MT Focus 6000 SCS and TSM

Printed Matter No. 9839 1210 01
Publication Date 2021-09-28

Control and drive unit

Valid from Serial No. -

Instruction Supplement

MT Focus 6000	8432085100
Seating control strategies and torque seating monitoring	

⚠ WARNING

To reduce risk of injury, everyone using, installing, repairing, maintaining, changing accessories on, or working near this tool MUST read and understand these instructions before performing any such task.

DO NOT DISCARD - GIVE TO USER

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Introduction

This document is a user guide for the Seating control step (SCS) and Torque seating monitoring (TSM) steps in the MTF6000 controller.

The document describes how to set up the SCS and TSM steps as well as in-depth information on how the steps can be used to ensure the best possible tightening.

Screw seating

Finding the seating point is of great importance for both the Torque seating monitoring and the Seating control strategy.

The seating point is the point in which the screw head touches the surface of the joint. In the figure below, a tightening graph displaying torque over angle, it is displayed as the dot on in the trace.

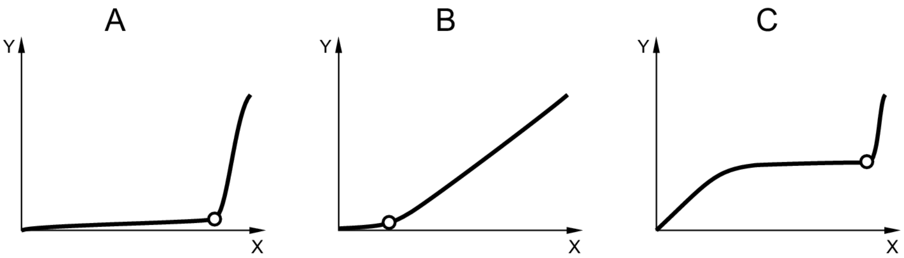


Illustration 1: Seating marked in traces from tightening in different types of joints

A	Hard joint	B	Soft joint
C	Self threading joint		
X	Angle	Y	Torque

Clamp force and clamp torque

When tightening a screw the desired output is that the joined parts are held together, this is achieved by the clamp force. The technology needed to measure the clamp force is difficult to include in a screwdriver.

The torque can be obtained by a strain gauge sensor or it can be estimated from the current from the motor. Due to friction and other losses, such as parts that needs to be pushed into place, some of the torque will not be transformed into clamp force. The clamp torque is defined as the torque installed in the joint from the detection of the screw seating. Using this measurement instead of the total torque applied will give a better correlation to the clamp force.

ⓘ Joints of thermoplastics is an exception to this due to the physical properties of the plastic. For more information see **Thread forming**.

Relevant Information

🗎 Thread forming [6]

Strip out torque

The strip out torque is the amount of torque applied from the seating of the screw until the joint breaks. This torque value is of utmost importance for setting up a stable tightening strategy with good process margins.

Seating control and Torque seating monitoring

The two steps, the Seating control step and the Torque seating monitoring step, both use detection of the seating point as a vital part of the tightening. The difference between the two is within how the final tightening is performed.

Variations in the tightening process, such as component variations and external mechanical forces, will cause the amount of torque needed to seat the screw to vary from joint to joint. In some cases this leads to the screw not being tightened enough or too much. An under-tightened screw might lead to the screw coming lose or in some cases not being seated at all. The latter is referred to as a floating screw. An over-tightened screw could damage or break the joint, often by stripping the threads or by deforming the joint material.

The **Seating control step (SCS)** takes an adaptive approach to the problems stated above. The first part of the step is to locate the seating point. After finding the seating point, a clamp torque or clamp angle is applied. This makes sure that all the screws are tightened the same amount of torque, in reference to the seating point. It will result in a consistent clamp torque and a more varying peak torque.

