**Abstract**

Appropriate monitoring of ESPs (Electric Submersible Pumps) can extend runlifes. The key to successful monitoring is to know which parameters to measure and how to interpret the data obtained properly in order to perform effective well and ESP diagnosis and interpretation. This paper will focus on how the downhole vibration parameter can be used to extend equipment runlifes, indicate well performance issues and diagnose integrity of the producing wellbore system.

Analysis of wells showing unusual vibration responses was performed using data obtained from a worldwide database. A series of case histories are presented that demonstrate how vibration can be used to determine well or ESP operability issues. In each case details of the well operating conditions will be provided, the problem will be discussed and the resulting action detailed.

**Introduction**

When considering downhole rotating systems such as ESPs we are dealing with complex systems where vibration can be introduced to the system in many ways. In the case of an ESP, vibration can be induced due to imbalance in the pump or motor, wear in the pump diffusers or impellers, manufacturing problems, electrical power instability or as result of the fluids being produced through the pump. Based on experience it has been possible to develop a set of practical guidelines detailing how the vibration parameter can be used.

In a downhole permanent completion installation we have limited ability to take action when a pump problem occurs – and in most cases a costly workover is to avoided. For this reason it is important to monitor the pumping system and take action to prevent a pump problem. Vibration is one of the parameters that can be monitored action taken to prevent a pump from operating in an undesirable condition. The case histories and guidelines presented in this paper provide one more diagnostic ‘tool’ to use in the battle to extend pump runlifes.
Vibration measurement and interpretation

Vibration is one of the many parameters available to assist with the diagnosis of ESP systems in order to optimise runlife. Like any other variable, it should always be used in conjunction with other downhole and surface measurements (particularly pressures) in order to obtain a complete picture of the pump and well performance.

The vibration sensor (accelerometer) is located in a housing below the motor and measures movement in a single direction (radially). It is calibrated to read in units of acceleration in “g” (gravity, 32.174 ft/s^2). In general terms, an ESP operating normally would have a vibration reading of less than 3g. Readings significantly above 10g would be a cause for concern.

Vibration is an indirect measurement of ESP performance since, like amps, it includes mechanical (e.g. sand, wear), electrical (e.g. frequency) and hydraulic (e.g. gas, viscosity) components. It is thus difficult to interpret an exact, absolute value of vibration – rather the trend of vibration is important and can indicate a range of problem conditions or change in normal operating conditions such as:

- change in frequency (pump speed) and operation around resonant frequencies
- change in wellhead pressure (by surface choke closure)
- increase in well watercut and indication of emulsions
- onset or increase in solids (sand/scale) production and tracking pump wear
- start of gas locking
- change of pump/motor temperatures caused by severe upthrust/downthrust operation

The purpose of this paper is to provide a set of practical guidelines for vibration interpretation. This will be done by the analysis of seven field examples where the vibration parameter has been used to diagnose pump performance and, in some cases, been used to shut down the ESP prior to catastrophic failure.

Field examples (see attachments)

Consideration of the following examples and case histories should help to explain how vibration can be applied in practice to analyse and interpret the performance of the well and ESP system:

1) normal operating conditions
2) start up and resonant frequencies
3) recirculation and overheating
4) sand production
5) closed surface choke and downthrust
6) solids production and surface choke blocking
7) severe pump wear

A complete analysis and description of the problem and solution is provided with each case history.

Conclusions

Vibration can be a valuable part of the armoury in the battle to prolong ESP system runlife. It can give warning of abnormal or severe operating conditions and be used to protect ESP equipment from premature failure.
ESP vibration examples

1) Normal operating conditions:

- pump is started at 14:45:
  - discharge pressure rises as tubing fills
  - high vibration due to initial surge of well completion fluids
  - pump shutdown to check and confirm rotation

- pump re-started at 15:30:
  - discharge pressure rises as tubing fills then stabilises
  - intake pressure decreases (due to dPpump) and increases reservoir drawdown until stabilisation
  - motor temperature initially increases sharply due to motor loading
  - intake temperature rises as hot reservoir fluid enters wellbore and pump intake

- vibration stable at under 0.5 g
ESP vibration examples

2) Well start-up and ESP resonant frequency:

