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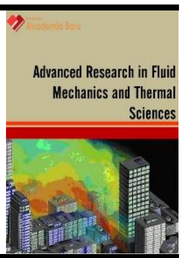

Analysis of High Vibration Causing 211-P-25A Centrifugal Pump Damage in Hydrocraker Process

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ABSTRACT

The more developing technology enhances the need for energy; this requires the maximization of the performance of power plant components and energy. Refinery Unit (RU) is currently one of the real applications. Reliable equipment is required in running a massive industry. In running the oil production process at Refinery Unit (RU), the thing that needs to be put into consideration is pumps. A pump is a device for distributing fluids from one place to another. In Refinery Unit (RU), the pump is not only for oil but also for other fluids. In this research at Refinery Unit, the pump that is to be discussed is a centrifugal pump 211-P-25A. The objective of this research is to analyze the damage of pump 211-P-25A, which indicated high vibration. This causes the pump not to work optimally, so it requires the right maintenance. The research is done by using an analytical method, visual observation towards impeller and shaft, and comparing the results in accordance to API 610. Afterwards, the right maintenance will be known for centrifugal pump 211-P-25A to reduce the high vibration that occurred in the pump. High vibration may be caused by cavitation and internal recirculation. The damage in pump 211-P-25A is caused by repeated internal circulation, which causes damage to the impeller and high-speed shaft. Pump 211-P-25A experiences high vibration due to low flow. The flow produced is 2.67 m^3/h, with a pump design minimum flow of 8.6 m^3/h. This causes damage to pump components. Due to this damage, the performance of the pump will not be optimal, and its efficiency will be reduced.

Keywords:
High Vibration; Internal Recirculation; Cavitation; Centrifugal Pump

1. Introduction

The more developing technology enhances the need for energy; this requires the maximization of the performance of power plant components and energy. Refinery Unit (RU) is currently one of the real applications. Reliable equipment is required in running a large industry. In running the oil production process at Refinery Unit, the thing that needs to be put into consideration is pumps. A

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pump is a device for distributing fluids from one place to another. In Refinery Unit (RU), the pump is not only for oil but also for other fluids. The pump is a hydraulic fluid flow machine that functions to move incompressible fluids from one place to another by increasing the displaced fluid [1]. Centrifugal pump is one type of dynamic pump that pushes the fluid perpendicular to the pump impeller shaft [2]. Internal recirculation is the effect of posterior circulation in the system. In the condition where the flow does not exceed the minimum flow of the system, the flow rotates back to the middle of the impeller. This reverse effect can increase the fluid velocity until evaporation occurs and then rupture when passing through a place of higher pressure [3].

Centrifugal pumps have an essential role in the process of the Refinery Unit. Thus it is expected that the research Refinery Unit can help in optimizing the performance of 211-P-25A centrifugal pumps by preventing the occurrence of high vibrations in the pump. This research aims to analyze the damage to the 211-P-25A pump, which is indicated by high vibration so that the pump function does not work optimally. It is widely known that vibration-based fault diagnosis played a critical role in preventive maintenance of important machineries [4]. Proper maintenance is needed to overcome the problem. The method used in this research is the analysis method using vibration-based analysis. According to Scheffer and Girdhar [5], one effective way to detect early symptoms of mechanical and electrical damage to equipment is vibration analysis, which is the most frequently used predictive maintenance strategy choice [6]. The advantage is that it can identify potential damage before it becomes severe which can lead to unscheduled downtime [7]. According to Agung *et al.,* [8], the vibration-based analytical method and the predictive maintenance method are the right methods to prevent high vibration from occurring, because it evaluates failure and direct observation. Research on the detection of high vibration on centrifugal pumps 211-P-25A is still rarely carried out so that in this study it is proposed to investigate the high vibration analysis method on centrifugal pumps using analytical methods by making visual observations carried out by observing the impeller and shaft directly. Figure 1 shows an example of a centrifugal pump.