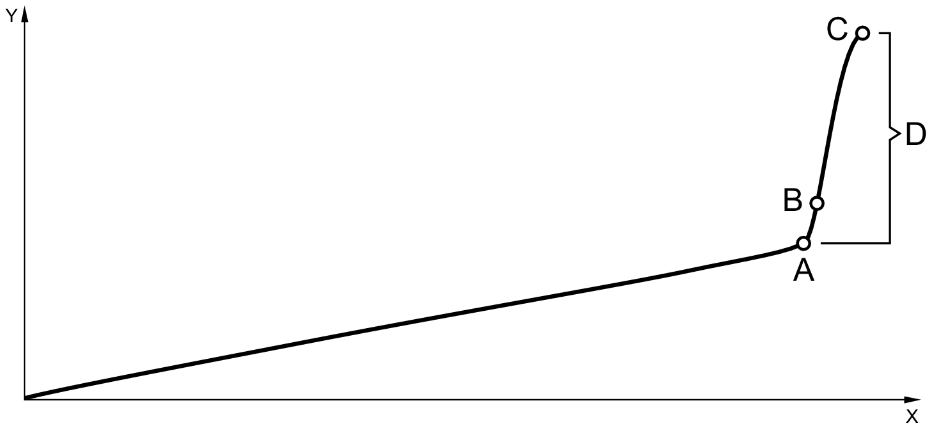


Illustration 2: SCS example - finding seating and adding 7.5 cNm

A	Seating	B	Seating detected
C	Final torque	D	Clamp torque
X	Angle	Y	Torque

The **Torque seating monitoring step (TSM)** is, in similarity to the Torque step, controlling the tightening based on a given target torque instead of the clamp torque. However, Torque seating monitoring is also monitoring the seating point and the amount of torque added after, the clamp torque.

Thus, the Torque seating monitoring will show consistent results on the target torque but a variation in clamp torque is expected. If the variation is too big, the step can abort the tightening. If the seating is not detected an error will occur, detecting floating screws.

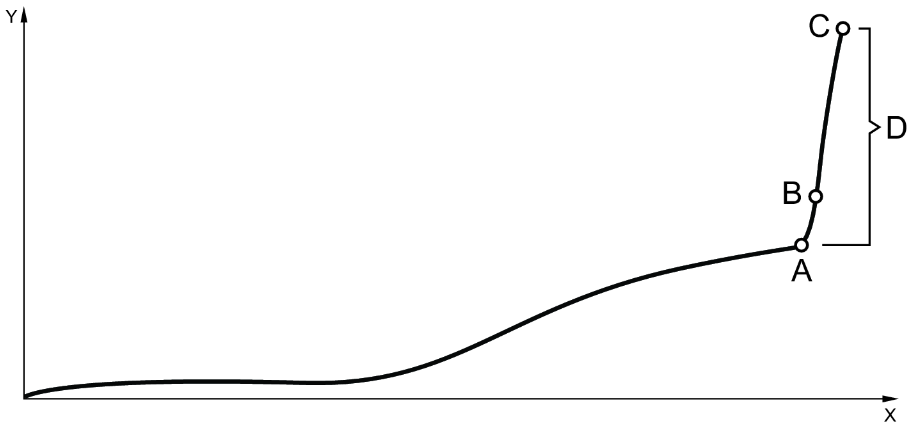


Illustration 3: TSM example - tightening to 13 cNm, generating a clamp torque of 7,692 cNm

A	Seating	B	Seating detected
C	Final torque	D	Clamp torque

X	Angle	Y	Torque

Common use cases

The Seating control step and Torque seating monitoring step are effective tightening strategies when it comes to joints with process variations.

The Seating control step has the ability to adapt to changes in process variations while the Torque seating monitoring step has the ability to detect and warn when the changes are too large.

Thread forming and thread cutting joints

Both the Torque seating monitoring step and the Seating control step are recommended to use for thread forming and thread cutting joints (these are sometimes called self-tapping joints) because of their adaptive properties.

The joints in question has no threads, this means that the screw will form or cut threads during the rundown. The joint usually consists of a molded or drilled hole. If the size of the hole varies, the amount of material that needs to be cut or formed will vary, which will change the amount of torque needed to seat the screw.

Thread cutting

A cutting joint will cut permanent threads from the material, making the joint more similar to a threaded joint if the screw is re-tightened. Loosening and re-tightening a thread cutting joint with the same torque target might cause strip out. When the threads are already cut, the amount of torque needed to seat the screw will vastly decrease and a larger part of the torque is used for clamping. A joint with too narrow strip out margins will likely break if loosened and re-tightened.

Thread forming

For thermoplastic joints the screw does not cut the threads. Instead the friction from the thread of the screw generates heat that melts the plastic. If the temperature of the plastic is below the plastics glazing temperature, the plastic will re-set around the screw and create the force holding the screw in place.

There are many factors that will affect such a tightening, including:

- The size of the hole
- The speed of the screwdriver (300-500 is the recommended speed range)
- How long the plastic has hardened
- The temperature of plastic

Misaligned parts

A common process variation is misaligned parts. When two parts are joined together and the screw-holes are not properly aligned the screw needs to push the parts in line, this will increase the torque needed to seat the screw.

