

Running Maintenance Torques

Screen 1:

Welcome Screen:

Welcome to the Running Maintenance Torques module of the ES44AC/DC Mechanical Systems Advanced course.

Screen 2:

Introduction to Running Maintenance Torques:

In this module, we will discuss different types of bolts and tightening methods, as well as special tools and torque values commonly used for the different tightening methods.

At the end of this module, you will be able to:

- Identify the different types of bolts based on thread profile, strength, and size.
- Identify the forces that operate on a bolted joint.
- Describe the different tightening methods used for locomotive maintenance.
- Describe special tools commonly used for different tightening methods.
- Define the recommended tightening sequences on the GEVO diesel engine.
- Identify the sources of documentation for standard bolt torque values.
- Convert torque values from U.S. Customary to Metric and vice versa.

Screen 3:

Disclaimer:

The standards discussed in this module are not comprehensive. They present some of the most common principles that are applicable to our locomotives.

Screen 4:

Introduction to Bolt Identification:

Threaded fasteners are classified by shape, material, and finish, which are specified by industry standards. In the United States, the American Society for Testing Materials (ASTM) sets the standards, which are often referred to as Unified, American, or Inch standards. In Europe, the International Standards Organization (ISO) sets the standards. The Metric fasteners are specified by the ISO. Both the Inch and Metric standards use a symmetrical V-shaped thread profile. The angle of the threads is 60 degrees with flat crests and rounded roots. The pitch of a thread has been standardized for coarse, fine, and extra fine threads, for various diameters. The Inch standard identifies pitch as the number of threads per inch, and the Metric standard identifies pitch as the distance between corresponding points on adjacent threads.

Screen 5:

Bolt Strength:

Strength is an important consideration when applying a bolt. Bolt material strength is determined by the alloy and the processing methods, such as cold working and heat

treating. The two important material properties are yield strength and tensile strength. Yield strength is the stress level at which the material yields or permanently deforms. Tensile strength, sometimes called ultimate strength, is the stress level at which the material breaks. The tensile strength is always higher than the yield strength. Materials with a large difference between the yield and tensile strength are considered ductile, meaning they will stretch substantially before breaking. For inch-size fasteners, the material strength is specified by the "grade". A grade 8 bolt is stronger than a grade 5, which is stronger than a grade 2. The grade is indicated by a series of marks on the bolt head. For metric fasteners, the term "property class" is used and is stamped directly on the head. When you replace a bolt, it is important to identify its grade correctly. If bolts are not replaced with the same grade, a failure can occur that could endanger lives and equipment.

Screen 6:

Size Identification:

Metric standard bolts are identified using a standard naming convention that includes an "M" followed by three numbers. In the example displayed, the first number is the diameter, the second number is the thread pitch, and the third number is the length. All three numbers are in millimeters. The example is therefore a Metric bolt with a 10 mm diameter and a 1.25 mm thread pitch, and it is 35 mm long. Inch standard bolts are named differently. The first number is the diameter, the second number is the number of threads per inch or thread pitch, and the third number is the length. The first and last numbers are in inches. The example shows a 5/8 inch diameter bolt with 11 threads per inch that is 1-3/4 inches long.

Screen 7:

Tightening Process:

Threaded fasteners are tightened for the obvious reasons of clamping parts together and transmitting loads. In gasket joints, tightened fasteners prevent leakage. In other joints, the clamping force is developed to prevent the parts from separating or shaking loose. A screw or bolt thread is an extension of one of the basic machines: the inclined plane. This inclined plane, however, is wrapped around a shaft. When the thread is turned, it moves the mating part or nut up the inclined plane. When more turning force, or torque, is applied to the shaft, the more force is exerted on the nut. This force creates tension in the bolt, which clamps the mating parts together. Preload is the technical term for the tension caused by tightening the fastener that holds the assembled parts together. Generating sufficient preload force is the key to strong and reliable bolted joints that do not loosen or break under load.

