Insight: Fire Pump Elastomeric Coupling Failures

Understanding the Risk

Couplings are a critical component on many pump applications- both in industrial and fire protection systems. Numerous documented failures, specific to elastomeric shear-type couplings utilized on fire pumps, have elevated reliability concerns. Fire pumps are typically installed to boost deficient water supply pressures needed for the successful operation of supplied sprinkler systems. And elastomeric coupling failures on fire pump system typically occur instantaneously without warning when the pump is operating under full load such as during a fire event. Without an operating secondary fire pump in parallel, the result is most likely the total impairment to all connected fire sprinkler systems from operation and successful fire suppression or control

Background

In general terms, a pump coupling connects (i.e. couples) an electric motor or diesel engine (i.e. driver) shaft to a pump impeller shaft facilitating the transfer of rotational power to spin the pump and move material or media. Elastomeric type couplings are commonly used in industry on processing pumps, fans, HVAC systems, blowers, compressors, conveyors, and mixers in a wide range of industries. For fire pump systems specifically, the pump rotation increases water supply pressure for connected hose and sprinkler systems.

Couplings come in various types with those most common to fire pumps falling into four categories:

1) Elastomeric Shear Type
2) Jaw Type (i.e. elastomeric-metal jaw type)
3) Grid Type
4) Shaft Type

With the exception of those that may not require coupling such as some direct-coupled end suction pumps bolted directly to a driver and vertical turbine pumps, most fire pumps require driver-to-pump connection for operation by coupling. For fire pumps, all couplings are referred to as “flexible couplings” due to their secondary purpose beyond power transfer- they are critical to allow for pump shaft and driver shaft elongation that occurs due to temperature changes when operating. During operation this could be relativity significant and the couplings allow linear “flexibility” for this expansion (i.e. shaft elongation with enough interior space so they do not directly contact each other).

Jaw type couplings typically cause confusion in identification as they have an elastomeric insert component but, unlike typical elastomeric couplings they are not a “shear type” coupling. Shear type couplings do not have an integrated secondary back-up metallic insert like jaw types do. Shear -type elastomeric couplings are designed (and installed on many industrial applications specifically for this purpose) to fail/break when the pump experiences an out-of-range misalignment or resistance to disengage and protect the pump from damage. This is contrary to fire pump design philosophy- to run indefinitely even to destruction in a fire. Jaw type couplings have metal teeth or jaws between integral elastomeric inserts that act as a redundant drive feature should the elastomeric component fail. This feature prevents total system impairment in a fire situation as is the concern with elastomeric shear type couplings.

Fire pump system design and installation guidance comes from global codes, standards, and guidance sources. One of the most commonly used is the National Fire Protection Association Standard 20 (NFPA20)[2]. Fire pump systems (referred to as "units" in NFPA 20) consist of a pump, a driver (typically electric motors or diesel-engines), a controller, and various support components/accessories which includes pump-driver couplings. Since 1996, NFPA 20 has required all critical components of a fire pump system including pumps, drivers, controllers, and couplings to be Listed or Approval by a recognized testing agency specifically for fire service such as Underwriters Laboratories[4] or Factory Mutual [5]. And while shear-type elastomeric couplings are common for industrial pump applications as they are very economical, maintenance free (requiring no lubrication), and easy to install, they are not approved for fire pump installations. They are accepted and are common in industrial applications other than fire pumps but have not been Listed or Approved for use in fire systems due to the reliability concerns captioned. Fire pumps are a critical life safety and property protection system needing the highest possible reliability and resilience. Fire pumps are also installed and operate under service conditions unique from industrial applications that create added failure potential. For example:

Elastomeric couplings can be more susceptible to failure from factors such as vibration under higher speeds and industrial application pumps typically run (rotate) at lower speeds than fire pumps. Shaft rotational speeds can be much higher on fire pump systems than most industrial applications- in excess of 3000 rpm.

Unlike other industrial pump systems and applications, fire pumps connected to electric motors can see immediate maximum torsion when energized which is transmitted directly through a coupling. And while there may be a slight speed ramp up on diesel-engine driven pumps, this torsional power transmission is also near instantaneous. Elastomeric couplings are very sensitive to significant and instantaneous torque. And most fire pumps, unlike most industrial applications, do not use variable frequency drives or other methods to create soft (slow speed ramp up) starts.