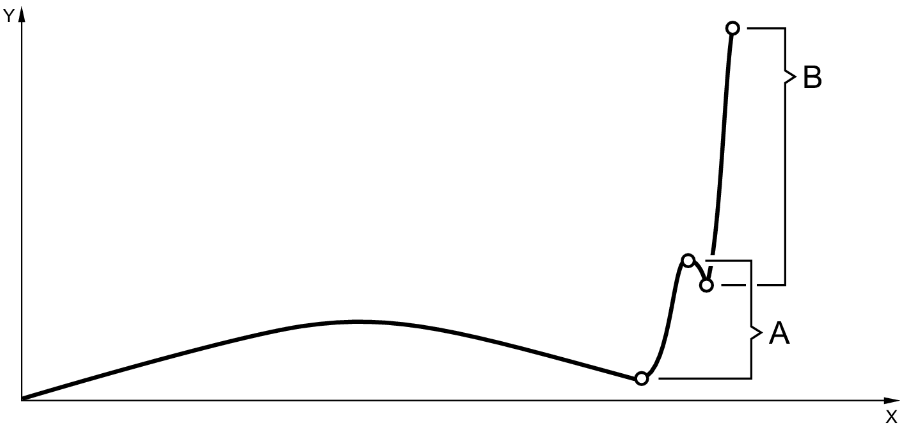


Illustration 4: Tightening of joint with misaligned part

A	Torque needed for pushing parts into place	B	Clamp torque

X	Angle	Y	Torque

Configuration

Selecting clamp torque

The target clamp torque or clamp angle for a Seating control step is defined from the seating point. The target clamp torque and the target clamp angle are not the same as the total torque inserted into the joint. and is not the total torque inserted into the joint. For the best possible setup the joint must be tested and verified to find the best target clamp torque and target clamp angle.

Depending on the application there are different approaches for finding the best clamp torque target. A common scenario is that the designer specifies a tightening torque or a specific clamp torque target. For a Torque seating monitoring step this value can be used straight away. A good approach is to set open clamp torque limits and collect data. With the data collected it is possible to use statistic methods to incrementally narrow the limits for a more stable process. For a Seating control step the assigned target torque can be seen as a starting point in finding the correct clamp torque.

Destructive tests on the joint is the recommended way to find a good clamp torque. If the joint has a specified value it is still valid to do a destructive test to check joint variations and check the process margins.

Destructive tests are done by tightening the joint until the joint breaks, strip out, or the screw driver reaches it maximum torque. The next step is to check the generated graph of the tightening and noting down the **strip out torque.**

ⓘ Use a one-step strategy, with Torque step with the intended speed for the final tightening part, for the destructive tests. In some cases it is not possible to set that speed in a Torque step, then a Thread engagement step can be used.

For each destructive test tightening, the strip out torque needs to be extracted manually from the graphs. The easiest option is to use the ToolsTalk MT graph program. The real time trace is only available when connected via USB. It is also possible to view the stored graphs, which can be found under the result section in ToolsTalk MT. With the information gained from this graph it is possible to calculate an average strip out torque.

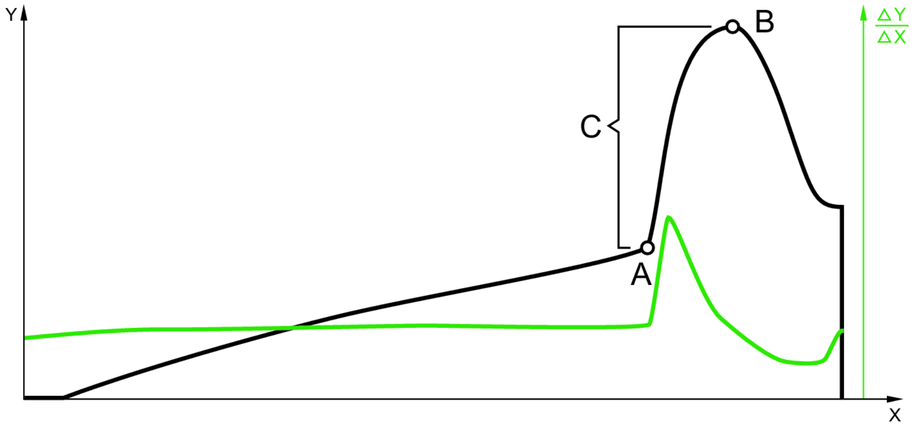


Illustration 5: Strip out torque

A	Seating torque	B	Joint failure
C	Strip out torque		
X	Angle	Y	Torque

The strip out torque value is then used to calculate a clamp torque target. Different materials have different recommendations on how to calculate the clamp torque, due to different behavior of the joint materials, for more information see **Plastic joints** and **Metal joints**.

ⓘ The clamp torque calculated using this method is considered a good starting point. It is strongly recommend that the calculated value is verified with mechanical tests, like stress tests and vibration tests, to make sure that it is the right torque target for the specific application is found.

ⓘ In some cases it may not be possible to strip the joint with a given tool. A tool with a larger max torque can then be used to establish the strip out torque. Knowing the strip out torque creates a better understanding of the joint.

Relevant Information

- Metal joints [9]
- Plastic joints [9]

Plastic joints

A well tested method for finding the clamp torque for plastic materials is to take the average strip out torque (strip out – seating) and divide by three.

