Process, Plant & Equipment UPTIME

Brilliant maintenance for managers, engineers operators and maintainers

From Trade-School.Education – Maintenance & reliability newsletter for students and employees.

CONTENTS

Volume 1 Edition 6 topics

Key topics

Special features

Corrosion in Agitated Conditions

Chemical corrosion occurs at increased rates in agitated conditions. Typical isocorrosion curves for alloy metals no longer apply. These curves only show corrosion rates at various chemical concentrations and temperatures in stagnant conditions. A typical curve is shown below. The curves are available from alloy metal suppliers on request. When metals are selected for agitated corrosive conditions the curves can only be used in a relative sense. They help grade the metal selection but they cannot provide absolute corrosion rates.

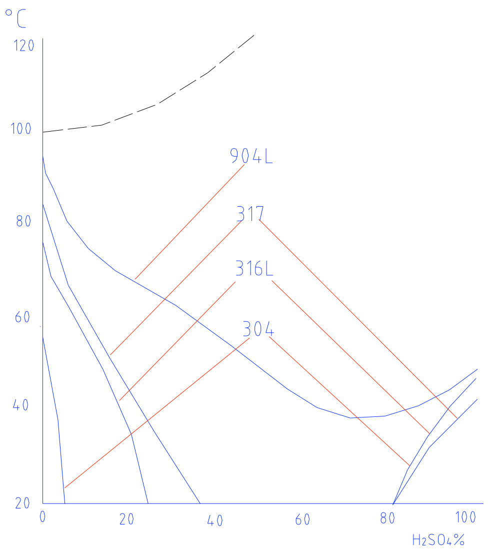

Fig. 1. Isocorrosion curves, 0.1 mm/year, in sulphuric acid. The broken curve indicates the boiling point.

CORROSION BARRIER

Metals can develop a corrosion barrier when they come into contact with certain chemicals. In some cases this protective layer can be easily removed. Carbon steel in contact with 98% sulphuric acid forms a protective ferrous sulphate layer. To prevent this protective layer from being removed the velocity of sulphuric acid in pipelines must be kept below 1 m/sec. Alloy steels when in contact with chemicals develop a corrosion barrier that protect the metal underneath. In agitated conditions this barrier is more easily removed and the fresh metal is exposed to renewed chemical attack. The rate of protective layer removal is greatly increased in agitated conditions.

Agitated conditions include stirred vessels and tanks, mixers and agitators, pumps, pipelines and valves. An example of incorrect selection was with the bolts and nuts holding paddles on an agitator in a reactor mixing 50% sulphuric acid with a slurry of powder in water. The operating temperature was 90 centigrade (195 F). The nuts and bolts installed to hold the agitator blades were wrongly chosen to be of 316 stainless steel and lasted two months. Inspection of the iso-corrosion curve above for the process conditions indicates the unsuitability of the metal for this service. Even a high alloy metal such as 904L would have limited life in the application. The nuts and bolts were changed to Hastalloy C and have been in the same service for over two years.

Another difficulty when selecting specialist alloys for agitated conditions is the availability of the metal in the form required, at an acceptable price. Sometimes compromises are necessary between availability, price and longevity. This situation can be seen with the construction of an agitator in contact with the chemicals mentioned previously. Hastalloy C was preferred but it was only available from overseas with a long shipping delay and at a high price. Locally 904L was available but the iso-corrosion curves indicated a limited life. However previous experience with a similar grade alloy from a different supplier in the same service conditions indicated a life of about four years. Because the choice of alloys was limited and repairs were required, the agitator shaft and paddles were constructed of 904L. To date they have been in service for over a year without obvious deterioration. Not an ideal selection but an acceptable one.

Use of the iso-corrosion curves combined with other available corrosion behavior data, such as pitting corrosion potentials, can be used to mix-and-match metals to reduce costs. For example a tank wall and floor in direct contact with the process chemicals may be made of a higher-grade alloy while the roof, which only sees the vapour, may be made of a lesser grade metal.

PIPELINE EQUIPMENT

Valves selected for corrosive services need to be designed to cope with agitated flow conditions. Some valves cause much turbulence. Gate valves have recesses in their bodies that cause the flow to swirl in the gate pocket. Under-and-over valves like globe valves cause the flow to twist up and around the plug and then turn back toward the outlet. Even butterfly valves, with their disc projecting into the fluid flow cause some agitation. When selecting valves for agitated conditions chose chemically compatible materials with wear resistance, which minimise turbulence and meet the pressure requirements of the process.