Screen 8:

Forces Operating on a Bolted Joint:

You can think of the fastener as a spring. It may seem odd to think of the engine as being held together by springs, but this analogy helps show what happens when the bolt and nut are tightened. Rotating the bolt or nut, which in turn stretches the spring, generates

preload force. The more the bolt or nut is rotated, the more the bolt stretches and generates more preload or spring tension. When no tension load (F_t) is applied to the joint, the clamping force (F_c) equals the preload force (F_p). If the tension load is equal to the preload, there is no clamping force. If the tension load is increased beyond the initial preload force, the joint separates. Even after the joint separates, it continues to take increased tensile loads until the ultimate tensile strength of the fastener is reached and the fastener breaks. From a practical standpoint, joint failure occurs well before the fastener actually breaks because the parts being held together will loosen and not function properly.

Screen 9:

Effect of Tension Forces:

Joints are loaded with shear force (F_s), tension force (F_t), or a combination of both. In a joint loaded with tension forces, the preload force on the bolt opposes the joint-separating forces. A cylinder head is a good example of this. For a joint with stiff mating parts, the load on the bolt remains constant at F_p until the tensile load is greater than the preload force. A simplistic view is that the ultimate strength of the joint is limited by the strength of the bolt. However, the higher the preload force, the better the joint, because it prevents the assembled parts from moving and the joint from loosening. A highly preloaded joint is also more resistant to cycling loads because less of the cyclic portion of the load is experienced by the fastener.

Screen 10:

Effect of Preload Forces:

In general, the preload force determines the strength of the joint. Joints are stronger and more fatigue resistant with greater preload force. It is important that the preload force be maintained in the fastener during operation. Highly loaded or critical fasteners tend to be long and they must be stretched a relatively large amount to generate the preload force. This allows them to maintain their preload, even if they expand a little or the mating parts shrink. An example of this includes the connecting rod bolts.

Screen 11:

Effect of Shear Forces:

The other type of joint is loaded by shear force (F_s). In a joint loaded in shear forces, the friction between the parts keeps them from moving when subject to a shear force. The friction between the parts carries the load, not the fastener. An example of this type of joint would be a shock absorber mount. The greater the preload force the greater the clamping force, the greater the friction, and the stronger the joint. With a properly designed and tightened joint, the bolt will not experience a direct shear load.

Screen 12:

Mating Surfaces of Fasteners:

The mating parts also act like a spring, but a much stiffer spring. Ideally, the mating parts are much stiffer than the fastener. Joints with soft gaskets are an exception to the "More

Preload is Better" rule. High loads can deform the gasket or mating surface, which causes leaks. Proper preload is the key to reliable bolted joints.

Screen 13:

Ensuring Reliability of Bolted Joints:

The drive for improved reliability has had a direct impact on assembly processes. To ensure satisfactory performance of mechanical equipment and avoid costly failures, it is important to tighten all nuts on vital bolts and studs according to values given in the appropriate maintenance instructions. It is also important to use the proper length bolt in all applications.

Screen 14:

Torque:

It is no longer sufficient just to run a nut down a bolt until it stops and hope that it is tight enough. The critical weakness in many products is found in the design of the joints – bolted joints in particular. One incorrectly tightened bolt can lead to the failure of the complete assembly. Too high a tightening torque can cause a bolt shank or thread stripping failure. Too low a tightening torque can cause inadequate bolt tension, allowing the joint to come apart.

Screen 15:

Length:

If the bolt is too long, it can bottom in the hole, damaging the bolt or associated parts. If the bolt is too short, enough thread engagement may not occur. Always clean out tapped holes and ensure that threads are in good condition. In some cases, you may need to retap the hole.