- discharge pressure responds to increased wellhead pressure (from pressure test of tubing)
- pump started for short duration;
  - discharge pressure increases due to choke at surface
  - intake pressure decreases due to dPpump
  - at pump shutdown, intake pressure shows typical pressure build up curve
  - high initial vibration (1.5 g)
- on second pump start-up;
  - initial discharge pressure fluctuations are due to choke adjustments (i.e. WHP changes)
  - intake pressure reflects these fluctuations (N.B. could be mistaken for a pump problem)
  - as frequency is increased, dPpump increases and hence lower intake pressure
  - note that there is virtually no change in discharge pressure (probably large tubing)
  - temperatures increase due to hotter well fluids; small difference shows good cooling
- marked vibration increase around 41 ± 2 Hz indicates ESP resonant frequency (but still < 1.5 g)
  - operation at or around resonant frequencies should be avoided where possible
ESP vibration examples

3) Recirculation and overheating:

- vibration indicates when pump is operating
- during second operating period (10:38 to 11:10);
  - discharge pressure increases very slightly
  - no change in intake pressure (no change in reservoir drawdown, therefore no flow)
  - very low dPpump: either mechanical problem (broken shaft) or high flow
  - abnormal increase in motor oil temperature (no cooling)
  - significant sharp jump in vibration towards end of operating period (up to 25 g)
- only possible explanation for all of the above is pump recirculation;
  - very low head requirement, so pump operates at maximum flowrate (high upthrust)
  - low pump efficiency at this point results in pump heating
  - recirculated fluids are hotter so temperature rise in pump increases quickly
  - no flow from reservoir therefore no flow across motor causing heating
  - vibration change is probably due to differential expansion causing binding
- this condition must be diagnosed quickly;
  - only remedy is to pull tubing and locate hole (or ensure bypass tubing plug in place)
  - the head generated by the pump can be used to estimate the position of the tubing leak
ESP vibration examples

4) Sand production:

- on the 19<sup>th</sup> October the surface choke was slowly opened to increase production:
  - wellhead pressure decreased and hence pump intake pressure decreased
  - lower bottomhole pressure causes increased reservoir drawdown and hence flowrate
  - higher flowrate brings increased sand content into the wellbore and ESP

- increasing sand content causes erratic and increasing vibration readings
  - magnitude approaching 3 to 4 g (from 1 to 2g prior to opening choke)
  - no change in motor or intake temperatures, so pump not yet significantly wearing
  - prolonged operation at this condition could lead to premature ESP failure
  - wellhead pressure should be increased to increase pump intake pressure and lower flowrate

- a sudden change in vibration of 2g or more should be closely monitored to discover the cause
5) Closed surface choke and downthrust:

- pump is operating normally until 10:00 hrs;
  - vibration low at 1.5 g
  - pump intake pressure and temperatures stable

- just after 10:00 hrs conditions deteriorate as the wellhead choke is inadvertently closed;
  - jump in motor oil and intake temperatures caused by low flow and operation in downthrust
  - wellhead pressure and discharge pressures increase and also pump dP (head)
  - relatively small change to pump intake pressure as these effects counterbalance each other
  - pump intake pressure builds slowly as flowrate decreases
  - significant sharp jump in vibration as pump continues to operate in downthrust

- prolonged operation at this condition will lead to premature ESP system failure;
  - vibration can be used to trigger an alarm condition so that the cause can be investigated
  - either shut in the well to examine the problem or open surface choke
ESP vibration examples

6) Solids production and surface choke blockage:

- Repeating cycle above is due to solids production blocking surface choke:
  - Wellhead pressure rises as blockage increases causing a lower well flowrate
  - Motor oil temperature responds rapidly to lack of cooling and ESP trips on high temperature
  - Heating of well fluids from hot motor after shut-in is seen by intake temperature increase
  - Pattern repeats after each ESP restart

- Vibration readings increase sharply from normal readings (2 to 3 g) up to 6 g
  - Vibration pattern caused by combination of motor heating and operation in downthrust
  - Reading above 6 g are an immediate reason for concern and cause must be determined
  - Reason for sand production should be investigated and remedied
  - If unavoidable, use sand resistance pump and upgrade size and materials of surface choke
7) Severe pump wear:

- pump operation until early April shows normal trends
  - pressures and temperatures stable
  - vibration readings low (<2 g) but erratic, indicating probable sand production

- massive increase in vibration during subsequent 3 week period;
  - sand production causes breakdown in pump performance and onset of severe wear
  - pump loses dP (head) and therefore pump intake pressure rises
  - well flowrate decreases and pump moves into downthrust, further increasing wear
  - vibration readings peak at 18 g, indicating a major problem with pump operation
  - ESP pulled and found to be severely worn

- vibration acts as early indicator of pump wear;
  - ESP replacement can be scheduled
  - if detected early enough, system can be pulled prior to probable motor burnout