Fig. 1. Centrifugal Pump [9]

2. Methodology

2.1 Analysis Method

Pump type of 211-P-25A is a type of centrifugal pump (undone pump), the role of this pump is in the Hydrocracker Complex area in the Light Naphtha Stripper phase at the refinery. This pump's function is to pump light naphtha, which will be used as reflux, and some of it will be distributed to the amine-LPG Recovery Unit as an LPG product. Pump 211-P-25A indicates high vibration; this causes the pump function not to work optimally, then the pump must be repaired. This research was conducted by analytic and observations of impellers and shafts at the pump, then compared with the API 610 standard. Visual representations were made by observing impellers and shafts directly. Descriptions are made after the impeller is cleaned so that the parts that are experiencing pitting and bending will be seen.

The analysis used to achieve the objectives of this study uses the following builder formulas.

a. Finding Pump flow rate (Q) : $A\ V$

b. Calculate Pump Head (H) : $\frac{(P_{discharge} - P_{suction})}{\rho g}$

c. Finding available NPSH values (NPSH $_A$) : $\frac{P_a}{g} - \frac{P_v}{g} - h_s - h_i$

d. Finding the required NPSH value (NPSH $_R$): σH_n

e. Importance of Pump Efficiency (η) : Pw / BHP

f. Mean Time Between Failure (MTBF) : number of years /n Failure

2.2 MTBF Analysis (Mean Time Between Failure)

History Record is a record of analysis, repairs/maintenance that have been carried out from 2009-2018. Mean Time Between Failure (MTBF) can measure the average time between damages that occur. Table 1 shows the MTBF pump 211-P-25A data.

Table 1
History Record pompa 211-P-25 [10]

Date	Activities
07.08.2018	211-P-25A, Overhaul gearbox & pump
03.04.2018	211-P-25A, Double mech seal replacement
05.09.2017	211-P-25A, Mech Seal Leaks
28.08.2017	211-P-25A, Mech Seal Leaks
16.09.2016	pump 211/212-P-25A/B Spill restructuring
14.09.2016	211-P-25A, Low Pump Press.
22.08.2016	212-P-25A/B, Up grade Mechanical seal.
17.06.2016	211-P-25A, High Vibrasi (Condmon)
06.08.2015	Repair 211-P-25A, 01-21-2016
03.06.2015	212-P-25A, Mech Seal Leaks.
10.09.2014	211-P-25A , High vibration
07.08.2014	211-P-25B, High vibration
21.01.2014	211-P25A , Mech Seal Leaks
10.10.2013	Repair 211-P-25A
06.08.2013	211-P-25A , Stuffingbox Leaks
03.07.2012	Recondition 211-P-25 A/B
22.06.2012	Mech Seal 211-P-25A replacement
12.09.2011	Repair 211-P-25A
30.06.2011	CONMON PdM 211-P-25A
23.07.2010	Service 211-P-25A, bearing is damaged
04.01.2010	Replacement of bushing 211-p-25a
05.10.2009	Mech seal 211-P-25A repair

Then, the MTBF at pump 211-P-25A / B is as 10 years /22 failure = 0.4 years /failure.

3. Results

By the pump design data, the resulting flow must be sufficient to meet the minimum flow of the pump design, Table 2 shows the flow specifications of the 211-P-25A pump design [11]. While in Table 3 shows the actual data measured by the flow meter in the HCC unit area.

Table 2
Specifications of the 211-P-25A pump design [10]

Tag. No	211/212-P-25A/B
Manufacture	SUNDYNE PUMP
Type/Model	LMV 322-37-142 SCSS
Normal Flow	14.3 Nm^3/h
Minimum Flow	8.6 m^3/h
Fluid SG at 38°C	0.559
Operating Press.	34.32 Kg/cm^3G
RPM	14,200 RPM

Table 3
Actual Data of Pump 211-P-25A [10]

Pump 211-P-25A Flow Meter in discharge pump	Unit 211 m^3/h	Note
FIC 524	0	Control valve close indicates valve passing
FIC 522	2.67	-
FIC 521	*Error*	The line spill back flow meter error and there is a valve that closes
Total Flow	2.67	Under the minimum flow 8.7 m^3/h

From the data in Table 3 about the actual data of the 211-P-25A pump, it can be concluded that the flow occurred at the 211-P-25A pump has a flow that does not reach the minimum flow according to the design of the 211-P-25A pump manufacture from this inadequacy recirculation [11].

