Electro-plated Tapping Screws Should Be Tested For Hydrogen Embrittlement

Hydrogen embrittlement failures are the most dangerous and costly problems associated with the use of electroplated tapping screws. It is not sufficient to bake electro-plated tapping screws after plating and then assume that there is no hydrogen in the parts. The only way to be assured that electroplated tapping screws will not fail from hydrogen embrittlement is to test every lot of parts prior to shipment.

What causes hydrogen embrittlement failures?

After heat treating and before plating, most platers dip screws into an acid bath to clean them so the electro-plating, the most common type being zinc, will adhere well and provide a uniform appearance. If the parts stay in the acid too long or the acid concentration is too high, hydrogen will form inside the screws.

Once the electro-plating is applied to the screws, any hydrogen that was created in the parts is sealed in. In most cases if the parts are baked within one hour after plating in an oven where the parts are held at 400º F for a minimum of four hours, the hydrogen is usually expelled from the screws. However, this does not always occur. Some tapping screws retain the hydrogen even after baking. The only way to be assured screws do not retain hydrogen is to test them as described later in this article.

When screws that have retained hydrogen are installed in assemblies, the hydrogen migrates to the points of high stress concentration. The two most common locations of high stress concentration in assembled screws are:

1. Where the screw's head joins the screw's shank

2. In the shank within about one screw diameter distance above the surface where the tapping screw has engaged into the assembly

After the assembly sits for a while, a small separation of the material boundaries begins at the surface of the screw where the stress is the highest. Once the separation begins it moves completely across the screw causing the part to break into two pieces. These failures do not occur immediately upon assembly. Hydrogen embrittlement failures generally occur within one to 24 hours after assembly.

What parts are susceptible to hydrogen embrittlement failures?

Steel parts having a core hardness of approximately Rockwell C 36 and higher are susceptible to hydrogen embrittlement failures. The higher the part's core hardness, the greater is the potential for this type of failure to occur. All steel tapping screws fall within this hardness range. Restricting the core hardness of tapping screws to a maximum of Rockwell C36 greatly reduces the chances of hydrogen embrittlement failures occurring.

What is the recommended procedure for testing tapping screws for hydrogen embrittlement?

Most tapping screw specifications have recommended practices for testing for hydrogen embrittlement. Most are very similar in their approach, but there are some differences. About 20 years ago I compiled all of the tapping screw specifications I could locate and then created one set of recommended practices that consisted of the most stringent requirements that were contained within all of these specifications. The reviewed specifications included those from the I.F.I., A.S.M.E., S.A.E., I.S.O., General Motors, and Ford Motor.

The resulting document was entitled the F.I.P.-1000 Tapping Screw Testing Procedure. The booklet contains five different tests including the ductility test, the drive test, the drive torque test (for thread rolling screws only), the drill time test (for self-drilling screws only), and the hydrogen embrittlement test. I consider the hydrogen embrittlement test to be the most critical of them, because of the huge losses that can result from hydrogen embrittlement failures.

Where did the recommended hydrogen embrittlement test come from and why was it selected for recommendation?

It was, and still is, my opinion that the test required in the General Motors tapping screw specifications is far superior to all other tests I considered. The primary reason I feel this way is because the General Motors procedure is the only one that establishes the test stress level for every individual lot of screws instead of using one stress level for all lots. The second reason I feel it is the superior test is that it requires parts to create their own threads in the untapped test plates as the screws perform in actual use. Several other test procedures require driving the screws into pre-tapped holes which is never the actual use of the screws.

The most common core hardness requirement in tapping screws is a range from Rockwell C28 to C38. Screws having a core hardness of RC28 have approximately 130,000 pounds per square inch of tensile strength, where as, screws having a core hardness of RC 38 have an approximate tensile strength of 170,000 pounds per square inch. If only one stress load (induced by torque) is used on all lots, the RC28 screws are stressed much greater than the RC 38 screws. The General Motors test requires that the stress load (applied by torque) must be determined for every individual lot. In my opinion this is a better test because it takes into consideration the differences in core hardness and screw finish in establishing the torque value used to stress the screws for each different screw lot.

What is the recommended tapping screw testing procedure for hydrogen embrittlement?

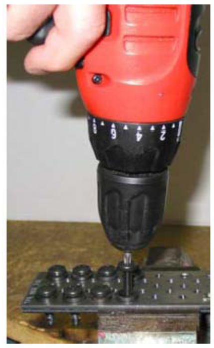
Following are the recommended steps in the procedure:

1. For every continuously processed electro-plating lot of tapping screws a randomly selected sample lot of at least 13 pieces should be taken. If the lot size is over 250,000 pieces an additional lot of at least 8 more pieces should be selected for every additional 250,000 pieces.