T_{Clamp} = (Strip out – Seating) / 3

ⓘ Adding more clamp torque in a plastic joint will not increase the clamp force in the joint. It can instead, due to physical properties of thermoplastics, weaken the joint. The plastic is for example more likely to crack if more torque is added.

Metal joints

For metal joints the method used to find the clamp torque is more of a suggested start value. The clamp force installed is directly related to the clamp torque, the friction also plays a part.

T_{Clamp} = (Strip out – Seating) / 2

The main reason for the suggested start value of the clamp torque is to have good margins for seating detection and strip out.

Mechanical tests, like stress tests and vibration tests, are necessary for finding the correct target torque for the specific application. These tests are more important for metal joints than plastic joints.

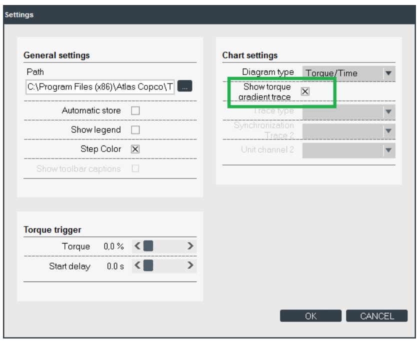
Seating detection

The method for detecting seating is the same for the Seating control step and the Torque seating monitoring step. Seating is detected when the torque over angle gradient rises above a definable limit, the gradient trigger point, shown in the graph below. The main method for finding a stable seating point is to collect data from several screws tightened with Torque seating monitoring or Seating control step on joints of the same kind and checking the resulting graphs, preferably in real time.

The best way to check the trace is to connect to the controller via USB and review the tracing in real time using the real time trace viewer, Analysis, in ToolsTalk MT.

It is also possible to open stored graphs in results section. Click on a result in the list and the graph will be opened on the bottom page. By double-clicking on the graph it can be opened in Analysis. The 1000 newest results will contain a graph. The stored graphs will have a lower resolution compared to a real time trace.

To see the gradient trace in Analysis, choose Show torque gradient trace under Settings.



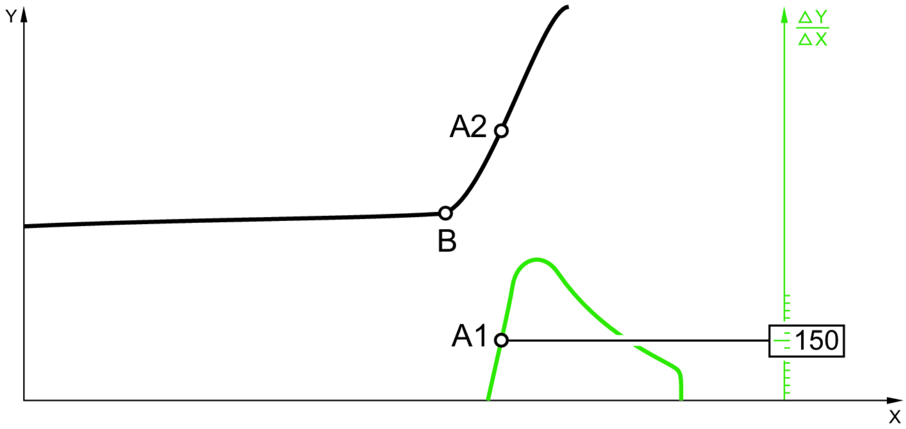


Illustration 6: Detecting seating- gradient trigger point at 150

A1	Torque gradient limit	A2	Torque value when seating is detected
B	Calculated seating point		
X	Angle	Y	Torque

The detection of seating is done after the actual seating occurs. When the torque gradient (ΔT/ΔA) reaches above the torque gradient limit, A1 in the trace above, seating is detected. Remember to adjust the seating detection to occur halfway between seating and the clamp torque, if the clamp torque is 10 cNm it is recommended to detect seating approximately 5 cNm after seating. In the figure below the seating detection is noted by position A.

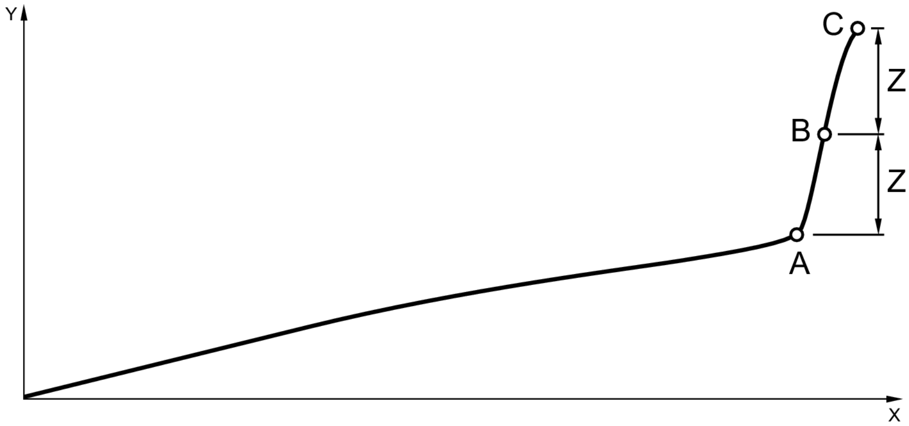


Illustration 7: Rule of thumb for placement of detection

A	Seating	B	Detected seating (halfway between seating and torque target)
C	Final torque		
X	Angle	Y	Torque
Z	Half of the clamp torque		