The selection of equipment in agitated corrosive conditions is difficult because both right and wrong decisions become expensive. High grade and high quality materials cost more and it is wasteful to specify exotic metals such as titanium if alloy steels could be used. In contrast using materials of inadequate abilities will mean money is lost because replacement is more frequent.

ALTERNATE MATERIALS

In looking at better material selection for corrosive services it is useful to consider the use of non-metals. Plastics can have excellent corrosion properties. Provided their temperature limits are respected they can be used to line the contact surfaces. Fully Teflon lined plug valves have performed well in sulphuric acid pipelines. Plastic lined pipes in corrosive service are common. Corrosion resistant bricks and mortars have been successfully used as linings. Fiberglass can be used provided the corrosion barrier layer is not worn away by abrasion. Rubber lined valves, such as diaphragm valves, have been used for agitated corrosive conditions for decades. Rubber lined agitators have been installed into reactors. The internals of pumps and pipes have been successfully protected with specialist epoxy coatings.

IN-SITU TESTING

Where the opportunity is available, the best method to confirm the suitability of a material is to put a test piece into the environment with which it must cope. In the case of the 904L agitator mentioned previously, test coupons of other alloys have been welded to the agitator blades so they could undergo trial under the full service required. If any prove to be more suitable than the 904L, the next agitator will be fabricated from that material.

Mike Sondalini - Maintenance Engineer

Keep Gearboxes Running.

A gearbox is used to control the operating speed of industrial equipment. It converts a high input speed to a lower output speed and so permits one driver element, such as an electric motor, to do numerous duties. Failure of the gearbox causes the equipment and associated plant to stop. Proper selection, care and maintenance of gearboxes is critical to your company's continued profitability.

GEARBOX SELECTION

A gearbox is selected for the duty it must perform. Each selection must take consideration of the following points.

Load type	- Steady, consistent - Intermittent, on-off, fluctuating - Impact, hammering, surging
Environment	- Temperature of location - Cooling and heat dissipation - Dustiness - Humidity, dampness
Forces	- How are the forces created? - Where are the forces located? - Where are the forces transmitted?
Robustness	- Is the mounting sturdy? - Will the shaft handle the torque? - Is the casing solid and rigid? - Is there sufficient excess service duty to handle unexpected loads?
Drive	- Direct coupled, chain, belt driven - Minimum bearing loads required - Orientation of gearbox in relation to the forces generated
Gear type	- Loads and forces applied to gears - Heat generated by the meshing - Lubrication type
Maintenance	- Parts availability - Standardisation across the site - Skill level of maintainers - Presence of procedures
Operations	- Production demands - Operator care - Overload potential

For example, in the selection of a gearbox to be direct coupled to an agitator for a stirred tank, consideration must be given to the distance the output shaft bearings are apart. Bearings positioned further apart cope better with the bending forces generated by the paddles located at the end of the agitator shaft.

The load type will affect the selection of the gear type. Steady, continuous loads can be accommodated by spur gears but impact loads can break spur gear teeth. A more robust gear to use in impact load situations would be a helical gear. This gear shape offers more tooth cross-sectional area and because of the helix dissipates impact forces axially and tangentially.

Another style of gearing often seen on slow moving, high load applications is the worm and worm wheel. Planetary gearboxes are available where space is limited for standard design gearboxes.

GEARBOX CARE

A well-selected gearbox will have a long service life. Long term maintenance will involve checking oil levels and for critical or expensive gearboxes checking oil quality. Oil quality ought to be tested at least every two years for stationary plant and every year for mobile plant. More often if the loading or service duty is arduous. A simple site test for gearbox oil is to take a sample and look at the color, note the smell, look and feel for presence of grit and feel the slipperiness compared to fresh oil. If you are concerned then send a sample to a lubrication test lab.

The choice of lubricant is critical. The oil must retain its properties at the operating temperature. The gearbox manufacturer is best able to advise the oil to use. Where the manufacturer cannot be contacted, one of the major oil companies can offer practical suggestions on the oil to use. Mixing of different oils in the same gearbox is poor practice. Unless you can tell the oil supplier with certainty what oil is already in the gearbox so a match can be specified, do not cross mix oils. Mineral and synthetic oils are not compatible. It is better to drain the old oil out, flush the gearbox through with the new oil, put in the new oil to the required level and run the gearbox for two to three hours and finally dump, flush and refill the gearbox again.

