Ward Lipscomb, Adhesive Services Company, USA, outlines methods to maintain long term rotating equipment reliability.

PLANNING AGAINST FAILURE

The long term rotating equipment reliability triangle is composed of three phases. Proper foundation design and installation is a good basis for reliability, but the longevity of reliability is a combined effort of continuous monitoring and preventative maintenance. Performing preventative maintenance on a foundation reduces the risk of experiencing a catastrophic failure.

Long term foundation monitoring of rotating equipment, as well as some preventative measures to help prolong equipment reliability, should be the basis towards a more comprehensive programme. Every equipment installation and operating condition is unique, and a thorough monitoring and preventative maintenance plan should be specifically tailored to each piece of equipment.



Figure 1. Dial indicator setup.

Laying the groundwork

A long term reliability monitoring programme should start prior to commissioning of the equipment. Baseline equipment benchmarks relative to the foundation should be recorded as the jack bolts are first removed. Prematurely removing the jack bolts before the grout has developed a sufficient amount of compressive strength should be avoided. Movement of the equipment relative to the grout can be monitored by using a dial indicator located near each jack bolt. After the dial indicators are positioned, they should then be zeroed. As the jack bolts are released and removed, the dial indicators should not detect any equipment movement. With the jack bolts removed, the anchor bolt may be torqued to the original equipment manufacturer's (OEM) recommended load, following the torqueing procedure provided by the manufacturer. As the anchor bolts are torqued, the dial indicators should detect no movement. Figure 1 shows an example of using a dial indicator to monitor for movement. If any crush is detected, the results should be compared to the equipment manufacturer's acceptable pull down limits.

The goal of rotating equipment alignment is to place the internal components of the equipment in an optimal operating position, as well as any equipment that may be coupled together. A long term monitoring programme will allow the end user to track any changes in elevation or alignment of the equipment. Establishment of permanent benchmarks provide a reference point for future checks, and will make it easier to predict when the grout will fail to a point that alignment will be lost, requiring a regrout of the equipment.

The basic intended design and function of a foundation is to support the equipment, while maintaining the critical alignment of the equipment over its economic life. When the foundation loses its ability to maintain the alignment of the equipment, the operational lives of the internal components are reduced. Due to the finite life of materials, a gradual decline in the foundation occurs; this is the result of undergoing millions of reversible loading cycles. A common cause of equipment installation failure is fatigue of the grouting system as the equipment gradually debonds, and develops movement relative to the underlying foundation. Failure to regrout when necessary can multiply the dynamic forces exerted on the foundation. Any conditions which deviate from the original design or installation may damage the underlying foundation.

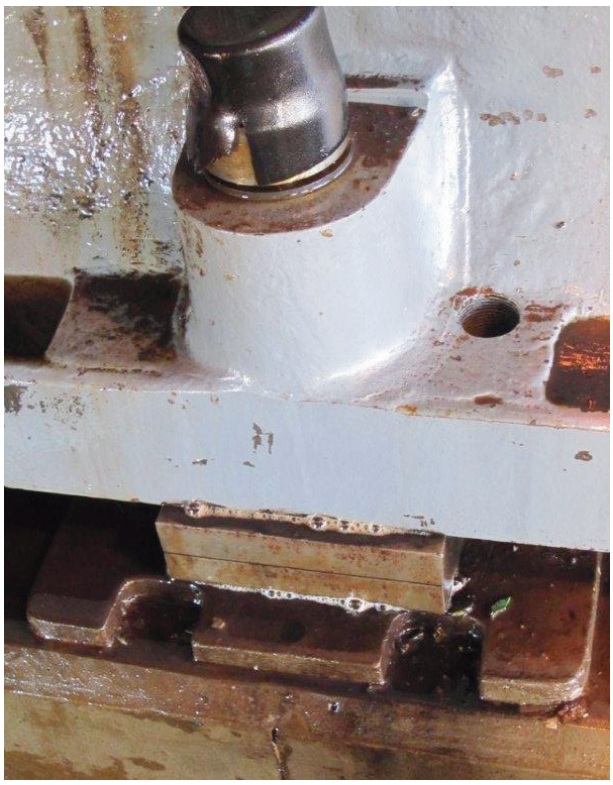


Figure 2. Oil penetration of steel chock.

