, a why-why analysis method was employed for analysis [10]. This approach enabled the determination of potential issues occurring in LP and MP casings, which were then subjected to validation to ascertain whether these identified possibilities indeed gave rise to vibration increase [11-13]. Vibration measurement were conduct on both condition, housing bearing Drive End (DE) and housing bearing Not Drive End (NDE).

III. Result and Discussion

Based on the results of the conducted investigation the problem in this study was categorized into two parts as follows:

A. *Case Study Analysis of Raised Vibration in MP Casing*

In April 2017, there was a significant increase in vibration in MP casing, specifically from 13.8 µm to 39.00 µm. The Table I shows vibration values monitored after the start-up in 2015.

Fig. 3 shows that the higher of speed, the greater of vibrations produced. Furthermore, there is no correlation between shaft vibration and lube oil temperature (see Fig. 4). Since some data is not recorded in the PI, such as oil viscosity and oil injection flow, we assume these variables are constant.

TABLE I. Vibration Values Monitored After the 2015 Start-Up

Merasurement period			**Spee d**	**DE**		**NDE**	
				275 A	***275 B***	***274 A***	***274 B***
A	Comissioning	Dec 2015	4961 rpm	7.7 µm	7.8 µm	14 µm	13.8 µm
B	Start increasing shaft vibration	Nov 2016	5136 rpm	6.5 µm	6.6 µm	13 µm	12.7 µm
C	Discussion with vendor	Feb 2017	5104 rpm	8.7 µm	8.3 µm	16.8 µm	16.1 µm
D	Speed The highest shaft vibration	April 2017	5292 rpm	26.8 µm	28.3 µm	39.6 µm	36.6 µm

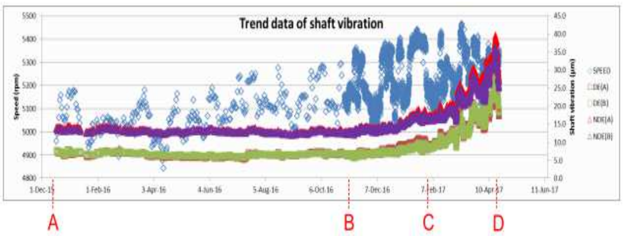

Fig 2. Trend data of shaft vibration related to Table I.

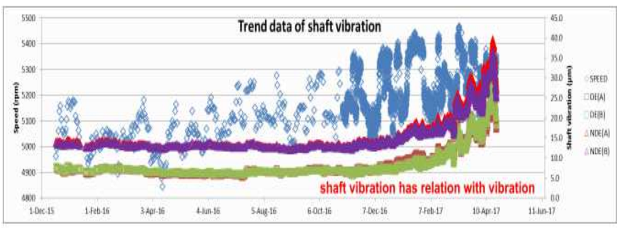

Fig 3. Vibration and speed trends.

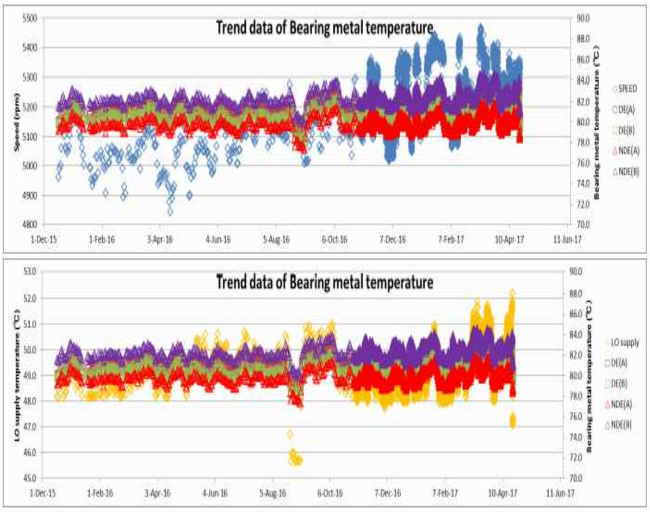

Fig 4. Lube oil vibration and temperature trends.