Seating point adjustment

When the seating point is detected, the system will calculate where the seating point should be placed. Increasing the **Seating angle displacement** will move the seating point to the left in the graph, and decreasing the value will move it to the right. The Seating angle displacement defines a window from the seating detection back a set number of degrees. The torque in this window is used to calculate the seating.

Monitoring

Monitoring is used to detect assembly errors and to ensure the quality of the performed tightening. For both the Seating control step and the Torque seating monitoring step there is monitoring for the both the complete step and for what occurs after the seating.

There is also monitoring that applies for the Pset as a whole, regardless of what step types being used, this is called global monitoring.

ⓘ For the SCS and TSM it is important to pay extra attention to the bit slip detection. If the bit slips out of the joint and then enters again, it is a large risk that the seating is falsely detected. This parameter is set to on as default and can be found in the general settings of a Pset.

Step monitoring (limits)

Minimum and maximum torque

The torque monitoring can be used to stop the tool if the torque rises too high, this can prevent the joint from breaking if the seating detection fails.

Minimum and maximum angle

The angle monitoring can for example be used to detect joint anomalies and incorrect screws.

Clamp monitoring

Minimum and maximum clamp torque

This setting for the minimum and maximum clamp torque is probably the settings that differs the most between Seating control step and the Torque seating monitoring step.

- For SCS the minimum/maximum clamp torque setting defines a margin of error for the final part of the tightening, how much overshoot or undershoot it is allowed to have. This window should be kept small, no more than ±5% of the target clamp torque.
- For TSM, the minimum/maximum clamp torque setting represents how much process variation that is allowed. Here, mechanical tests, such as stress tests and vibration tests, should be used to verify the torque target in the specific application. Another approach is to do a statistical analysis or an analysis from traceability studies of failed units.

Minimum and maximum clamp angle

The following parameters can be used to detect if something is wrong with the joint:

- parts missing – low clamp angle
- defect parts – high clamp angle

Global monitoring

Bit slip detection

The Bit slip detection stops the system if the bit slips out of the joint. It is very important that Bit slip detection is enabled for both the Seating control step and the Torque seating monitoring step. If this parameter is not enabled, seating can be falsely detected if the bit loses touch with the screw head for some period of time.

Bit slip is particularly a problem with:

- Thread forming / cutting joints
- Bits and screws with Phillips or slot type heads

Damaged thread detection

The damaged thread detection function can detect some types of damaged threads, for example strip out in plastic joints, by monitoring torque drops. This makes the setting very helpful for tightening screws in plastic joints.

ⓘ “Cross threads” in machined threads will not be detected. For that angle monitoring is more efficient.

ⓘ When damaged thread detection is enabled it may cause a false positive detection when the torque is generated during parts of the rundown.

Re-hit detection (Controller setting)

This parameter is used to detect tightenings on already tightened screws.

Re-tightening screw can be a problem due to:

- Adding too much torque to an already seating screw causing strip out
- Make it difficult counting tightened screws in an application for Batch sequence or an external system.

Total angle monitoring

The Total angle monitoring is used to get the total picture of how many degrees the screw has been turned.

Total time monitoring

The total time monitoring limits are used to abort ta tightening that has exceeded the total duration time. An exceeded time limit is a strong indicator that something went wrong. Time monitoring is more useful for automation then for operator stations since the operator can see that something went wrong and abort the tightening manually, an automation station will only wait for a definite result signal OK/NOK from the controller.

Example configuration

Finding the correct clamp torque for plastic joints

- Select the speed you want to use, this could affect when the threads are stripped
- Create a thread engagement or torque step to max torque and selected speed
- Open Analysis, real time trace viewer in ToolsTalkMT (only accessible when connected via USB)
- Tighten a number of joints (a minimum of 10) until they break. An increased test population will give a better sense of the variations in the process. Picking test samples from different batches is also recommended.

ⓘ Enable gradient and select automatic store in Analysis, real time trace, see **Seating detection**.