Moving sideways

Horizontal movement is most common on chock rail or chock soleplate installations. The only mechanism to resist horizontal movement is the frictional resistance between the mating surfaces. The coefficient of static friction between non-moving surfaces is higher than the coefficient of kinetic friction between moving surfaces, and the frictional force is a product of the normal force exerted by each surface and the appropriate frictional coefficient. During the course of equipment operation, oil penetrates between the mating surfaces of the support system, significantly reducing the coefficient of static friction. Figure 2 is an example of a steel chock with oil penetration.

As the coefficient of static friction decreases, so does the frictional force required to resist horizontal movement. Relative movement between the equipment and the chock not only causes fretting of the surfaces, but also causes the chock to 'walk out' from beneath the equipment. The common reaction to chocks that have walked out is to hammer them back underneath the equipment. Hammering causes deformation of the steel chocks, increasing the amount of fretting on the mating surfaces. Figure 3 is an example of steel chocks that have been hammered underneath a piece of equipment.

Epoxy chocks are more susceptible to alignment issues and movement than steel chocks. Epoxy chocks have a

modulus of elasticity, compressive strength, durability, and abrasion resistance that is much lower than steel chocks. The physical properties of epoxy chocks fluctuate with the operating and ambient temperatures. Epoxy chock manufacturers recommend applying a release agent to the mating surfaces to prevent the epoxy chock from bonding to the equipment. If the release agent is applied too thick, it may cause excessive pull down of the equipment. Although the intention of the release agent is for ease of removal and replacement of the epoxy chock, in actuality it reduces the frictional forces between the different material surfaces. Due to the material properties and installation application, epoxy chocks are in constant need of maintenance.

Once horizontal movement has developed between the equipment and the foundation, increasing the torque of the anchor bolts is a common misconception of how to stop the movement. The lesser amount of kinetic friction will not be sufficient to eliminate further movement of the equipment. This becomes increasingly more difficult when oil penetrates between the two surfaces. Because of the presence of oil and continual surface abrasion, constant tightening of the anchor bolts will lead to plastic deformation in the form of bottlenecking and eventual anchor bolt failure. Anchor bolt repair or replacement requires a temporary removal of the equipment from operation.

Various problems

Pocket grouting is not an industry recommended practice, but it is a commonly encountered form of equipment installation. Separation occurs between the materials due to the differences in the modulus of elasticity, thermal coefficient of expansion, ultimate tensile strength, and the shear resistance of epoxy grout and concrete. Vertical cracks and fissures in the foundation provide a pathway for lubricating fluids and liquids to penetrate and hydraulically fracture the underlying foundation. As the underlying concrete foundation absorbs oil, a gradual decline in both the tensile and compressive strength of the concrete will follow.

Edge lifting of epoxy grout occurs because of the different thermal absorption and dissipation rates between epoxy grouts and concrete. Thermal cycles throughout the day and night create thermal induced stress cracking in the concrete. During the cool nights, as the surface of the epoxy grout cools, it begins contracting, placing the underlying concrete foundation in tension. The condition reverses during the warmer days, placing the underlying concrete foundation in compression. Since the tensile strength of concrete is 8 – 10% of its compressive strength, the concrete eventually cracks just below the grout cap. The thermal heating and cooling cycles will continue to propagate the cracks towards the base of the equipment. Even though edge lifting is considered cosmetic cracking, the cracks should be sealed to prevent the emergence of any liquid contaminants from degrading the underlying concrete foundation.



Figure 3. Hammering steel chocks.