Breathers are fitted to prevent shaft seals blowing out as the internal pressure rises when the gearbox is warming up to operating temperature. A breather allows moisture in the air and dirt from the surroundings to enter the gearbox. Locate and protect the breather to reduce the risk of contamination. Check with the gearbox manufacturer to see if a breather is needed and if not then do without it.

Unexpected high working loads can occur that will destroy gearboxes. For overload conditions shear pins can be installed in the drive train or motor overload protection can be fitted to the power supply. For those services where impact loading is normal such protection is mandatory.

A belt or chain drive gearbox should be oriented so the forces in the drive pull the gearbox down onto its feet. Where the orientation of the gearbox causes the gearbox to be pulled off its feet there is a risk the feet will break from fatigue caused buy fluctuating loads. In this case additional clamping of the body may be necessary.

GEARBOX MAINTENANCE

When a gearbox is open cleanliness is critical. Dirt and dust entering bearings and gear teeth spaces will cause wear and rapid failure. If gears with chipped teeth are reused, chamfer the chipped edges to remove loose metal.

Gearbox bearings may require pre-loading to a minimum bearing load to prevent excessive noise and wear. Pre-loading bearings insure the rolling elements are properly bedded onto the races and prevent the rolling elements skipping and sliding around the tracks.

Mike Sondalini - Maintenance Engineer

The Importance of Fit, Tolerance & Clearance.

Many equipment breakdowns and stoppages occur because of improper clearance between holes and shafts. The shaft is too tight in the hole; the center of the hole is not at the center of the shaft making it off-center; one part is loose on another and slips out of place or does not seal as it should.

CLEARANCE

Equipment is designed so that parts have either a gap between them so they can move separately to each other or they are firmly in contact and do not move relative to each other. The gap or lack of it, between the hole and shaft is called the clearance. Clearance is determined by the size difference between the parts. Fits and tolerances are used to specify the size range of parts.

FIT

The types of fits have been given names. They range from an interference fit, where the parts are purposely made to be forced together. This fit can be further described as heavy through to light interference. Whereas a clearance fit is for parts made to have a space between them. This fit can be further described as tight through to loose. Between these two fits is the transition fit where interference may or may not occur. The amount of interference or clearance is achieved by specifying the tolerance range for the parts possible sizes.

TOLERANCE

Because of gradual cutting tool wear and minute changes in the machine tool internals due to temperature changes and wear/movement of internal parts, machined items can not all be made perfectly to the same dimension. It is permitted to make the part to within a range of sizes. That range is called the tolerance on the dimension.

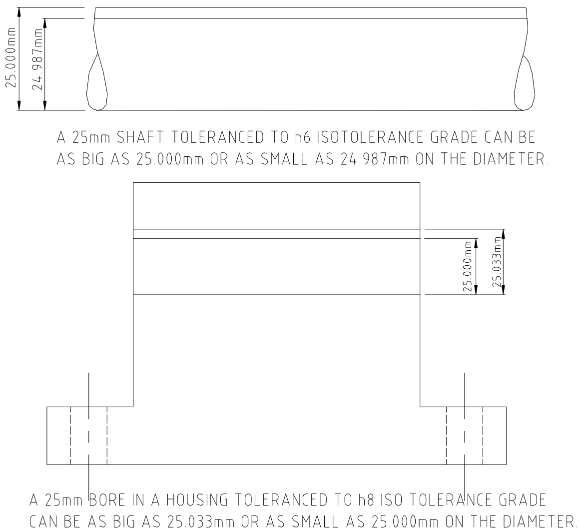

Figure 1. A dimensioned and toleranced shaft and hole.

Figure 1 shows a dimensioned shaft and a dimensioned hole in a block with tolerances to provide a transition fit when assembled. At the largest sized shaft and the smallest sized hole they would contact. This tolerance is too tight for a shaft that had to move through the hole but might be suitable for the outer race of a bearing fitted in a bearing housing of a rotating shaft. In such a case the bearing race must not move on the shaft (spin) as it will wear the shaft, so an interference fit might be suitable. If the load on the bearing was large, or there was a lot of vibration or the shaft was spinning very fast it would be better to make it a light interference fit. If the shaft were large and rotating at low speed and repairs had to be done by the tradesman while in-the-field without access to bearing removal and installation equipment, it might be better if it was a tight clearance fit.

Selection of tolerances for a part is made after considering -

- the speed at which the part moves
- the applied loads and forces it must withstand
- the amount of vibration permitted
- whether grease or oil lubrication is used
- ease of assembly
- changes in size due to thermal expansion.

