ARMSTRONG

White paper

Design Envelope Pumps Mitigate Motor Bearing Damage

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1.0 Abstract

While the incidences of **PWM (Pulse Width Modulation)** adjustable frequency drives causing damage to the bearings of AC induction motors are quite rare and permanent magnet motors even rarer, there is an increasing concern in the marketplace regarding such damage. Armstrong Design Envelope Pumps include a number of unique design features to eliminate this damage to motor bearings. Armstrong Design Envelope pumps are complete pumping units including controls and certification to **ULSTD 778 & CSA STD C22.2 NO 108**, to cover **North American** needs and appropriate approvals in other locations. In the unlikely events of any problems the complete pumping unit has been manufactured and warranted by one manufacturer, Armstrong, who carries the responsibility for the complete pumping unit. No need to coordinate a drive, motor and pump manufacturer along with an electrician to troubleshoot problems.

2.0 Unique control features to eliminate Motor Bearing Damage

2.1 Low peak voltage transitions at the stator

In many bearing failure scenarios the damage is a direct result of a large peak voltage being impressed on the motor stator windings. The Armstrong Design Envelope pump has a number of features that limit the peak voltage applied to the motor. These include:

- **Soft switching IGBTS**

The rise time of the voltage pulses that the Design Envelope pump control produces are significantly longer than they are for most other PWM drives. As a result, the peak voltage that is generated at the motor is reduced.

- **Elimination of output reactors on most sizes**

Advances in drive current detection and shorter fault reaction times have eliminated the need for output reactors in Armstrong Design Envelope pump control. As a result, the snubber-diodes in the control's output inverter section have very little impedance separating them from the motor. Therefore, these diodes can more effectively clip voltage spikes throughout the output wiring.

- **60 Degree Asynchronous Vector Modulation (60OAVM)**

The greater the stator voltage change during a PWM switching operation, the greater the voltage change imposed on the motor. It is these fast, high amplitude voltage fluctuations that are often the cause of the motor bearing damage mechanisms.

Once the Design Envelope pump control reaches a normal operating speed, it automatically switches to a mode where each output IBGT is locked on for 60 degrees of each output cycle and is locked off for the opposite 60 degree segment. As a result, only two pairs of transistors are actively switching most of the time. This limits the amplitude changes in the voltage that is impressed on the motor's stator. Instead of all transistor pairs switching continuously at the drive's carrier frequency, which may be at a rate of thousands of cycles per second, 60OAVM limits such transitions to 6 times per output cycle. At an output frequency of 60 Hz, this corresponds to only 360 of such transitions per second. At reduced output frequencies, this number is even lower.

2.2 Reduced frequency spectrum in the PWM pulses

A standard PWM waveform is rich in high frequency components. The faster the rise time of the PWM pulses, the greater the high frequency components of the pulses. The longer rise time of the Design Envelope pump control's PWM pulses reduces the high frequency component of these pulses and so increases the impedance of the capacitive paths through the motor, restricting current flow through these paths.

2.3 Automatically controlled carrier frequency

Damage to motor bearings does not occur immediately. Small imperfections in the bearings build over time until the bearing's races and rolling elements cause objectionable vibration, audible noise and related problems. By reducing the carrier frequency of the pulses supplied to the motor, the service life of the bearing can be extended. The problem with this is that the carrier frequency of most PWM drives is fixed. It is often set to a high frequency in order to avoid objectionable audible motor noise when the pump is being driven at a low speed. The Automatic Switching Frequency Modulation (ASFM) feature of the Design Envelope pump controller provides a solution. For Design Envelope pumping units up to 60 hp (at 460V AC), when the motor is lightly loaded, ASFM will increase the carrier frequency of the drive's output to reduce objectionable audible motor noise. However, when the load on the motor increases, ASFM will automatically adjust the carrier frequency. While this provides many operational advantages for the control, the automatic reduction in the control's carrier frequency during periods of heavy output load is a significant factor in extending motor bearing life.

Of course, the 60OAVM feature, mentioned earlier, has the effect of making an extreme reduction in the frequency at which the motor receives high amplitude voltage pulses.

2.4 EMI / RFI filters

Built in EMI/RFI filters help to ensure peak voltage are contained within the controls and do not travel to the motor. Armstrong Design Envelope pumps include filters as necessary to ensure compliance to low emission and immunity requirements EN61800-3 to the 1st environment class CI (EN55011 unrestricted sales class B).