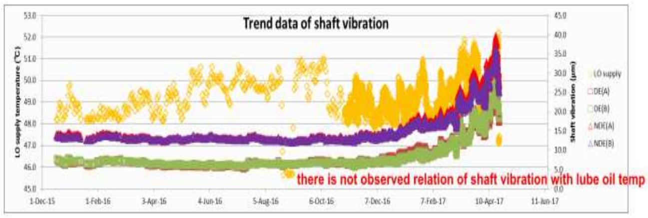

Fig 5. Vibration and temperature of metal bearings trends.

Preliminary data collected in MP casing provided insights into the root causes of the identification problems. The following presents a why-why analysis of the issues occurring in MP casing. Based on the data shown in Table II, vibration observed in MP casing was closely linked to rotor imbalance. The following item should be considered regarding rotor unbalance:

- Impeller sliding or leaning
- Rotor bending
- Coupling unbalance
- Fouling at rotor
- Damage on the rotating part

TABLE II. A Why-Why Analysis of High Vibration in MP Casing

Possible cause	**Checkpoint**	**Check result**	**Possibility**
Rotor unbalance	Spectrum of vibration (1x)	1x is the main spectrum	High
Rubbing	Shaft orbit (Flat shape)	The orbit shape was a circle	Low
Malfunction of the rotor support system	Bearing metal temperature	Bearing metal temperate was an acceptable level	Low
	Shaft center movement	The shaft center was almost the same compared with the high and low vibration periods.	Low
Misalignment	Spectrum of vibration (2x or 3x)	1x is the main spectrum.	Low

Rotating stall	Spectrum of vibration (0.2 – 0.3x)	1x is the main spectrum.	Low
Surging	Spectrum of vibration (0.1x)	1x is the main spectrum	Low
Liquid carries over	Spectrum of vibration (Non-synchronous)	1x is the main spectrum	Low
Self-exciting vibration	Spectrum of vibration (Non-synchronous)	1x is the main spectrum	Low

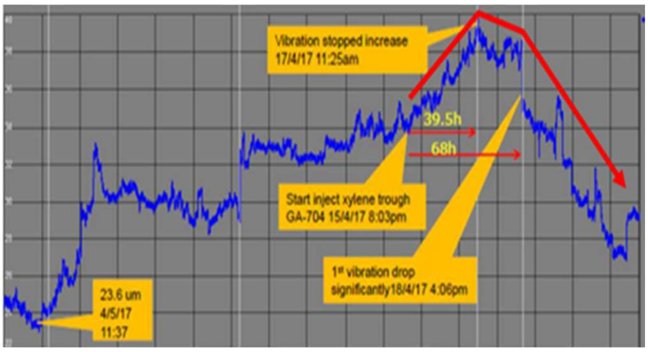

Fig 6. Trend of shaft vibration during wash oil injection.

Fig. 6 provided evidence that the addition of wash oil could effectively reduce vibration. According to the phenomena that occur on the graph, it is highly likely that the problem in MP casing is primarily caused by fouling in the impeller area.

To avoid fouling, two improvements were implemented at petrochemical plant. These improvements were as follows:

- Increase the capacity of wash oil injection: Upon reevaluation, it was determined that the installed wash oil capacity in the field fell short of the required amount by the licensor. During the revamping process, recalculating the wash oil requirement was overlooked.
- Reduce the discharge temperature by using water injection: Although compressor could inject water for gas temperature reduction, this particular company had not installed the necessary facilities. This caused the discharge temperature in stage 3 to exceed 88ºC, leading to polymerization issues within MP casing.

B. *Case Study Analysis of Raised Vibration in LP Casing*

In November 2017, CGC was shut down by the process team due to a boiler problem. Once the problem was resolved, CGC was scheduled to be restarted 1 day after the shutdown. During the first attempt, when the turbine speed reached 1985 rpm, compressor tripped because the dry gas seal (DGS) vent flow exceeded the alarm threshold. In the subsequent trial, compressor encountered a similar problem, and, hence, the decision was made to bypass DGS vent flow.