Engineering drawings follow a recognised standard for displaying the dimensions and tolerances required for a machined part. The Figure 2 shows two acceptable ways to dimension and tolerance a part.

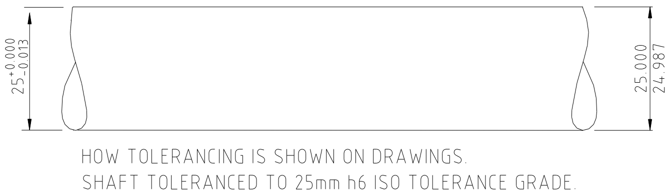

Figure 2. Methods for tolerancing parts

It is critical to know the fit, tolerance and clearance required for replacement parts. Often damaged parts are measured-up in order to manufacture a replacement. If the old part is worn and no allowance is made for wear, the clearances will be in error and the machine may not operate properly or for long.

FITTING TOLERANCED PARTS

When tolerances are too loose parts rattle about causing vibration and wear. An oversized bore on a shaft coupling allows it to flop about on the shaft. At high speed the coupling is thrown about causing noise, vibration and shaft distortion. Bearing failure occurs well before time. Always machine parts to the proper size and tolerance for the application. Drive couplings must be bored centrally and axially to prevent out-of-balance. Bored couplings directly mounted on the shaft should have a light interference fit and be heated on assembly to slide onto the shaft and key.

Machine parts heat-up when operated and they expand and change size. If there is insufficient clearance when the parts have expanded they may contact, or loose contact or prevent sufficient lubrication thickness to develop. When parts make contact heat is generated and material is scraped off into the lubrication system. Eventually contamination and damage become severe and the machine fails.

Thermal growth of machine parts can also cause alignment changes. There have been occasions where a machine aligned when cold, goes out of alignment when at running temperature. Various parts have grown in length with the warmth of operation and contacted neighbouring parts. The forces generated cause deformation and distortion.

ALWAYS MEASURE & CHECK THE CLEARANCE

To be certain sufficient clearance is available between parts for radial and axial thermal growth the dimensions of the parts must be measured and the clearance checked. Corresponding dimensions on each part are measured with micrometers. The measurements are then subtracted from each other and the difference is the clearance when the parts are cold. In critical applications it is necessary to determine the growth in size when the machine is at operating temperature. The formula for thermal expansion is available from machinery handbooks. The growth in size is added to the 'cold' dimensions and the clearances again determined.

An example of a thermal expansion problem because of insufficient clearance for shaft axial elongation was a bearing failure on a high speed rotating 80-mm (3") shaft.

The shaft ran on two bearings mounted in separate housings. The drive end bearing was the floating bearing and the other the fixed bearing. This configuration, of one fixed and one floating bearing, is the correct way to allow for shaft expansion. The fixed bearing's outer race was clamped in place inside the housing by the end covers and spacers. However the axial clearance between the floating bearing's outer race and the housing's rear cover had not been checked and was insufficient. As the shaft grew in length with the heat of operation, the floating bearing was forced against the end cover causing tremendous heat and noise.

During machine assembly the available gap between holes and shafts can be readily checked with micrometers. It is more difficult to check axial spacing. A simple method to check axial clearance is to insert plasticine between the shoulder and the abutting face and mount the parts fully. The plasticine is squeezed into the available space and the parts are again stripped down and the thickness of the plasticine checked with a micrometer. Only use enough plasticine so the parts still pull-up properly together as if finally assembled.

Mike Sondalini - Maintenance Engineer

Experiences with Belt Bucket Elevators

This article covers some of the problems that can occur with bucket elevators and provides possible remedies. Bucket elevators lift bulk materials from one level to another. They are used on powders, granules, grain, chip shaped products and lumpy materials. They function well when designed properly for the duty, and used as designed.

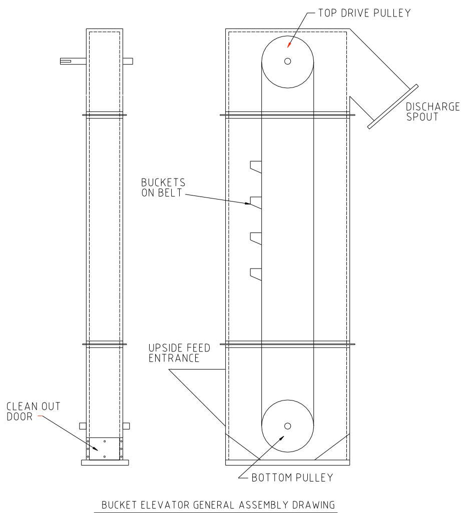

Figure No 1 A belt bucket elevator.

