HYDROCARBON
PROCESSING

Raise profitability through continuous performance evaluations

10.01.2014 | **Bhachu, U.**, Canadian Natural Resources Ltd., Calgary, Alberta, Canada

Keywords:

Reliability engineers use a wide variety of tools to support plant equipment and to optimize unit uptime and availability. Sound reliability programs assist organizations to be more competitive in the constantly changing economic environment. Performance evaluation is a vital tool that reliability engineers can effectively apply. The presented case history focuses on a poorly operating centrifugal pump. Such pumps are common to refining operations. Under-performing centrifugal pumps can lead to high maintenance and operating costs. Applying performance evaluation programs can improve the operation of major rotating equipment such as centrifugal pumps.

MEANINGFUL PERFORMANCE EVALUATION

The performance evaluation of any machinery, including centrifugal pumps, begins with the original vendor-supplied data. This data includes original performance curves, operating conditions, power and efficiency curves as calculated by the original equipment manufacturer (OEM), and various other important information. This information forms the benchmark from where the condition of any machinery, including a centrifugal pump, can be ascertained.

Proper monitoring system

The second most important prerequisite is establishing the proper plant monitoring system. Today, medium- to large-scale operating facilities, including petrochemical plants and refineries, use state-of-the-art process/equipment monitoring systems. These systems are capable of showing real-time information, and they are often capable of trending, managing and monitoring complex process operations. Additionally, such systems are often user friendly and can be customized with visual basic programming or other languages to interface with external applications, such as Microsoft Excel or Office applications, to present and evaluate the available data into a meaningful and productive format. This case history used a commercially available monitoring system and Excel spreadsheets to capture, trend and evaluate key information about the centrifugal pump. The system provided real-time performance monitoring of critical machinery.

CASE HISTORY

Boiler feedwater (BFW) pumps are critical equipment; they supply feedwater to the boiler systems that, in turn, produce steam for the entire plant. This steam is used in various process operations and heating systems, and in running critical turbomachinery including both small and large steam turbines throughout the plant.

BFW pumps are also used in the enhanced underground heavy oil recovery operation known as steam-assisted gravity drainage (SAGD). Evaluating these pumps proactively helps avoid unnecessary operational interruptions and shutdowns, thus increasing process uptime and plant profitability.

The evaluation

Table 1 lists the steps to implement a productive performance evaluation. As listed in Step 1, all relevant operating/performance data must be collected on the critical equipment. **Table 2** summarizes the essential operating data for the BFW pump at different flowrates. In Step 2, the collected data is organized as information. In this case, efficiency and performance curves are developed to monitor the pump in daily operations, as shown in **Figs. 1–3.**

TABLE 1. Methodology to apply performance monitoring

Step 1.	Develop the spreadsheets with all the relevant performance data for the pump.
Step 2.	Generate the appropriate graphs required to monitor the performance of the pump.
Step 3.	Use a plant monitoring system to capture and develop all process tags available in the database regarding particular machinery. In this case, it is the BFW pump.
Step 4.	Utilize spreadsheets by integrating real-time process data to analyze and monitor information, then to take corrective action to increase uptime and to save operating costs.

TABLE 2. Head, flow, power and efficiency test data for BFW pump

Performance points	Flowrate, Q, m^3/hr	Differential head, H, m	Power, kW	Efficiency, %
1	576.15	824.62	1,504.42	78.70
2	702.11	759.05	1,641.28	80.91
3	627.71	802.8	1,564.41	80.27
4	558.28	836.35	1,479.59	78.64
5	486.39	866.6	1,382.68	75.96
6	412.79	888.36	1,276.17	71.60
7	342.37	902.8	1,164.67	66.13
8	272.74	912.19	1,061.67	58.42
9	197.99	918.98	953.42	47.56
10	577.91	827.23	1,506.09	79.10

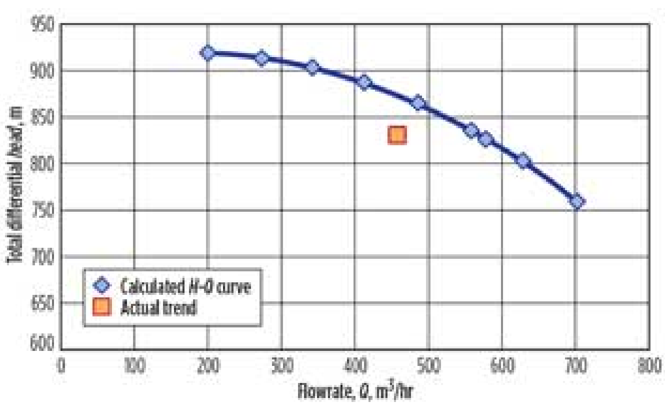


Fig. 1. *H–Q* curve for BFW pump.

