Magnetic particle testing and evaluation of AMS AQ test samples

Better understanding the sampling, inspection, processes, and reporting steps necessary to complete an “Aircraft Quality” test per AMS standards.

Aircraft quality (AQ) testing of steels per AMS 2300, 2301, 2303, and 2304 requires specialized sampling and specimen preparation prior to final evaluation using fluorescent magnetic particle inspection. Last month’s Materials Matter column provided insight into the sampling and test specimen preparation, and this month, we conclude our discussion of the AMS AQ standards and look at the inspection, evaluation, and reporting requirements.

Each of the four AMS 23XX standards has slightly different quality requirements. The original AMS 2300 standard issued in 1959 is specified for the highest-quality materials produced using steels that are re-melted using VAR or ESR steelmaking practices. In 1995, the AMS 2304 standard was adopted that has essentially the same quality requirements as AMS 2300 but does not require re-melt steelmaking. AMS 2301 was adopted in 1960 and is intended to qualify steel produced by conventional steelmaking techniques and requires a lower quality level as compared to AMS 2300 and 2304. AMS 2304, issued in 1967, is similar in quality level to AMS 2301 but is specifically for martensitic corrosion-resistant steels.

Despite the differences in quality levels between the four AMS standards, the method of inspection is the same for each. All the AMS standards use magnetic particle inspection performed in accordance with ASTM E1444 entitled “Standard Practice for Magnetic Particle Testing.” The ASTM E1444 standard is a broad document that details every type of magnetic particle inspection that you might encounter, including the various types of magnetization, field directions, wet and dry particles and visual or fluorescent examination methods. The AMS standards require only one very specific type of magnetic particle inspection: circular, wet, continuous method. Per ASTM E1444, “Direct magnetization is accomplished by passing current directly through the part under examination.” By passing current through the part, a circular magnetic field is induced as illustrated in Figure 1.

Application of the direct current must be controlled per the AMS standards to be 800 to 1200 amperes per inch of diameter (32 to 48 amperes/mm). The “continuous” method requires that the liquid particle suspension be streamed over the test sample simultaneously with, or slightly before, energizing the part. The suspension must contain the required concentration of particles and be gently sprayed or flowed over the area to be examined. ASTM E1444 contains the details on the required particle density of the suspension, along with the corresponding testing methods to confirm compliance.

The presence of a non-metallic inclusion at or near the surface of the test piece will cause a disruption of the magnetic field (flux leakage) that attracts the fine iron particles suspended in the suspension to the site of the inclusion revealing an “indication.” When using fluorescent particle suspension, the room lights are turned off and the sample is illuminated using an ultraviolet light to reveal the indications. Again, ASTM E1444 specifies the allowable ambient light and the intensity of the UV light source used for this inspection. The UV light must have a minimum intensity of 1000µW/cm² at the surface being examined (Figure 3). Next, the indications are measured, counted, and recorded (Figure 4).

Up to this point in the procedure, the steps and requirements are identical for all four of the AMS standards. The first apparent difference between the standards is the size of the indications that are considered relevant and must be measured and reported. Recalling that AMS 2300 and 2304 have the highest quality requirements, these standards require any indications of 1/64” or larger to be recorded. The lower quality requirements of AMS 2301 and 2303
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Figure 3: AQ sample illuminated with ultraviolet light to reveal indications. No indications are visible in this image.

Figure 4: Example of an indication with a length of 8/32”.

require recording indications that are 1/16” or larger.

After the relevant indications are counted and measured, the frequency (F) calculation can be completed. The frequency is simply the total number of relevant indications for each specimen divided by the surface area of the test specimens in square inches. The final reported “average frequency” (F) equals the total frequency rating of all test specimens from a heat divided by the number of test specimens.

Next comes calculation of the severity rating (S). This gets more complicated as the AMS standards provide a table of “Progression Factors” or weighting factors. It is recommended that you refer to the specific AMS standard for the complete severity rating details. How it works is each standard provides a table with a progression factor corresponding to a range of indication sizes. For example, in AMS 2300 and 2304, an indication with a length greater than 1/8” must be multiplied by 256. In the AMS 2301 and 2303 standards, an indication between 1/8” and 1/4” is only multiplied by 1 and an indication between 1” and 1.5” is multiplied by 16. The severity rating (S) for a sample is calculated by multiplying the number of indications within each size range provided in the table times the corresponding progression factor. You can start to see how significant the quality differences are between the two tiers of AMS standards. The sample severity rating (S) is determined by multiplying each indication by its corresponding progression factor and then dividing the result by the total surface area of the test specimen in square inches. The severity ratings are then totaled for all indications observed in the heat. The final reported “average severity rating” (S) equals the total severity rating of all test specimens from a heat divided by the number of test specimens. A final AMS test report is a frequency (F) and severity (S) number.

Once the frequency (F) and severity (S) results are completed, they must be evaluated against the AMS standards acceptance criteria to establish Pass or Fail criteria. Each of the four AMS standards has their own specific acceptance criteria. The simplest is AMS 2304, which specifies the maximum acceptable rating with the maximum frequency rating (F) of 0.25 and the maximum average severity rating (S) of 0.50. The other standards get more specific and have acceptance criteria that vary by steel carbon content and product nominal size.

This series of columns was intended to help the reader better understand the sampling, inspection, processes, and reporting steps necessary to complete an “Aircraft Quality” test per AMS standards. These standards can be purchased from SAE International (www.sae.org). The referenced ASTM E1444 specification governing the magnetic particle inspection process can be purchased from ASTM International (www.astm.org).

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