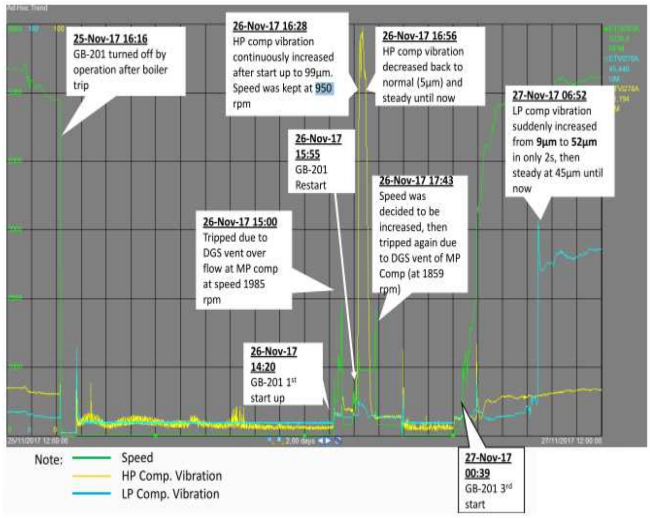

Fig 7. Chronology of vibration increase in LP casing.

Based on analysis, it was discovered that bypassing the vent flow was not dangerous. When the flow still exceeded the normal threshold during regular speed, it was recommended to turn off system and conduct further investigation. On the third attempt, compressor operated correctly, but after 1 minute at its normal speed, vibration in LP casing significantly increased to 52 µm (see Fig. 7).

After analyzing the preliminary data collected in LP casing, a why-why analysis for the problems, which occurred in this casing was presented. From the data in Table 3, vibration observed in LP casing was associated with rotor imbalance. Consequently, the following factors were taken into consideration:

- Impeller sliding or leaning
- Rotor bending
- Coupling unbalance
- Polymerization in the rotor
- Damage to rotating parts

While sudden damage unrelated to wash oil injection could not be ruled out, there remained a possibility of damage occurring in the above-mentioned areas. However, confirming the likelihood of such damage could only be achieved during the upcoming 2019 Turn Around Maintenance (TAM). Based on this condition, it was recommended to prepare replacement parts for these potential issues during TAM 2019.

TABLE III. A WHY-WHY ANALYSIS OF HIGH VIBRATION IN LP CASING

Possible cause	Checkpoint	Check result	Possibility
Rotor unbalance	Spectrum of vibration (1x)	1x is the main spectrum	High
Rubbing	Shaft orbit (Flat shape)	The orbit shape was a circle	Low
Malfunction of the rotor support system	Bearing metal temperature	Bearing metal temperate was an acceptable level	Low
	Shaft center movement	The shaft center was almost the same compared with the high vibration period and low vibration period.	Low
Misalignment	Spectrum of vibration (2x or 3x)	1x is the main spectrum.	Low

Rotating stall	Spectrum of vibration (0.2 – 0.3x)	1x is the main spectrum.	Low
Surging	Spectrum of vibration (0.1x)	1x is the main spectrum	Low
Liquid carries over	Spectrum of vibration (Non-synchronous)	1x is the main spectrum	Low
Self-exciting vibration	Spectrum of vibration (Non-synchronous)	1x is the main spectrum	Low

IV. Conclusion

Based on the analysis, the following conclusions were drawn: the occurrence of high vibration in MP casing of CGC was attributed to fouling or polymerization problems affecting the impeller/rotor. Furthermore, the problem of high vibration in LP casing of gas compressor still presented several potential causes, including impeller sliding or leaning, rotor bending, coupling unbalance, polymerization within the rotor, and damage to rotating parts, such as the impeller, DGS, or rotor. Moreover, the problem within MP casing was further analyzed during compressor overhaul scheduled for August 2019 TAM. In order to prevent similar incidents in the future, it is recommended that the following facilities be prepared such as: implementation of wash oil injection as advised by the licensor to reduce fouling and utilization of water injection to reduce compressor discharge temperature.

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