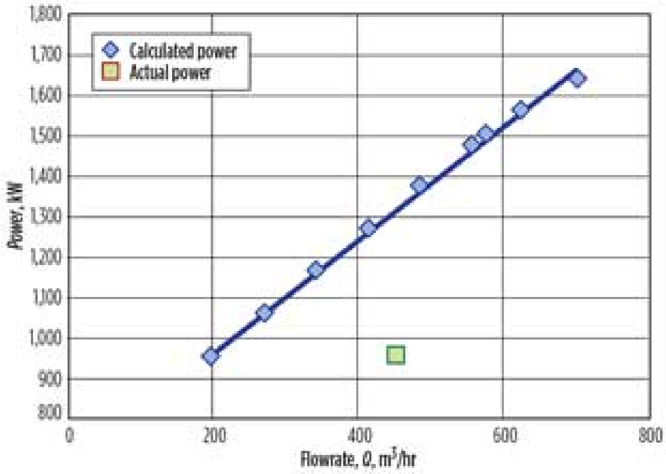


Fig. 2. Power vs. flowrate of BFW pump.

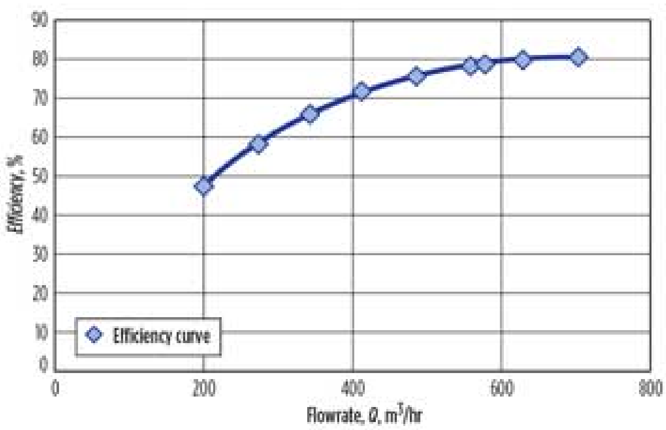


Fig. 3. Efficiency curve for BFW pump.

In Step 3, a proper plant monitoring and software system is selected and installed to capture and develop all process tags. The tags are organized into a database; all critical information about particular machinery can be found in the database.

This case is the BFW pump. **Fig. 4** is a snapshot developed in the process book for the BFW pump, which is being run by a steam turbine. It is important to capture all of the important tags that are relevent to the operation of the designated piece of equipment. In this case, the critical information includes the X and Y vibration readings, suction and discharge pressure, flow, bearing temperature, and speed for the BFW pump. These tags capture and present real-time process and vibration information as the pump is operating.

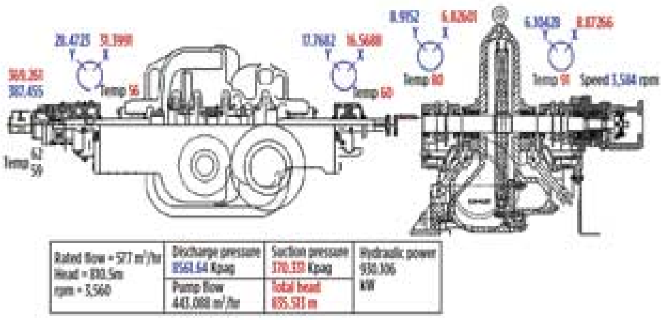


Fig. 4. BFW screen showing the pump-turbine layout and tags.

Many tags can be used in commercially available software. Flow, *Q*, suction pressure, discharge pressure, calculated total dynamic head (TDH) and hydraulic power for the pump were imported into Excel spreadsheets, as shown in **Table 3,** for analysis and monitoring of this pump.

TABLE 3. Process and calculated data for BFW pump

Process data	
Discharge flow, Kpa	8,517.39
Flow, *Q*	458.78
Suction flow, Kpag	365.71
Total head, m	831.47
Hydraulic power, kW	965.43

Real-time action

In Step 4, the collected data is organized into Excel spreadsheets. The data is integrated into real-time process data to analyze and monitor. From this information, corrective action can be taken when necessary to increase uptime and reduce operating costs.