   This means the test sample lot size for a lot size up to 250,000 pieces is 13. For a lot size of 500,000 pieces a sample lot of 21 pieces should be taken, and for a lot of 750,000 pieces a sample lot size of 29 pieces should be taken, etc. These sample sizes are minimum recommendations based on the sample size required for hydrogen embrittlement testing in the quality assurance specification ASME B18.18.2. Larger test sample sizes increase the likelihood of hydrogen embrittlement being discovered in a lot of screws if it is present. When hydrogen embrittlement does occur it is usually in a small percentage of the lot and is never in 100% of the parts.

2. Apply washers to all test screws so the total thickness of the applied washers is greater than the length of two thread pitches. This it to make sure the parts are stressed under their heads and not just where the thread runnout joins the screw's head. This means that if a screw has a distance from one thread to another of .050" (20 TPI) washers totaling at least .100" should be applied to every test screw.

3. Using a power driver, install the 13 screws into the correct untapped test plate so that the parts are NOT seated on the washers. Stop driving the screws so that there is at least a one thread pitch distance between the screw's head and the washers.



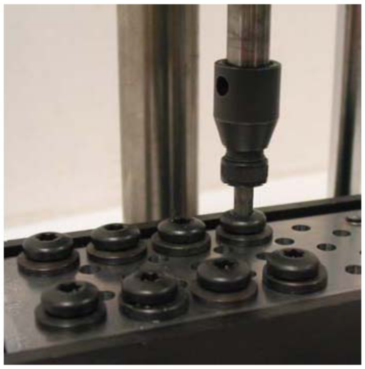
4. Place the test plate in a test fixture and tighten five of the test screws using a calibrated torque wrench until the screws twist into two pieces or until the screws strip out of the test plate. Record the torque value at which each of the five screws failed.

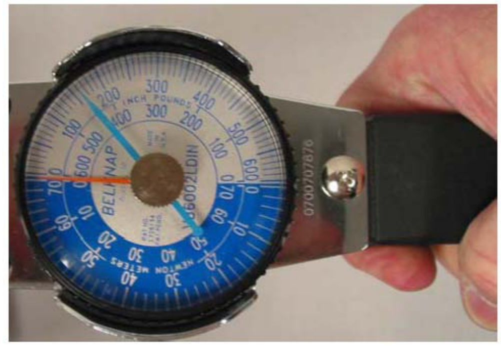
5. Calculate the hydrogen embrittlement test torque for the particular tapping screw lot being evaluated by first determining the average of the five failure values and then by multiplying that average by 80%. As the example in the photographs shows, the average failure value was 200 inch pounds. The test torque is then 160 inch pounds (200 X .8).

6. Tighten the remaining 8 or more samples to the calculated test value determined in step 5.

7. Let the samples sit for 24 hours and then re-apply the same torque value as was originally applied 24 hours earlier in the same clockwise (tightening) direction. If no screws break either before the torque is re-applied or while it is being re-applied the tested lot has a very high probability of not having hydrogen embrittlement.

Note: Some test procedures require an additional torque application at 48 hours. This is one more step that can be added to increase the supplier and/or end user's confidence that hydrogen embrittlement is not present in the tested lot of screws.





How is failure determined and what should be done when a failure is experienced?

It is obvious when screws fail from hydrogen embrittlement during this test. The screws end up in two pieces with the breaks located in one of the two locations described earlier.

If any parts break into two pieces during this test procedure the entire lot of screws should be rejected. Shipping a lot of screws that has even one failure out of 100 samples is extremely risky and the potential for damaged assemblies is great.

Many lots can be re-processed to save them, but every step should be carefully followed and monitored. Those steps are as follows:

1. Strip the plating off the screws.
2. Bake the unplated screws for at least 4 hours at 400º F.
3. Re-plate the parts.
4. Bake the parts again for a minimum of 4 hours at 400º F.
5. Re-test the lot of screws using the hydrogen embrittlement test procedure described above except it is recommended that the test sample sizes be doubled from 8 pieces for every 250,000 pieces to 16 pieces.

If any failures are experienced after this second test, the parts should probably be scrapped.

As stated at the beginning, a hydrogen embrittlement failure is the worst problem a tapping screw user can have because it is not evident until after assemblies have been completed. The resolution of hydrogen embrittlement failures frequently involve the end product being disassembled to some extent and then re-assembled with new screws. This is very costly. All suppliers of electro-plated tapping screws should make hydrogen embrittlement testing a part of their routine processing procedures.

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