3.0 Other ways Design Envelope pump design minimize the risks of motor bearing damage

Equipment Location

It is generally best to keep the drive and the driven motor as close to each other as possible. This helps to reduce both the peak voltage that is impressed on the motor's stator windings and the impedance of the ground path between the drive and the motor. As a result, it generally makes sense to avoid mounting drives in motor control centers, where the lead length between the motor and the drive will most often be quite long. Design Envelope pumps ensure the minimum distance possible between the control and motor as the control is integrated into the unit up to 450 hp / 350 kW to minimize connection length.

Control Enclosure

When one attempts to mount a drive near the driven motor it is also important to consider the environmental requirements of the drive. Placing the drive in a significantly wet, dirty, or hot location is never a good idea unless the environment is considered when selecting the drive's enclosure. Many drives are simply Nema 1 / IP 20 rated enclosures.

Design Envelope pump with integrated controls have a minimum enclosure rating of Nema 12 / IP 55/54.

Grounding

Proper grounding is essential when designing a system that includes PWM adjustable frequency drives. Items to consider include:

- Do not rely on conduits to provide the ground. These do not provide a reliable, low impedance ground for the high frequency components that are associated with PWM drive operation.
- Size ground wires appropriately. The size of the ground wire will generally be larger than would be used if a plain constant speed motor starter was used. This large wire size helps provide a low impedance path for the high frequency components that are associated with PWM drives.
- Wire the ground to the drives properly. Each drive should be supplied with its own ground wire that returns to a reliable electrical ground. Do not "daisy chain" a ground wire from one drive to another.
- Run an individual ground wire in the conduit between each drive and its motor or use shielded cable which includes a ground wire. As with the drive ground wire, this will likely be a larger wire that you would generally use. This ensures a low impedance ground to the high frequency currents minimizes harmonic voltages.
- Do not run the motor wiring for more than one drive in a single conduit. While there are a number of reasons for this, the concern here is the ability to minimize the impedance of the ground lead.
- Ground the driven equipment to the motor. This ensures that there is no voltage difference between the voltage of the driven equipment and the voltage of the motor's shaft. If there is no voltage difference, grounding currents won't flow through the motor's drive end bearing, through the motor shaft, and into the driven equipment.

Design Envelope pumping units are constructed and assembled in a clean factory environment to exacting standards and the complete pumping unit is certified to UL778 requirements. The pump end and motor units are bolted together in a metal to metal fit assuring grounding. Every unit utilizes the best practices in wiring and grounding.

The power wiring from the Motor Control Centre (MCC) or the panel to the Armstrong Design Envelope pump should be bonded to ground and size properly for the power of the unit.

Design Envelope pump speed change

There is incidental evidence that running a motor at a constant speed can contribute to bearing damage. It is theorized that a vibration can be established in the rolling elements of the bearings that tends to make all discharge currents occur at the same location on the bearing. Changing the speed of the motor occasionally breaks up this vibration pattern.

Design Envelope pumps incorporate sensorless speed control and when used in an installation ensures the pumping unit continuously reacts to the changing demand of the system and therefore continuously varies speed.

Varying magnetic flux

A separate but related topic is the tendency for large motors and generators to generate varying magnetic flux currents. The circuit path for these currents consist of the rotor, drive end bearing, frame and non- drive end bearing. This current typically has high voltage and low amperage and insulating one bearing will open the circuit and prevent current flow.

ALL DESIGN ENVELOPE PUMPS NEMA 400 FRAME OR IEC 90 KW AND ABOVE FROM THE DATE OF THIS ISSUE INCLUDE INSULATED NON DRIVE END BEARINGS.

4.0 Summary:

Armstrong Design Envelope pumps with integrated controls include control features, electrical and mechanical standards assured by factory environment assembly and complete unit certification to UL 778 or appropriate approvals in areas outside North America which all eliminate the risk of motor bearing damage. In the event of any problems the complete unit supply by Armstrong means one source responsibility under warranty. No need for customer coordination of electrical and mechanical contractors and pump, motor and drive manufacturers. Armstrong does not recommend the use of shaft grounding on Design Envelope pumps with integrated controls up to 450 hp.

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