Step 4 is a crucial step; it integrates all of the available information to efficiently monitor the equipment. **Figs. 1** and **2** show the *H–Q* and power curves, respectively. These curves have been incorporated with real-time information showing the *TDH, Q* and pump hydraulic power, respectively. These curves present the real-time pump operation relative to the actual operation of the pump during performance testing. Visual presentation of this information helps to understand how far the pump has moved away from the actual operating point during normal operations. It also helps to estimate the operating power losses due to a drop in pump operating efficiency.

Efficiency, η_p, of a centrifugal pump is simply defined as the ratio of the amount of power from the pump to the amount of power inputted to the pump. It is easy to see that pumps operating away from the best efficiency point (BEP) are not being utilized correctly. There are several causes leading to such operations; they include:

- Internal wear of running mechanical components leading to recirculation
- Issues with pump bearings contributing to high preload or over-lubrication
- Operation of the pumps with throttled discharge valves
- Incorrect pump selection for the application.

Magnitude of costs

To better understand the magnitude of costs involved in operating pumps inefficiently, engineers should consider the lifecycle cost (LCC) of the pump:

$$LCC = Cic + Cin + Ce + Co + Cm + Cs + Cenv + Cd \qquad (1)$$

Cic = Initial costs, including purchase price, pump, system, pipe, auxiliary services
Cin = Installation and commissioning costs
Ce = Energy costs as defined as the predicted cost of operating the system, including drivers
Co = Operation costs, including labor cost of normal system supervision
Cm = Maintenance and repair costs, including routine and predicted repairs
Cs = Downtime costs, including lost production
Cenv = Environmental costs
Cd = Decommissioning/disposal costs.

Energy cost. *Ce* consumption will usually dominate Eq. 1. Therefore, it is critical to maintain and operate pumps efficiently. Assume that the BFW pump in this case history is using an electric motor as opposed to a turbine to run it. For this case, assume that the cost of power is $0.07495/kWh. The efficiency for the pump with an electric motor is calculated as:

$$\eta_{pump} = \frac{Power_{out}}{Power_{input}} \qquad (2)$$

$$P_{hydraulic} = \frac{H \times Q \times SG}{3,600} \qquad (3)$$

Using a modified version of Eq. 3, the hydraulic power of the pump was recomputed . From the vendor curve in **Fig. 2,** the OEM proposed the shaft power for a given flow would have been for a new pump. It was determined that the pump was operating at an efficiency of 0.74. Assuming a motor efficiency of 0.80, the power required for the system would be:

$$Power_{input} = \frac{H \times Q \times SG}{366 \times \eta_{pump} \times \eta_{driver}} \qquad (4)$$

Eq. 4 yields a power input requirement of 1,612 kW for this pump and the assumed motor. Assume $0.07495/kWh for energy cost and if this system were running throughout the year for 8.765 hours. The total approximated energy cost of running this pump would be *$1,059,427*. This shows how important it is to operate pumps close to their BEP and to proactively monitor the condition of the pump to mitigate excessive energy waste. The process of calculating energy costs at different operating points is based on the efficiency of the pump. This process can be automated in Excel. It is quite evident that energy waste costs can quickly escalate for multiple pumps and other turbomachinery in an operating plant. Time averaging of the input power would provide a more concise estimate of energy cost associated for a given machine.

Options

It is beneficial to develop performance monitoring programs for all plant machinery. Integrating process data in a common database can provide an accurate measurement of equipment performance and its subsequent impact on energy costs. A proactive approach can impact the bottom line of an operating plant in a positive manner. **HP**

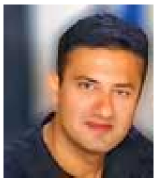
Notes

[1] This case history used a system called PI Process Book developed by OSIsoft, along with Excel, to capture, trend and evaluate key information about the centrifugal pump, and to present the advantage of real-time performance monitoring of all critical machinery.

Bibliography

The Hydraulic Institute, Pumps.org
Perry's Chemical Engineers' Handbook, Eighth Edition.

The author



UMEET BHACHU, P.Eng, CMRP, is a registered engineer in the province of Alberta and is working as a rotating equipment engineer for the Canadian Natural Resources Ltd. (CNRL). His work with CNRL has included reliability simulations, technical assessment of rotating machinery and, most recently, an international assignment in Krakow, Poland, on an expansion. He earned a diploma in mechanical engineering from the British Columbia Institute of Technology and then graduated with a BS degree in chemical engineering from the University of British Columbia in 2005. His work has spanned various reliability and engineering design positions specifically focused on rotating machinery and turbomachinery. He is an ISO CAT II vibration analyst and a Certified Maintenance and Reliability Professional.