Being able to distinguish between two types of foundation cracks is important when evaluating the structural integrity of a foundation. Foundation cracks that appear as a result of externally applied dynamic forces from rotating equipment constitute a structural failure. The plane of these foundation cracks runs parallel to the axis of the crankshaft and can be commonly found at the bottom corners of the oil pan trough or as cold joints. The plane of thermal growth cracks runs perpendicular to the axis of the crankshaft, and does not constitute a structural failure. These cracks commonly originate at anchor bolt locations or the ends of equipment. Even though these cracks are less severe, they provide a pathway for lubricating fluids and liquids to penetrate and further progress the crack.

Inspection and prevention

Preventative measures to stop oil from entering the mating surfaces or interiors of the foundation should be exercised. Periodically pulling the steel chocks to remove oil from the mating surfaces of the soleplate, rail and equipment is a good measure for maintaining the optimal static frictional forces. Installing an elastomeric and oil resistant room temperature vulcanisation (RTV) silicone around the base of the equipment and in the grout's expansion joints will function as a primary seal to oil penetration. All jack bolt holes should be filled with silicone to prevent the collection of oil and to reduce further oil penetration from hydraulic head pressure. If any vertical grout surface cracks are encountered, the cracks should be routed to obtain a width to depth ratio between one and two. Periodic inspection of the silicone should be performed, with any missing silicone replaced as soon as possible. In addition, practicing good housekeeping by removing any collection of oil from the top surfaces of the grout, and promptly sealing any oil or coolant leaks of the equipment will help promote long term grout reliability.

Rechecking the torque of the anchor bolts on a regular basis is good practice to ensure they are providing an adequate amount of hold down load on the equipment. Over the course of equipment operation, the anchor bolt's nut tends to back off, resulting in a gradual reduction of the clamping force. Ensuring the anchor bolts are properly torqued will reduce the risk of anchor bolt fatigue and failure. With most anchor bolt failures occurring in the upper 12 in. of the stud, any damaged upper stud should be

replaced as soon as possible to prevent further damage to the surrounding anchor bolts.

It is advisable to retorque the anchor bolts during the planned maintenance intervals of the equipment. This is a good opportunity to not only ensure the anchor bolts are properly torqued, but to check the equipment base for soft foot. Equipment soft foot is characterised by a net change in elevation as the anchor bolts are tightened. A dial indicator is located adjacent to each anchor bolt and zeroed. As the nuts are loosened, upward movement of the equipment should not be encountered. Any upward movement may be an indication that the grout has crept, and the grout bond failed, as the equipment recaptures its relaxed position. When the nuts are retightened, pull down of the equipment should not be encountered. Any pull down of the equipment is an indication that the grout is fatigued and has further crept. If excessive pull down is detected before the final torque amount of the anchor bolt is reached, the torqueing procedure should cease in order to prevent further deflection of the equipment. The alignment of the equipment should be checked and verified prior to restart.

Conclusion

Proper foundation design and installation is a good basis for reliability, but the longevity of reliability is a combined effort of continuous monitoring and preventative maintenance. Even the best designed and properly installed new equipment eventually fails as its finite life is exhausted. Constant operational abuse and neglect of both the equipment and foundation gradually reduces equipment reliability. Long term monitoring of equipment helps the end user chart operational changes over time. This valuable data becomes a tool to predict when failures may occur, and helps prepare a repair plan and procedure for these events. Monitoring the equipment and collecting data does not in itself increase equipment reliability.

The goal of preventative maintenance or planned maintenance is to help prevent and control the occurrence of unplanned breakdowns and failures. Taking a proactive maintenance role is more beneficial than a reactive maintenance role. Not all breakdowns and failures can be predicted and avoided, but a majority of them can be avoided by performing preventative maintenance. Unfortunately, some end users believe that regularly scheduled equipment downtime and maintenance costs are higher than those associated with a complete failure. Cost related factors like loss of production, loss of time, availability of parts, interruption of normal plant process, availability of skilled repair persons, mechanical trouble shooting, etc. must be taken into consideration.

The old saying ‘time is money, and money is time’ is a testament to effectively using the limited time and resources available to a company. Maintaining equipment in peak mechanical condition not only improves reliability, but it also increases the efficiency of the equipment and plant process. Ultimately, minimising unplanned equipment downtime while increasing production contributes to a better bottom line.