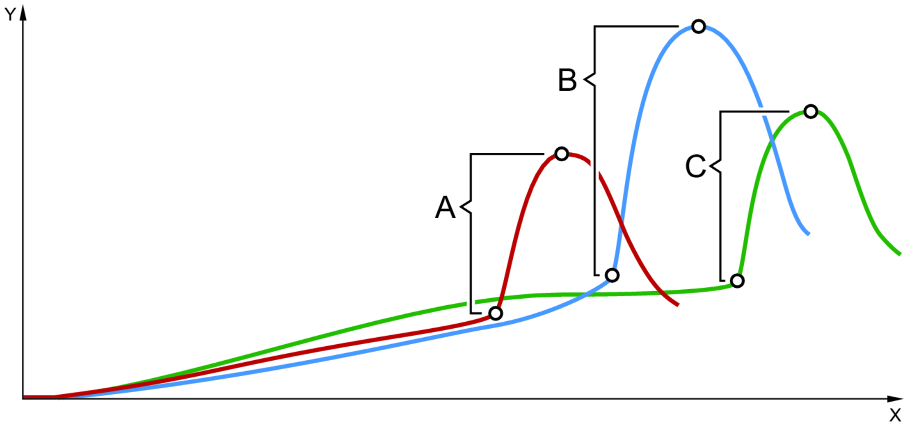


Illustration 8: Destructive tests - finding a strip out torque

A	Strip out: 8.3 cNm	B	Strip out: 11.7 cNm
C	Strip out: 9.1 cNm		
X	Angle	Y	Torque

The destructive tests in the example above yielded an average strip out torque of 10 (rounded from 9.7), using the formula for plastic (see **Plastic joints**) gives a clamp torque of 10 / 3 = 3.3 cNm rounded up to **3.5 cNm**.

ⓘ Given the accuracy of the method and the added safety margin of 66%, the rounding is not an issue. As mentioned in **Seating clamp torque** this value is only considered a starting point and should be verified with mechanical stress tests before it is used in production.

Relevant Information

- Seating detection [9]
- Plastic joints [9]
- Selecting clamp torque [8]
- Finding the correct clamp torque for metal joints [13]

Finding the correct clamp torque for metal joints

There are significant differences here depending on threaded and thread cutting joints.

For threaded joints it is generally OK to use pre-defined values from the R&D department as they are. For thread cutting joints, destructive tests as previously suggested are recommended. The method is very similar to that for plastic but the rule of thumb for selecting torque is slightly different, see **Configuration**.

Relevant Information

- Finding the correct clamp torque for plastic joints [13]
- Configuration [8]

Seating detection in plastic and metal joints

The first seating detection settings can be found in the trace from the destructive tests, as shown in the figure below. By finding the seating and adding half of the clamp torque, the optimal trigger point is found, see **Seating detection** figure Rule of thumb . Checking the gradient curve at that points gives a good start value.

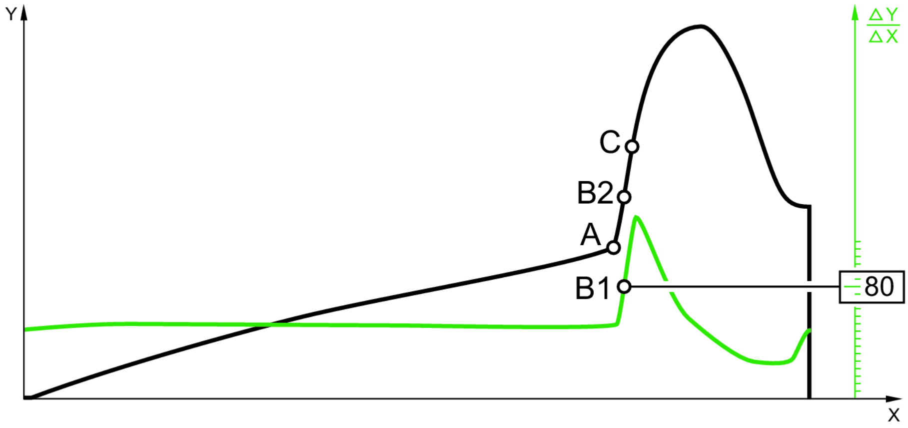


Illustration 9: Finding a first gradient trigger point from a destructive tightening

A	Seating		
B1	The gradient value (80) at the optimal seating detection point	B2	Optimal seating detection point - Torque half way between Seating and intended clamp torque
C	The intended clamp torque		
X	Angle	Y	Torque

The example in the graph above gave an initial gradient trigger point of 80.

Relevant Information

- Seating detection [9]

Monitoring plastic and metal joints

The results from destructive tests and test tightenings stored on the controller contains valuable information that can be used to set the step monitoring parameters, see the Result section in the **MT Focus 6000 Configuration Manual** for more information.

Minimum and maximum torque

The minimum and maximum torque depends on the variations on the joint. These could be left open [0:Tmax], if any issues occurs with broken joints due to failed seating detection, the max torque limit can be lowered to stop the joints from breaking. For example, if the strip out torque occurs around 14 cNm a good max torque for these joints would be right below 14 cNm to avoid breaking the joints.

