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IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.2.1	
Subject	
Flexural Fatigue and Ductility, Foil	
Date	Revision
3/91	**D**
Originating Task Group	
N/A	

1.0 Scope With this test method the flexural fatigue life for any given bend radius, the flexural fatigue behavior and the ductility in percent deformation after tensile failure can be determined.

Note: The indirect determination of foil ductility by using a fatigue test is made necessary by the geometry and dimensions of foil samples which make tensile elongation and rupture tests inadequate for ductility determination.

2.0 Applicable Documents

IPC-TM-650

Method 2.1.1, Microsectioning

Method 2.4.18, Tensile Strength and Elongation, Copper Foils

3.0 Test Specimen Foil of sufficient size to permit cutting of three 3.2 mm [1/8 inch] wide specimens of at least 50.8 mm [2 inches] in length. Specimens must be clean cut and free of burrs and nicks.

4.0 Apparatus

4.1 Ductility Flex Tester, Universal Mfg., Model FDF or 2FDF or equal (see 6.4 and Figure 2).

4.2 Sample cutter, punch or tensile cut router. Note 6.4.

4.3 Micrometer tool capable of measurement to the nearest 0.0025 mm [0.0001 inch].

4.4 Programmable Calculator, Hewlett-Packard HP-67, or equivalent.

4.5 Sample holders, 203.2 x 12.7 mm [8 x 1/2 inch], of very flexible but durable material, e.g., epoxy-impregnated glass cloth, paper, etc.

4.6 Microscope

5.0 Procedure

5.1 Preparation of Samples

5.1.1 The samples should be smooth and undistorted (wrinkle free).

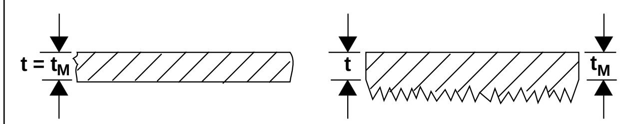

Figure 1 Smooth and rough foil

5.1.2 Use the sample cutter to cut the 3.2 mm [1/8 inch] wide test specimen. Examine each specimen for nicks, cuts, or curled edges. Discard any specimen with defects.

5.1.3 Use the micrometer to determine the specimen thickness, t, in center of each specimen to the nearest 0.0025 mm [0.0001 inch]. If one or both specimen surfaces are rough, it is necessary to determine the core thickness, t_M from a microsection (see Figure 1).

Note: Thickness is a critical parameter in the determination of fatigue ductility. A 10% error in t_M results in a 14% error in D_f.

Note: The core thickness, t_M, is preferably determined as a fraction of the specimen thickness, t, from a microsection prepared per IPC-TM-650, method 2.1.1 and measured with a metallurgical microscope at 200X minimum with a suitable filar eyepiece or reticle. The measurement is to be made from the valley of the rough surface to the smooth surface, or valley to valley, where both surfaces are rough. The t_M is to be made once on a batch or lot basis, and this fractional value of t_M/t is then multiplied by all other micrometer, t, values to achieve core values for all samples.

Note: Care must be taken that during thickness measurements the specimens are not compressed or surface roughness crushed, producing false low thickness readings.

5.1.4 Attach test specimen to the ends of 2 sample holders with adhesive tape and clamp 84 grams [3 ounce] foil weight (not the 8 ounce weight shown in Figure 2) to the free ends of the sample holders to form a loop (See Figure 2).

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Figure 2 Fatigue ductility flex tester

Note: For flexural fatigue tests lasting in excess of 1000 cycles, the adhesive tape attachment needs to be substantial enough to prevent relative sliding of specimen and sample holder as a result of the cyclic flexure movements.

5.2 Test Procedure

5.2.1 Mount mandrels to flex tester, adjust the support roller positions for a clearance of 1.27 mm [0.05 inch] (shim provided) between rollers and mandrels.