Industrial system pump couplings may be installed for a secondary purpose of vibrational snubbing and alignment compensation. In commercial applications alignment is typically more closely monitored and tested. Elastomeric fire pump couplings, while called "flexible," are only so for linear shaft alignment. They are prone to failure with even slight angular and parallel horizontal misalignment. And both are commonly not properly checked on fire pumps at installation nor routinely after installation. Due to the higher sensitivity (and failure) of elastomeric couplings to even slight misalignments, a visible or "straight edge" alignment check also may not be adequate. Alignment, especially with elastomeric couplings, should always be completed annually as a minimum[3] by qualified personnel (such as a trained millwright or engine mechanic) and, by laser alignment.

Elastomeric couplings have temperature considerations. Frictional heating experienced by a coupling, especially under full load, can cause degradation of the plasticizers within the component resulting in embrittlement of the material. The elastomeric materials used can also lose strength as temperatures rise- such as in a diesel engine fire pump room during an extended fire event.

Base securement of fire pumps is often not completed as part of installation. NFPA 20 recommends consideration of base plate movement as part of installation- i.e. baseplate grouting when a fire pump is installed on a steel frame. Grouting of base plates, even though a NFPA 20 requirement, is often not done and missed at commissioning. This in turn increases the chance of misalignment, especially under full load as in a fire, due to vibration which in turn increases elastomeric coupling failure potential as alignment maintenance is not completed.

Figure 1 Centrifugal Fire Pump Assembly

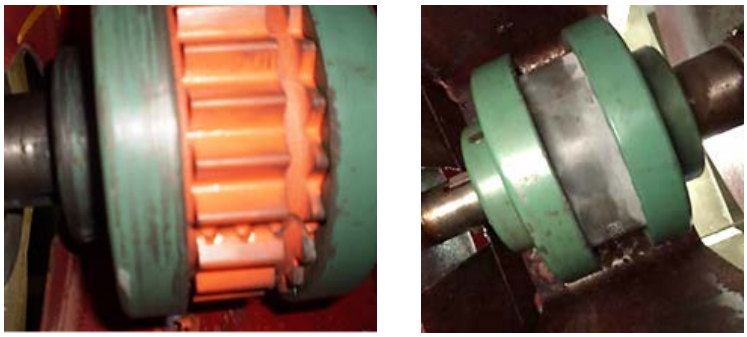

Figure 2 The Most Commonly Found Elastomeric Couplings- Not Listed/Approved for Fire Pump Systems (picture on right shown with coupling boot)

Figure 3 Failed Not Listed/Approved Fire Pump System Elastomeric Coupling

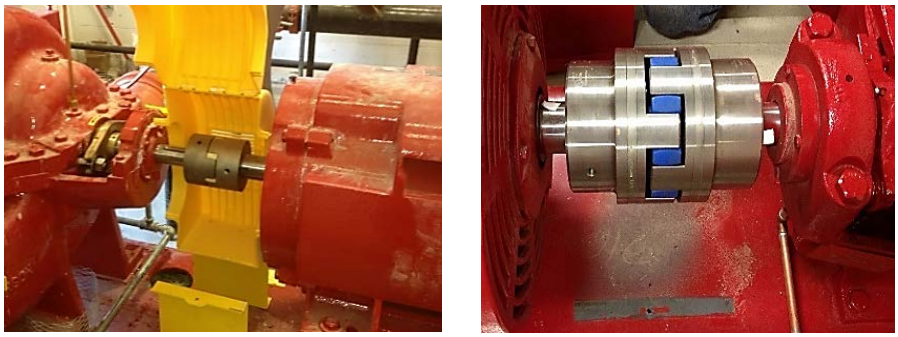

Figure 4 The Most Commonly Found Jaw Couplings (with elastomeric component) Listed/Approved for Fire Pump Systems

Recommendations

Years of industry experience (and failures) have indicated that couplings relying on all-elastomeric material without metallic jaw inserts to transmit power from driver to pump can fail catastrophically and unpredictably without warning. This failure severs the connection between the pump and driver which, during a fire, would result in lost water flow and pressure to facility sprinkler systems and an uncontrolled catastrophic fire event.

Therefore, AIG recommends the replacement of any identified elastomeric coupling(s) with a UL Listed or FM Approved or other third party testing laboratory that meets or exceeds the requirements of the U.L. or FM Approval Testing Criteria for fire pump coupling.

Resources / Standards

The references are:

[1] The Coupling Handbook: Part III", Lovejoy

[2] NFPA 20: Standard for the Installation of Stationary Pumps for Fire Protection

[3] NFPA 25 Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.

[4] UL Test Standard 448A: Flexible Couplings and Connecting Shafts for Fire Pumps"

[5] FM Approvals Approval Standard 1336: Flexible Fire Pump Couplings and Flexible Connecting Shafts for Fire Protection Service

For more information, contact your local AIG representative.

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