Minimum and maximum angle

The limits can be set loosely to detect if the wrong type of screw was used or other joint anomalies. How tight these limits should be set depends on the process, if there are problems with inserting the screw, it can be difficult to set accurate limits. By adding an initial step, like thread engagement or a vacuum pick-up pre-step, the angle limits setup will be simpler and the limits will be more accurate for each tightening.

Minimum and maximum clamp torque

Setting the minimum and maximum clamp torque to ±3% of clamp target is a good start. A finer limit is generally not needed since the seating detection itself adds a higher degree of variation, see chapter about precision and speed for more details.

Minimum and maximum clamp angle

A good default minimum clamp angle could be set to about 50% of average clamp angle. If there is need to detect a missing washer or similar, it is recommended to test tightenings with and without the washer to find out a good limit.

The maximum limit depends on process variations. A good starting limit could be the average seating angle multiplied by 1.2.

Precision and speed

Precision

The MicroTorque tool series are sold with guarantees of torque accuracy defined as scatter and deviation from target. The scatter and deviation gives an overall picture of the accuracy of the tool. The scatter statistic [±3σ] measure the scatter between the individual tightenings in a measurement series in regards to each other, how tightly the measurements are gathered in relation to each other. The deviation measurement gives a value based on how far the mean value of all the tightenings in a measurement series is from the target torque value.

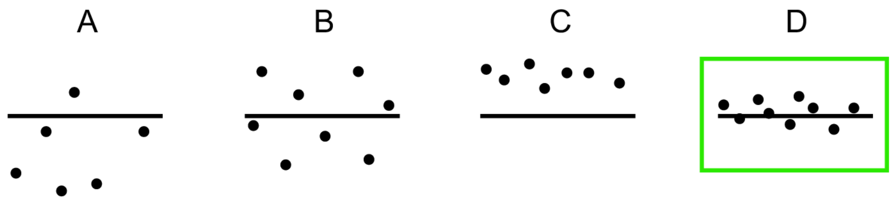


Illustration 10: Quantifying precision in terms of scatter and deviation

A	High scatter, high deviation	B	High scatter, low deviation
C	Low scatter, high deviation	D	Low scatter, low deviation

Tightening speed and precision

To be able to maintain the same accuracy, in terms of percentages, the speed needs to be limited on all torque levels. It is not possible to run the tightening at the same speed on the min torque as for max torque and maintain the same accuracy.

The reason for the limiting is in three parts:

- The tool is stopped after the torque target is reached. The tool takes some time to stop, which can generate an overshoot. The amount of torque applied as overshoot is related to the speed.
- What counts as 1% overshoot at 100 cNm counts as 10% overshoot at 10 cNm
- The kinetic energy built up in the tool. This part cannot be detected with a current controlled tool, only with a sensor based tool.

ⓘ Speeds lower then 75 rpm during the final tightening increases the friction and can decrease the accuracy. The physical properties of the joint determine how low the speed can be set.

Seating control step and speed limitation

The Seating control strategy has a clamp target, a target that does not reflect the total torque of the tightening. This makes it impossible to set a speed limitation.

In the example **Finding the clamp torque for plastic material**, a clamp torque of 3.5 cNm is found. Most tightenings on that joint results in a total peak torque around 12 cNm.

The minimum torque target for a Torque step for the Handheld Screwdriver ETD M 27 ABL V2 tool is 7.5 cNm, which is limited to 150 rpm. If that limit was set on this seating control step, the speed of the tightening would most likely disqualify it for use in many applications. It would not be usable for installing the correct clamp torque needed in the example.

The clamp torque target of 3.5 cNm is much lower than 7.5 cNm, that speed limit cannot be applied. This is why the is no upper speed limit on a Seating control step.

Apply the following steps to make sure that the right speed is set:

- Use the intended speed in the destructive tests
- Set an appropriate margin between clamp target and joint failure
- Use an inline torque transducer to check the final torque.

Relevant Information

🗎 Finding the correct clamp torque for plastic joints [13]

Torque accuracy and clamp accuracy

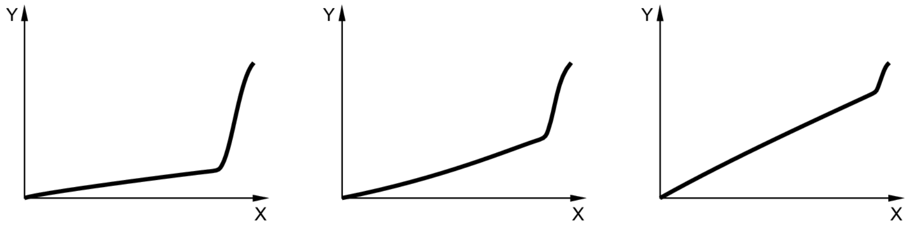
The main goal of a tightening is to join/clamp two or more parts together by a clamp force. Torque is the simplest measurable unit to gauge how much clamp force that was installed.