Screen 16:

Tightening Methods:

To set the correct, precise preload in bolted joints, you must choose the appropriate bolt tightening method. Insufficient preload caused by an inaccurate tightening method is a frequent cause of bolted joint failure. Four main methods are used to control the preload of a threaded fastener:

- Torque control
- Angle control (also known as turn-of-the-nut)
- Bolt stretch or elongation measurement
- Tensioning

Screen 17:

Torque Control:

The most prevalent controlled method of tightening threaded fasteners is tightening to a specified torque value. In this method, generally known as torque control, rotary force is applied to the nut as it moves down the threads of the bolt. Once the nut contacts a

surface, it begins to act like a screw jack, forcing the bolt to stretch. The problem is determining exactly how much clamping force that the applied torque generates. A torque wrench can indicate how much force is being applied to the nut, but not how much stretching or clamping power is really being generated. This is because some of the torque we are measuring is being absorbed by friction between the nut and the threads or mating surface, or by twisting in the bolt.

Screen 18:

Applied Torque and Friction:

So what is applied torque? If you tighten a bolt and nut with a torque wrench, the applied torque is dispersed to stretch the bolt and to overcome friction. Somewhere between 50% and 80% of the applied torque is needed just to overcome friction. The types of friction experienced when applying torque to the nut and bolt include nut face friction, thread friction, and thread torsion. Nut face friction is caused by the metal-to-metal contact between the nut face and the mating surface as the nut is being turned; and sometimes by dirt and corrosion. Thread friction is caused by irregularities in the thread surfaces, dirt, and corrosion. Thread torsion, also referred to as twist, occurs when the bolt begins to twist under the applied torque. So, how can we reduce this friction? Ensure that the hardware is clean, free of dirt and rust. In some cases, you may need a tap and die set to clean the threads of the bolt and nut. Apply proper lubrication to the threads and the faces of the bolt and nut. If a washer is used, apply lubrication to both sides of the washer. Always use the lubricant specified in the maintenance manual instructions. Lubricants are not interchangeable; each type of lubricant can affect the clamping load differently. The physical makeup of the parts may influence the torque values being applied. Always refer to the maintenance manual for the correct torque values and proper lubricant for each application.

Screen 19:

Angle-Control Tightening Method:

Another tightening method often used is the Angle-Control method. This method is also known as the turn-of-the-nut method. The nut or bolt is turned a predetermined number of degrees after all play has been removed from the joint. The main disadvantage of this method is the precision required to determine the angle, usually through experimentation. An advantage of this method is that, because of the predetermined angle, the friction factor is eliminated. However, the accuracy of the maintainer measuring the angle directly affects the accuracy of this method.

Screen 20:

Bolt Stretch or Elongation Measurement Tightening Method:

Bolt elongation measurement is a tightening method that still depends on torque to stretch a bolt, but provides improved measurement of the actual clamping force that is produced. In this method, accuracy is achieved by measuring the length of the bolt before torque is applied, and then measuring it again after the torque has been applied. Once you measure the amount of stretch in the bolt, you can estimate the amount of clamping

force produced. A disadvantage of this type of tightening is that it allows only one bolt to be tightened at a time, which can lead to uneven clamping and point loading along gaskets and surfaces that are being joined. Also, bolt elongation measurement cannot account for variations in bolt shank size, which will change the amount of clamping force that is produced. When a 2 inch diameter bolt and a 7/8 inch diameter bolt are stretched an identical distance, the larger of the two bolts produces more clamping force.

Screen 21:

Tensioning Method:

Tightening large bolts requires very high tensioning torques that can be difficult to achieve. You can overcome this problem by using a hydraulic torque wrench. Hydraulic tensioning devices are commonly used for bolts over 20 mm in diameter. The tension method uses a small hydraulic ram, which fits over the nut. The threaded portion of the bolt or stud protrudes well past the nut, and a threaded puller is attached. Hydraulic oil from a small pump acts on the hydraulic ram, which in turn acts on the puller. The puller stretches the bolt or stud. The nut can then be rotated by hand with an integral socket aided by a bar or pin. Control of the hydraulic pressure effectively controls the preload in the bolt. However, a small amount of preload reduction occurs when the pressure is removed as the nut elastically deforms under the load. It can also be difficult to remove nuts corroded to bolts with this method. The tensioning method solves most of the problems with torque control and bolt elongation measurement tools. In addition, hydraulic tensioning devices eliminate the problem of thread galling and allow all the bolts or studs on that part of the assembly to be tightened with identical amounts of force, all at the same time. This eliminates the danger of uneven pressure distribution on parts and gaskets.