Note: For the ductility test, it is important that the specimens fail between 30 and 500 cycles. Mandrels with 2.0 or 1.0 mm [0.079 or 0.040 inch] diameter are suggested but for some samples, mandrel diameters different from these diameters might be necessary. Larger mandrel diameters result in longer cyclic life and smaller diameters in shorter life.

5.2.2 Mount test specimen between mandrels, attach relay leads with alligator clips to foil weight wing nut to form ''slip-off'' electrical connections, plug relay leads into relay jacks, set counter to zero, and start flex tester.

5.2.3 Complete separation of the foil specimen constitutes failure and the flex tester stops automatically when the dropping foil weight dislodges the alligator clips from the wing nut.

5.2.4 Record cycles-to-failure indicated on counter.

5.3 Evaluation

5.3.1 Ductility Test

5.3.1.1 Calculate the ductility for each specimen by iteratively solving the formula below:

$$N_f^{-0.6} D_f^{0.75} + 0.9 \frac{S_u}{E} \left[\frac{\exp(D_f)}{0.36} \right]^{\left(0.1785 \log \frac{10^5}{N_f}\right)} - \frac{2t_M}{2e+t} = 0$$

where:

D_f = fatigue ductility, inch/inch (x100,%)

N_f = cycles-to-failure

S_u = ultimate tensile strength, psi

E = modulus of elasticity, psi

t_M = core thickness, inch

t = specimen micrometer thickness, inch

e = mandrel radius of curvature, inch within 0.005 mm [0.0002 inch]

Note: Determine S_U as per Test Method 2.4.18 of IPC-TM-650. Determine E during the test for S_U by unloading and reloading after about 2% elongation and measuring the slope of the reloading curve.

Note: The determination of E foils is not a straightforward procedure. It is therefore suggested that for specification purposes standard values of E be adopted. For copper foil such standard values might be: E(CF–E) = 12 x 10^6 psi for electrodeposited foil, E(CF–W) = 16 x 10^6 psi for wrought (rolled) foil.

Note: The calculator program described in paragraph 6.2 solves the ductility formula and conveniently prompts for all necessary input parameters.

5.3.1.2 Report the average ductility from at least three specimens.

5.3.2 Fatigue Test The number of cycles to failure, is the flexural fatigue life in fully reversed bending for the bend radius corresponding to the radius (1/2 diameter) of the test mandrels used. An average flexural life from at least three specimens should be reported.

5.3.3 Fatigue Behavior The fatigue behavior of a sample can be obtained by determining the flexural fatigue life with a number of different-diameter mandrels. Plotting the results in a strain range versus fatigue life Manon-Coffin plot log $\Delta\varepsilon = [2t_M/(2e + t)]$ versus log N_f) allows intra- and extrapolation to other bend radii or fatigue lives.

5.3.4 The flexural fatigue life at bend radii other than mandrel radius can also be obtained by evaluating the ductility formula for the flex life in cycles-to-failure using the fatigue ductility determined in 5.3.1.2 and the desired bend radius.

6.0 *Notes* For further technical details, reference the material shown below.

6.1 Document in paragraph 2.0 (IPC-TP-204).

6.2 Engelmaier, W., ''Fatigue Ductility for Foils and Flexible Printed Wiring,'' Program No. 1883D HP-67/97 User's Library, Hewlett Packard Co., Corvallis, Oregon, 1978.

6.3 Engelmaier, W., ''Fatigue Ductility Flex Tester,'' Drawing L520163, Bell Telephone Laboratories, Inc., Whippany, New Jersey, 1978.

6.4 Test Equipment Sources The equipment sources described below represent those currently known to the industry. Users of this test method are urged to submit additional source names as they become available, so that this list can be kept as current as possible.

6.4.1 Fatigue Ductility Flex Tester, Universal Tool & Machine Inc., 171 Coit St., Irvington, NJ 07111; 201-374-4400.

6.4.2 JDC Precision Sample Cutter, Model JDC 125-N or equal.