The reduced flow generated by the pump will produce vibrations in the pump [11]. Based on the Vibration measurements, the values and vibration spectrum of the 211-P-25A pump are obtained. Table 4 shows the results of Vibration measurements in point ID (inner diameter).

Table 4
Results of Vibration measurements

Report No.							
Reference No:							
Date/Time	02/08/2018						
Machine Name/Tag No.	211 PM-25A						
Point ID	3GR DE H-ACC						
Overall High	2.1						
Alarm Status:							
% Change							
Alert High	4.5 mm/s						
Danger High	7.1 mm/s						
Measurements	Routine	Routine	Routine	Routine	Routine	Routine	Routine
Point ID	2-Aug-18 (mm/s)	24-Jul-18 (mm/s)	19-Jun-18 (mm/s)	5-Jun-18 (mm/s)	22-May-18 (mm/s)	8-May-18 (mm/s)	24-Apr-18 (mm/s)
2M DE V-VEL	1.91	2.19	1.82	1.64	1.63	1.66	1.61
2M DE H-VEL	2.11	1.81	1.04	1.35	1.51	1.43	1.49
2M DE H-ENV	0.53	0.26	0.77	0.60	1.24	0.82	0.69
2M DE H-ACC	1.16	0.68	4.47	1.76	2.38	1.18	1.50
2M DE A-VEL	1.36	1.33	0.81	0.70	0.60	0.67	0.48
3GR DE V-VEL	2.27	2.07	3.31	1.99	2.24	1.82	2.40
3GR DE H-VEL	2.68	2.09	3.03	2.92	2.11	1.75	2.70
3GR DE H-ENV	1.10	0.95	2.16	2.45	1.89	1.10	2.66
3GR DE H-ACC	2.10	2.02	4.73	5.39	3.86	2.22	3.86

3GR DE A-VEL	1.85	1.88	3.61	1.30	1.11	1.64	1.65

Based on Table 4 in the box, it was found that there was an increase in vibration during the 3GR DE H-ACC acceleration. From the unachieved flow produced by the pump, will increase the vibration, from this increase in vibration will damage other components [11]. Figure 2 shows the vibration measurement curve and the vibrational increase spectrum.