Screen 22:

Special Tools:

Special tools often used to maintain the Evolution Series locomotives include torque wrenches, adapters, and tensioning tools. The clicker torque wrench, sometimes called a digital wrench, works by preloading a "snap" mechanism with a spring to release at a specified torque. When the mechanism releases, the ratchet head makes a "click" noise. Rotating the handle until the desired torque is shown in the window sets the torque. Older clicker wrenches have a micrometer-style scale along the handle instead of a window. The ratchet head makes it easy to use in confined spaces. It is a good practice to set a clicker wrench to its lowest setting before putting it away to prevent the spring from permanently stretching. Avoid rough handling and dropping the torque wrench because it can damage the mechanism. Do not use the torque wrench to loosen fasteners; this may damage the calibration mechanism. Torque wrenches should be calibrated on a regular schedule depending on tool usage.

Screen 23:

Adapters:

With a torque wrench, you may need to use adapters to reach inaccessible bolts or nuts. When adapters are used, the reading of the torque wrench dial is different from the actual torque exerted. The additional torque exerted on the nut or bolt over that shown on the dial depends on:

- The length of the adapter and
- The angle at which the adapter is positioned on the wrench.

When you apply an adapter to a torque wrench, you increase the mechanical advantage. Therefore, you must make an adjustment to the torque wrench setting to apply the correct torque value to the fastener.

Note: When using a torque wrench adapter, a 90-degree torquing angle is recommended. If unable to torque at a 90-degree angle, apply the adapter to the torque wrench at the angle needed to tighten the fastener; however, the torque wrench setting must be adjusted to the proper value as discussed in GEI-81913, TORQUE WRENCH APPLICATION AND VALUES, which provides details to manually calculate the correct torque wrench setting.

The torque wrench setting must be formulated by using the torque wrench length and the adapter length measurements. The length of the adapter (A) is added to the length of the wrench from the wrench head to the midpoint of your grip on the handle (B), to get the overall length (C). The actual torque wrench setting is calculated by dividing dimension B by dimension C, then multiplying the answer by the torque specification. When the torque adapter is offset, the measurement must still be taken in a straight line with the torque wrench. Let's try an example. In this example, the wrench length (B) is 3' and dimension A is 6". Therefore, overall length (C) would be 3.5' (3' + 6"). Using the formula from before, will give you the necessary torque setting. With the added mechanical advantage provided by this adapter, a torque wrench setting of 86 lb.-ft. will apply 100 lb.-ft. of torque to the fastener. It is important that the pull on the torque wrench handle be concentrated at the pull point position, marked as "P" in the figure. A shift in this position causes a considerable discrepancy between the torque reading and the effective torque. The threads of both parts must also be clean, free of burrs, and properly lubricated, using the same lubricant as was applied to the contact face of the nut or bolt.

Screen 24:

Tensioning Tools:

Each tensioner is designed for a specific application. For example, the cylinder head bolt tensioner is designed to fit the four cylinder head bolts. Regardless of the specific application, all tensioner tools contain the same basic elements:

- A base that rests on the component, providing an anchor for the pulling force.

- A hydraulic cylinder that threads onto the bolt and stretches it to its recommended tension.
- A cap that mates with the nut and allows the operator to apply or remove the nut.