By finding the seating, the part of the torque used to overcome friction and cutting threads can be ignored. Focus will instead be on the part of the torque used for creating clamp force.

Using a Seating control step with a higher speed than what is allowed in a torque step may introduce more variation in the torque accuracy. This has to be compared to the accuracy gained in the clamp torque compared to a step not using any control on the clamp torque.

Example:.

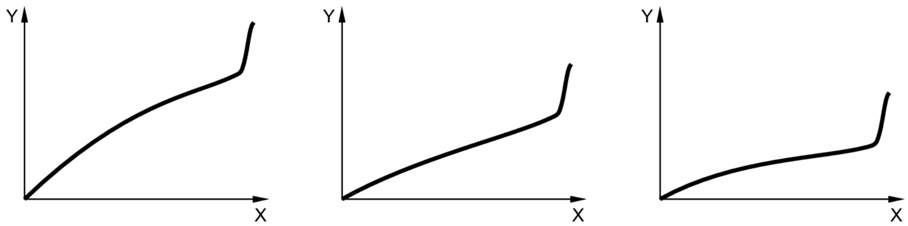
The three tightenings below were done on a plastic joint with a target torque of 12 cNm tightened with the maximum speed of 250 rpm. The traces below illustrates how the clamp torque varies but the target torque is always hit with accuracy.



X	Angle	Y	Torque

Using a seating control step with a target of 3.5 cNm running 400 rpm shows a very consistent clamp torque but a torque overshoot of 0.5 cNm due to the speed.

From destructive test it is known that the margins to strip out are 66% and running the higher speed is better for the plastic. As mentioned before, due to physical properties of thermoplastics the optimal speed is between 350-500 rpm for this type of joint.

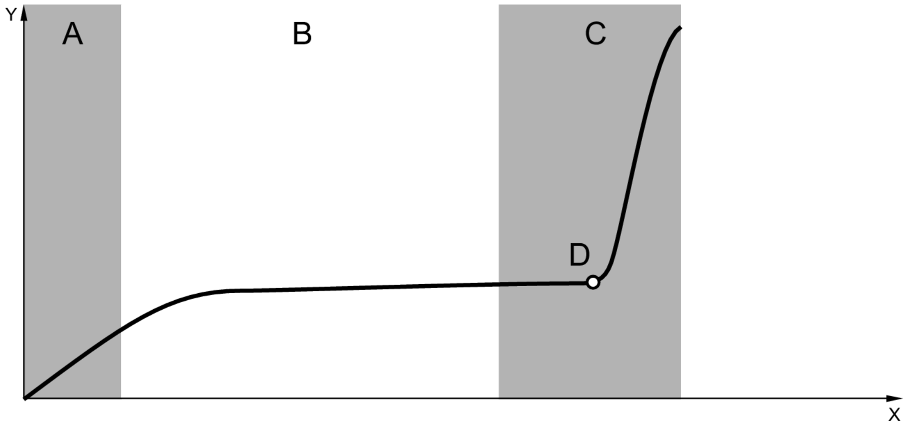


X	Angle	Y	Torque

Optimizing speed

For best performance, in non self threading plastic joints, it is recommend that the speed when the screw is seated is limited to what the speed is recommended for a torque step with the average peak torque value. If the customer needs to speed up the tightening, a fast angle step can be added to cover about 80% of the rundown of the screw.

When an angle step is added, it is important that this step always ends before the seating is discovered to avoid overshoot and to not miss seating detection. This can not be done without a stable and controlled tightening process.



A	Thread engagement	B	Rundown phase, about 80% of actual rundown
C	final tightening	D	Seating
X	Angle	Y	Torque

Error handling

Monitoring and detecting errors is a vital part of the process but has little worth without a well worked out error handling plan. It is vital that the operators and line technicians know what to do when an error occurs.

Re-work

It is a good idea to have a formal approach to re-work of work pieces. A good first approach is:

- analyzing the error
- (optional: moving off line to re-work station)
- loosening the screw a set number of degrees
- inspecting the ingoing parts for issues
- retightening the joint
- log the problem for further reference

Password protection

For a stable production line it is possible to password protect the removal of tightening errors. The error can be cleared by a password, or even better, by a technician logging in to the system via a RFID scanner.

It is possible to connect a RFID scanner directly into the controller and setting up rules so that the number on the RFID badge gets access to the controller that the operator does not have.

Stripped threads

When the tightening error suggests “damaged thread”, it is vital to verify this and remove the product from the line.

Traceability and Quality assurance

To support on visualization and analysis of results the software ToolsNet 8 is recommended. It stores tightening results and other information, giving the possibility to identify the root cause of tightening issues. It can also be used to alert the person responsible when an error occurs.

Original instructions

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