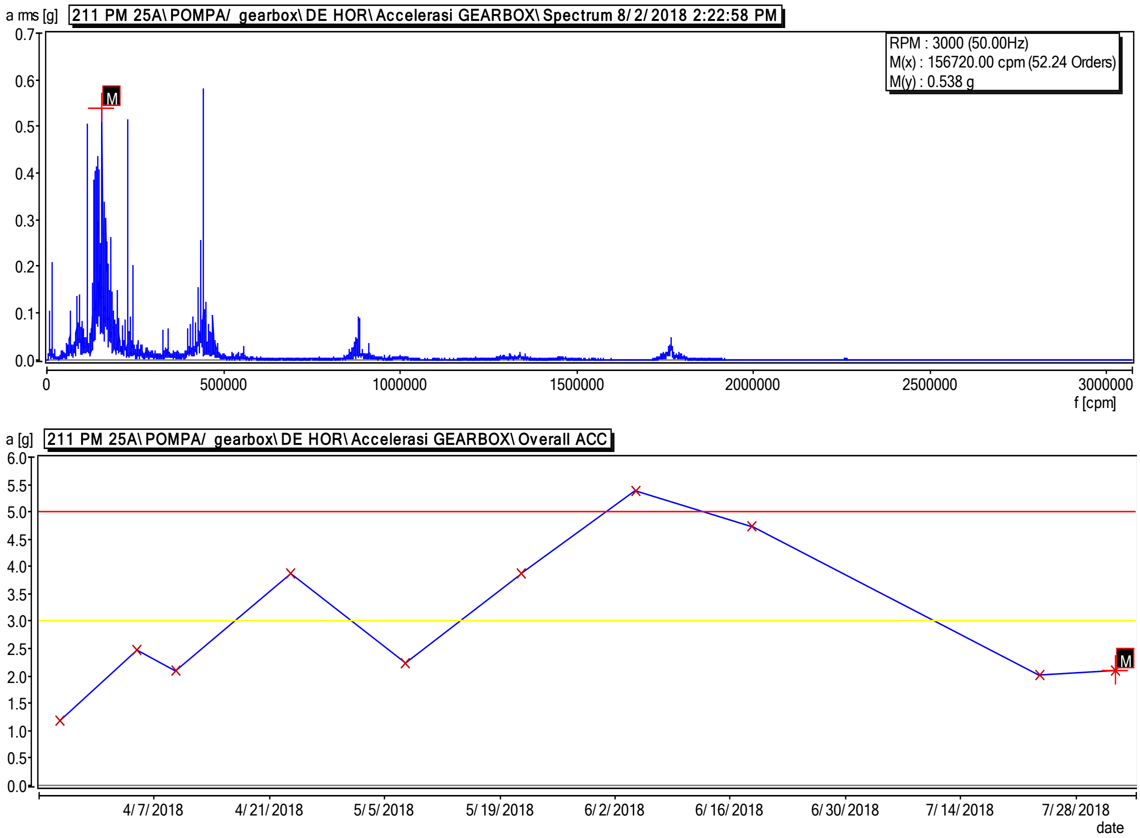

Fig. 2. Vibration measurement curve 211-P-25A [10]

Then, the spectrum results are compared with API 610 and Technical Associates regarding the typical spectrum that occurs. Cavitation generates higher random frequency broadband energy, which usually coincides with the harmonic frequency. Cavitation is the phenomenon of changes in the vapor phase of a liquid that is flowing because the pressure decreases to below the saturated vapor pressure [13]. On the pump, the part that often experiences cavitation is the suction side of the pump [14]. Cavitation can be very damaging to the internal pump if it is not repaired, and this cavitation is an effect ofrepetitive internal circulation [15]. Figure 3 shows typical cavitation spectrum

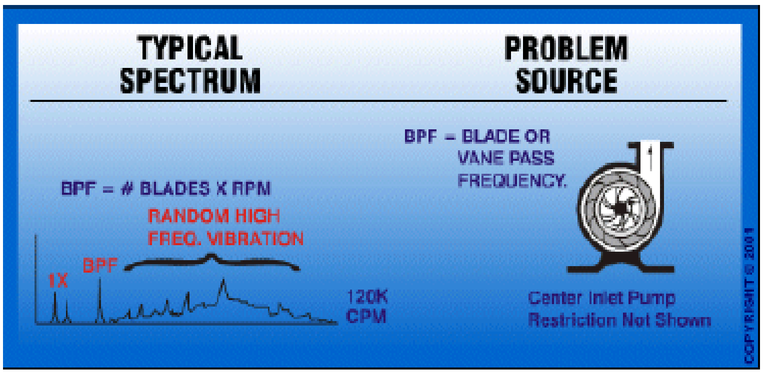

Fig. 3. Typical cavitation spectrum [12]

As a result of the internal recirculation effect, an inspection was conducted in the workshop area of Refinery Unit. It was found that the impeller on the 211-P-25A pump was pitting and bent. And there is also a scratch on the high-speed shaft gearbox.