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Recommended Tightening Sequences:

Two types of tightening sequences are used to minimize bolt preload variations due to elastic interactions. In some instances, a pre-torque/final torque sequence is used. With this sequence, each bolt is tightened to a pre-torque value on the first pass, and then the final torque value on the second pass. This reduces the preload reduction caused by tightening the other bolts in the joint.

Screen 26:

Standard Torque Values:

When maintaining the locomotive, it is essential that you apply the correct torque values to all fasteners. Different types of hardware have different standard torque values. Use standard bolt torque tables when a specified value is not listed in the maintenance manual instructions for a particular application. Most torque wrenches have both units of measurement, Pound-Foot (or Foot-Pounds) and Newton-Meters. If a conversion has to be made, the conversion table provides the conversion factors. The metric equivalent uses a comma instead of a decimal point in some documentation. When doing conversions, use a decimal point in place of a comma.

Screen 27:

Specified Torque Values:

Each type of locomotive has its own documentation where you can find torque data and the many ways that our engineering group specifies torque values. Each Running Maintenance and Backshop Manual publication has a Data or Torque Values section located at the back. The torque value for a particular application is listed as part of the procedural step. There are two ways in which torque values are specified: Pre-torque vs. Final Torque, and Range of Torque Values. Some fasteners have a pre-torque and a final torque value. The reason for this is to minimize the variations caused by friction between fasteners. What this means is that all fasteners are first torqued to the pre-torque value and then to the final torque value. Pre-torque and final torque values are indicated by separating them with a "/". For example, for the crankshaft drive gear bolt values 300/970 Nm, the first number is the pre-torque value and the second number is the final torque value. A fastener can have a higher specified pre-torque value than a final torque value. Always torque the fastener to the values specified in the maintenance manual. Our engineering group indicates a Range of Torque Values in two ways: by using a range of values, and a plus-or-minus value. For example, in 50 to 60 lb.-ft. (commonly read as ft.-lb.), any torque value of 50 through 60 lb.-ft. is valid. For 90 plus or minus 9 lb.-ft., a valid torque is 81 through 99 lb.-ft.

Screen 38:

Summary:

You have reached the end of this module!

In this module, you learned to:

- Identify the different types of bolts based on thread profile, strength, and size.
 - Bolts are classified by shape, material and finish, which are specified by industry standards, such as the American Society for Testing Materials (ASTM) and the International Standards Organization (ISO). Inch standards are set by ASTM and Metric standards by ISO.
 - Both the Inch and Metric standards use a symmetrical V-shaped thread profile.
 - The Inch standard identifies pitch as the number of threads per inch and the Metric standard identifies pitch as the distance between corresponding points on adjacent threads.
 - For inch-size fasteners, the material strength is specified by the "grade".
 - For metric fasteners, the term "property class" is used.
- Identify the forces that operate on a bolted joint.
 - Threaded fasteners are tightened for clamping parts together and transmitting loads.
 - A screw or bolt thread is an extension of an inclined plane. This inclined plane has been wrapped around a shaft. When the thread is turned, it moves the mating part or nut up the inclined plane.
 - When more turning force, or torque is applied to the shaft, the more force is exerted on the nut. This force creates a tension in the bolt, which clamps the mating parts together.
 - Generating sufficient preload force is the key to strong and reliable bolted joints that will not loosen or break under load.
 - Rotating the bolt or nut, which in turn stretches the spring, generates the preload force. The more the bolt or nut is rotated, the more the bolt stretches and generates more preload.
 - When there is no tension load (F_t) applied to the joint, the clamping force (F_c) equals the preload force (F_p).
 - If the tension load is equal to the preload, there is no clamping force.
 - If the tension load is increased beyond the initial preload force, the joint will separate.
 - Joints are loaded with shear forces (F_s), tension forces (F_t) or a combination of both. In general, the preload force determines the strength of the joint.
 - The mating parts act like a spring, but a much stiffer spring. In the ideal case, the mating parts are much, much stiffer than the fastener.
 - To ensure satisfactory performance of mechanical equipment and to avoid costly failures, it is important to tighten all nuts on vital bolts and studs according to values given in the appropriate maintenance instructions.