Figure No 1 is of a belt bucket elevator. The buckets are bolted to a belt, driven by a pulley. The frame and housing enclose the belt, buckets and product. The buckets scoop up the material fed into the base or boot of the elevator. At the top it is flung through the outlet chute. Adjustable screws move one of the pulleys to provide belt tensioning and tracking. Inspection doors at the top and bottom allow viewing of the belt when making tracking adjustments

The drive pulley can be either the top or bottom pulley. With a top pulley drive the motor and gearbox are clear of product spills and dust fall-out. The belt tension only needs to be sufficient to provide enough friction between belt and pulley to lift the material. Access platforms to the drive at the top of the elevator is needed for belt tracking and maintenance.

With bottom pulley drive maintenance access is easy but belt tension is doubled to provide the same drive friction. This increases loading on all the moving components. If the bottom drive pulley becomes coated in product or the belt stretches, the belt slips. Top pulley drives have less operating problems.

Where the bucket elevator is used for multiple products, quick cleaning access for operators is required. Flanged and bolted access doors seal well but removal is slow and threads become crusted with dust. Other options on non-hazardous materials are to use doors like those in Figure No 2.

The bottom pulley ought to be a self-cleaning design and not allow product to build up between belt and pulley. One method is to use round bar to create a grizzly bar design. Gluing rubber to the drive pulley will increase the drive friction. Cut the rubber splice at an angle of 45 degrees to the pulley axis so the splice gradually feeds into the friction area of the pulley.

The belt speed must be sufficient to throw the material clear of the bucket and into the outlet chute. Too slow and the material slides from the upturned bucket as it comes over the top pulley and falls back to the bottom of the elevator. Too fast and the material is flung out too soon and hits the top of the elevator before falling back to the bottom. Formulas are available to determine the right belt speed and throw for the material.

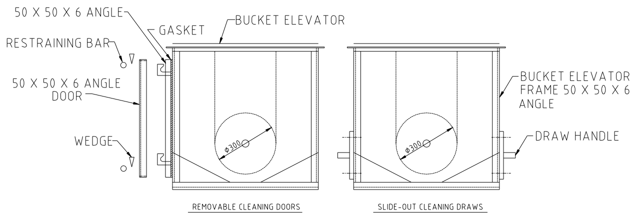

Figure No 2 Clean-out doors.

The pulley shaft bearings are best mounted on standoff brackets to the outside of the elevator housing in case the shaft seals leak. Shaft sealing should be well designed to stop any leaks. The UP-TIME article on Protecting Bearings in Dusty Conditions can be consulted for some useful shaft sealing ideas.

Feeding the product into the elevator boot is done by allowing material to fall through a chute under gravity or by forced methods such as a powered feed screw. Both the feed chute angle and its cross section must be large enough to prevent product hang-up or build-back. A clear passage without obstructions is critical. Similarly the discharge chute angle, size and design must allow product to flow freely.

Pressurisation commonly occurs inside the elevator housing as the buckets drag air on the downward run from top to bottom. When the feed rate into the elevator boot is less then the removal rate of the buckets, the flow of air is carried through the filling section and upward with the filled buckets. Dust is raised inside the elevator and the internal air pressure forces the dust out through openings and seals. The problem is worst with powdery or dusty products.

If it is important to reduce the amount of dust, the boot should be kept choked without bogging the elevator. Increasing the feed rate into the boot slightly above the bucket removal rate will cause plugging. With such a feeding arrangement it would be necessary to also install build-back detection to periodically stop the feed until the boot was cleared. An alternative, successfully used on powdered products, is to feed the product in from the downward side of the elevator. With this method the product filling the boot moves through with the bucket and both product and bucket act to plug off the bottom of the boot to the flow of air.

Quick detection and stoppage of the feed to a bogged bucket elevator is critical. When this is overlooked the belt stops but the drive continues to run. If undetected the rubber on the drive pulley peels off and the belt is eventually worn through. To detect bogging, a proximity detector is fitted to confirm the presence of rotation of the non-drive shaft. A stationary shaft would raise an alarm and stop the elevator and feed system.

Mike Sondalini - Maintenance Engineer

The connection between nut torque and bolt tension.

Why threads strip and bolts break.)