Damage to the impeller is due to erosion of the impeller blade, causing damage to the impeller due to repeated internal circulation effects so that the impeller subjected to pitting and bent conditions. This effect causes the impeller to become unbalanced, which will affect the damage to other components. The impeller in the 211-P-25A pump serves to provide velocity energy to the fluid. The internal recirculation effect produces air bubbles, which then burst. If operated for a long time, there will be damage to the surface of the channel wall. The duct wall's surface will be potholes due to cavitation erosion as collisions of bubbles that break on the wall continuously. This is what causes the impeller subjected to pitting. Bent occurs because the impeller is continually experiencing the effects of internal recirculation and deforming the impeller blade. Internal circulation results in a decrease in pump engine performance. Internal circulation tends to occur in a low average flow rate and when fluid leaves the impeller by forming a vortex [11]. Figure 4 shows the bent and pitting of the pump impeller 211-P-25A

(a) bent (b) pitting

Fig. 4. (a) Bent and (b) pitting on centrifugal pump impeller 211-P-25A [10]

As with the impeller due to the low pump flow rate, the impeller subjected to pitting and bending, so that the bearing at the pump is subjected to wear and gear experiences a considerable backlash, causing instability movement on the high-speed shaft in the pump gearbox and produces scratches on the high-speed shaft lower and upper shaft bearing area [11]. As with the impeller due to the low pump flow rate, the impeller experiences pitting and bending.

Wear and scratch on the shaft causes vibration to the pump. Besides, the shaft also has a bent, due to the impeller experiencing unbalance so that the bent on the shaft also produces vibration. Damages that occur include the category of major damage, making the high-speed shaft must be replaced, the replacement of the high-speed shaft based on the LMV 322 instruction and manual specifications, it is stated that the high-speed shaft must be replaced if the outside diameter is less than 1.4960 inch [16]. And has clearances with a min limit on the upper high-speed shaft of 0.13 mm and a lower high-speed shaft of max 0.15 mm [11]. If it does not experience major damage and is still by API 610 standard, the shaft that is subjected to wear only needs to be checked on the worn part and polishing. But this is done for temporary repair [17].

Damage to the 211-P-25A pump is caused by internal circulation that repeatedly occurs, causing damage to the impeller and high-speed shaft components. This damage will result in pump performance that is not optimal and reduce pump efficiency. This is by the flow rate produced because the pump's damage is obtained a flow rate of 2.67 m^3/h, which should have a minimum flow of pumps of 8.6 m^3/h [18]. So the pump performance will decrease. Figure 5 shows Scratch on High Speed Shaft, and Figure 6 shows effect of flow rate on pump performance , and simple flow chart to analyze the high vibration causes shown in Figure 7.


Fig. 5. Scratch on High Speed Shaft [10]