- Describe the different tightening methods used for locomotive maintenance.
 - Insufficient preload, caused by an inaccurate tightening method, is a frequent cause of bolted joint failure.
 - There are four main methods that our engineering group utilizes to control the preload of a threaded fastener:
 - Torque control
 - Angle control (also known as turn-of-the-nut)
 - Bolt stretch or elongation measurement
 - Tensioning
 - In torque control method, a rotary force is applied to the nut as it moves down the threads of the bolt. Once the nut contacts a surface, it begins to act like a screw jack, forcing the bolt to stretch.
 - Angle control is also known as the “turn-of-the-nut” method. The nut or bolt is turned a predetermined number of degrees after all play has been removed from the joint.
 - Bolt elongation measurement is a tightening method that still depends on torque to stretch a bolt, but it does allow for improved measurement of the actual clamping force that is being produced.
 - A method which solves most of the stated problems with torque control and bolt elongation measurement tools is the tensioning method.
- Describe special tools commonly used for different tightening methods.
 - Some of the special tools commonly used include:
 - Torque wrenches
 - Adapters
 - Tensioning tools
 - The clicker torque wrench, sometimes called a digital wrench, works by preloading a "snap" mechanism with a spring to release at a specified torque.
 - It is often necessary to use adapters with a torque wrench to reach inaccessible bolts or nuts. When adapters are used, the reading of the torque wrench dial is not the actual torque exerted.
 - The additional torque exerted on the nut or bolt depends on:
 - Length of the adapter.
 - Angle at which the adapter is positioned on the wrench.
 - Each tensioner is designed for a specific application. The basic elements of a tensioner are:
 - A base that rests on the component, providing an anchor for the pulling force.
 - A hydraulic cylinder that will thread onto the bolt, then stretch it to its recommended tension.
 - A cap that mates with the nut and allows the operator to turn it on or off.
- Define the recommended tightening sequences on the GEVO diesel engine.
 - The tightening sequences used are:

- Criss-cross tightening sequence for circular bolt patterns.
 - Spiral tightening sequence starting in the middle for non-circular bolt patterns.
- Tightening sequences result in minimizing bolt preload variations due to elastic interactions.
- In some instances a pre-torque/final torque sequence is used. With this sequence, each bolt is tightened to a pre-torque value for the first pass and then the second pass at the final torque value. This will reduce the preload reduction caused by the tightening of the other bolts in the joint.
- Identify the sources of documentation for standard bolt torque values.
 - It is essential when maintaining the locomotive to apply the correct torque values to all fasteners.
 - The standard bolt torque value tables should be used when a specified value is not listed in the maintenance manual instructions for the particular application.
 - Each Running Maintenance and Backshop Manual publication that contains maintenance procedures has a Data or Torque Values section located at the back of the publication. Also, the torque value for a given application is listed as part of the procedural step.
 - Some fasteners have a pre-torque and a final torque value. The reason for this is to minimize the variations caused by friction between fasteners. This means that all fasteners are first torqued to the pre-torque value and then to the final torque value.
 - One way our engineering group indicates a pre-torque and final torque is by separating the two values by a "/".
 - There are two ways that our engineering group indicates a range for the torque: For example, in 50 to 60 lb.-ft (commonly read as ft-lb), any torque value of 50 through 60 lb.-ft is valid. For 90 plus or minus 9 lb.-ft, a valid torque is 81 through 99 lb.-ft.
- Convert torque values from U.S. Customary to Metric and vice versa.
 - Most torque wrenches have both units of measurement, Pound-Foot (or Foot-Pounds) and Newton-Meters.
 - If a conversion has to be made, 1 lb.-ft. = 1.3558 Nm.
 - The metric equivalent uses a comma instead of a decimal point in some documentation. When doing conversions, use a decimal point in place of a comma.