ABSTRACT

The connection between nut torque and bolt tension (Why threads strip and bolts break). When a bolt and nut is tightened to draw the bolt head and nut together it stretches the shank, deforms the threads and loads the object trapped between the bolt head and nut. The bolt shank acts like a spring being pulled apart and it tries to return to its unloaded condition. The amount of tension developed in the shank is dependent on the number of turns of the nut. The size of the torque required to turn the nut has little to do with the tension applied to the bolt shank. Rather the amount of torque needed to turn the nut reflects the slipperiness of the threads. Keywords: bolt tension, yield stress, coefficient of friction,

The nut torque stated in bolt tension tables is based on lubricating threads with light oil. When other lubricant is used the torque values must be adjusted to get the 65% to 75% yield stress recommended for bolted connections.

The ease with which a nut moves on a bolt thread affects the torque required for it to turn. As the nut tightens down, its threads are squashed against the threads of the bolt shank. The two threads wedge together against each other. The turning nut rides down the bolt shank threads, eventually squashing against the clamped surface until the combined thread and nut bearing surface friction resistance prevents further movement.

The bearing surface area under the nut and bolt head is larger than the cross-section of the bolt shank. In the case of metal flanges being clamped together the nut bears against the flange, the bolt shank begins to lengthen, and the threads in the nut and bolt start to distort. The threads distort and become loaded one at a time. As the shank lengthens the strain causes the atomic structure to deform. The atomic structure reacts like a taut spring and a counter force acts to hold the atoms together. If the nut continues to be tightened the shank lengthens further and the stress rises.

If the stress reaches a sufficient amount known as the yield stress, the atomic 'spring' structure deforms permanently. And if the nut is turned further the bolt eventually shears at the area of greatest stress.

If instead the threads were the weaker part of the bolt assembly, it would be they that distorted to the point of failure and strip.

Bolts are tensioned normally by turning the nut until the effort to turn the nut reaches a certain force. An alternate method is to heat the bolt to a specific temperature that expands it a given length and then put the bolt into the hole with the nut done up firmly snug and then let the bolt cool down.

The torque-up method is cheap and quick but poor in accuracy. The bolt lengthening method is very accurate but time consuming and costly.

The torque-up method relies on friction between nut and bolt threads to produce the reaction to the tightening torque. If the friction is low the threads will undergo more loading before the friction force matches the tightening force. If the threads are rough the friction force is greater and sooner matches the tightening force.

Good practice is to never do up threads dry but to always lightly lubricate them. The lubricant reduces the effects of the thread surface roughness and lowers the friction between the nut and bolt. It provides a near consistent friction value on all the bolts and improves the accuracy of getting the same bolt load in all the bolts. It also improves the accuracy of reaching the same bolt load for those bolts used repeatedly.

Rub your hands together and feel the friction they generate. Now put some liquid detergent and water on them and rub the detergent into your hands. When you rub them together with the detergent as lubricant there is much less friction and they slide over each other easily. In other words the detergent reduces the force required to rub your hands. The same occurs when a lubricant is put on bolt threads. Less torque is needed to do up the nut.

The more slippery the lubricant, the less the torque needed to get the bolt loaded. The table below shows the maximum and minimum coefficients of friction for a range of thread surfaces with lubricants. As the coefficients of friction drops, less torque is needed to tighten the nut. With very low friction on small diameter bolts the nut can be turned so easily that the bolt will stretch past its yield before the right nut torque is reached, and the bolt breaks.

Surface/Lubricant	Friction Coefficient Min	Friction Coefficient Max
Bare passivated surface	0.1	0.25
Baked on MoS_2 film	0.04	0.1
Molycote G Paste	0.04	0.09
Liquid Teflon (water based) on MoS_2	0.03	0.10

If using Teflon coated threads the recommended nut torque based on oil lubricated threads no longer applies and the torque value must be lowered to prevent the bolt being over-loaded. Check with the bolt supplier as to the correction factor or do your own bolt stress verses lengthening trials under specific torque loads.

The total nut turning torque depends on both the thread slipperiness and the slipperiness of the bearing face under the turning fastener component. The surface area of the nut contacting the flange produces additional friction. At times it is necessary to turn the bolt because it is not possible to turn the nut. In this case the required torque for the bolt turning will not be the same as that for turning the nut.

Mike Sondalini – Equipment Longevity Engineer.

References: Fastener Handbook, AJAX Fasteners, 1999.
http://www.engineeringatboeing.com/docs/BoltAnalysisGuidelines.html.