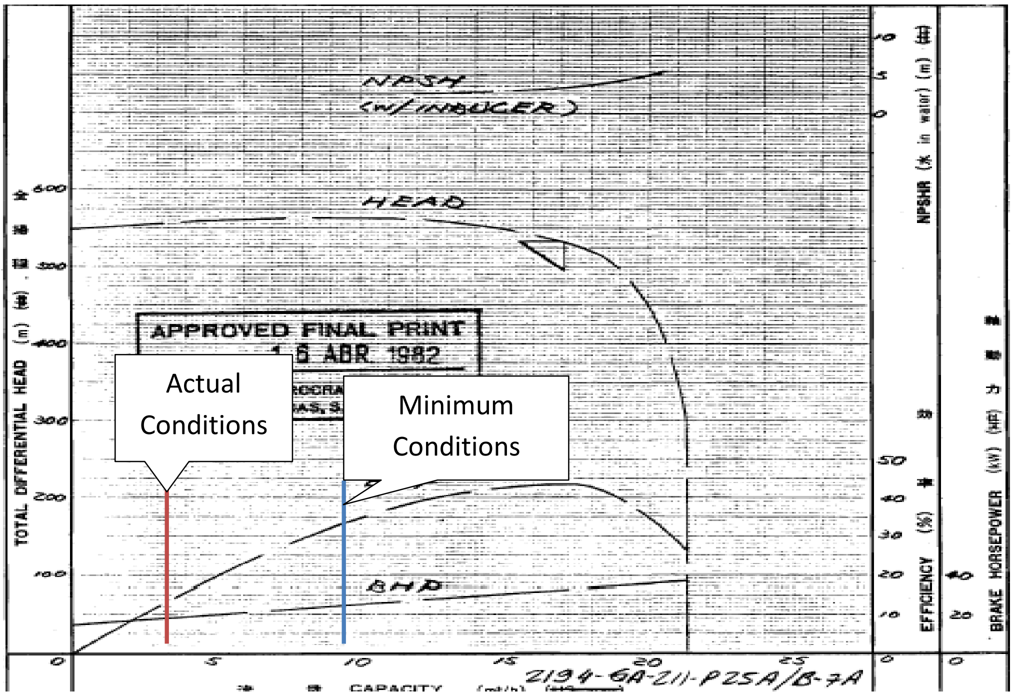

Fig. 6. Effect of flow rate on pump performance [9]

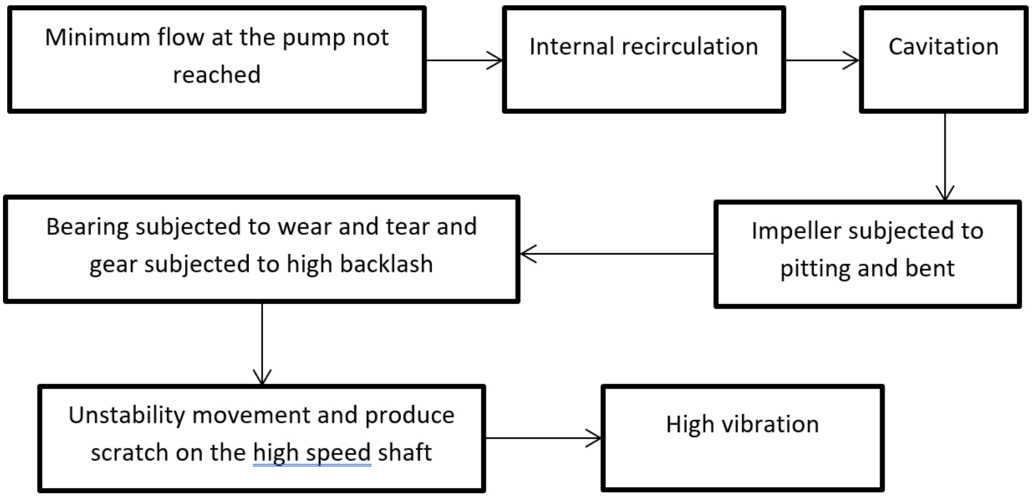

Fig. 7. Simple flow chart to analyze the high vibration causes

To eliminate low flow, additional flow can be done by fully opening the line bypass control. Then, if the flow requirement is above the minimum flow, additional flow is done manually by closing the line spill back after the maximum flow control FC-522 is no longer achieved [18]. Furthermore, the addition of instruments to the 211-V-23 vessel with auto stop with a minimum suction head of 3.5 m according to the pump NPSHr [19]. To increase pump efficiency, it can re-rate the pump impeller according to operational needs. This can be done with affinity law, to be able to change the flow and still maintain pressure to the system from the pump.

4. Conclusions

Based on the results of discussions conducted on the 211-P-25A pump, during practical work at RU II, it can be concluded that the 211-P-25A pump experiences high vibration, due to low flow. The resulting flow is 2.67 m^3/h, with a minimum pump design flow of 8.6 m^3/h. Damage to the pump impeller occured due to the internal recirculation effect. In high-speed shafts, damage caused by high-speed shafts wears over bright with min limit at the high-speed upper shaft of 0.13 mm and lower high-speed shaft of max 0.15 mm because damage to the impeller has damaged parts gearbox parts including one of them is a high speed shaft. Internal circulation effect caused the damage to the 211-P-25A pump impeller. So that it damages other components such as bearings, gears, so that the gearbox experiences major damage

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