Manufacturing Process for Cantilever Spring Blades for Advanced LIGO

APPROVALS	DATE
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1 Scope

This process specification is for manufacture of cantilever spring blades for Advanced LIGO. It includes material requirements, limitations on shaping, detail on the nickel plating process and details of the age hardening fixture. These springs are for use in an Ultra-High Vacuum (UHV) system.

2 Manufacturing Process

The following is the default process. An alternative process is defined in Section 3 below. Please ask LIGO staff if this option has not been defined for you.

2.1 Material

The sheet, plate or block material is called out on the associated drawing for the cantilevered spring. Materials are limited to either Maraging C-250 per AMS-6520[1] or Maraging C-300 per AMS 6521. The sheet or plate should be hot rolled, de-scaled and solution annealed.

The material grain direction shall be oriented parallel to the long axis of the blade spring.

Upon receipt of the material, measure hardness in several locations and verify a Rockwell C hardness of 29-33 for the annealed state. These measurements locations should be chosen so as not to create upsets or dimples in the final springs surfaces. Provide these measurements in certification documentation to LIGO.

2.2 Shaping

All shaping and forming operations are performed on the material in the annealed state with exception to the finish machining of thick springs.

The thin (< 0.2 inch, or < 5 mm), curved cantilevered springs used in LIGO suspension systems are ground to the required thickness, machined to plan form dimensions and then rolled to the radius of curvature defined on the associated drawing.

[1] Two materials that we know meet this specification are VascoMax c-250 (Allvac, an Alleghany Technology Company) and Marval 18 (Albert & Duval).

The thick (> 0.4 inch, or > 10 mm) cantilevered springs used in the LIGO seismic isolation systems are either flat or curved. The flat springs are machined .010 - .015” oversize then age hardened per section 2.7.2. After age hardening the flat blades are finish ground to final thickness. The curved blades are cut by EDM .18 - .20” oversize and age hardened per section 2.7.2. After age hardening the curved blades are EDM cut to its final shape. This procedure is necessary to remove distortions that may occur during the age hardening.

All machining fluids shall be water soluble (not simply water miscible) and free of sulfur, chlorine and silicone, such as Cincinnati Milacron’s Cimtech 410 (SSTL).

Machine all surfaces to remove oxides and mill finish. Abrasive removal techniques other than Blanchard grinding or double disk grinding, are not acceptable. A surface finish of 32 microinches is required. The vendor will need to confirm this surface finish in the inspection report.

Intermediate machining and strain relief steps are acceptable.

Thoroughly clean part to remove all oil, dirt and chips.

2.3 Dimensional Check

Perform initial dimensional check on all dimensions, including, but not limited to the thickness at various positions along the length, the radius and the height. If the dimensions are not within the tolerances called out on the drawing, forward this information to LIGO for review.

2.4 Cleanliness

The cleanliness of the blade springs must be maintained during all of the following steps. When not undergoing processing, the springs must be stored in cleaned & baked, covered, stainless steel containers or wrapped in clean UHV foil[2], handled only with latex gloves and exposed as little as possible to the environment.

Clean (and not previously used) latex gloves must be worn when clean parts are handled during the various processes below. If the gloves come in contact with anything other than clean surfaces, they must be replaced with new ones.

2.5 Electroless Nickel Plating

Prior to nickel plating, the parts must be electrocleaned (or electropolished).

[2] Part # ASTM B 479, UHV Certified Aluminum Foil, All Foil, 4597 Van Epps Road, Brooklyn Heights, Ohio 44131 (216)661-0211 Voice; (216)398-4161 Fax

2.5.1 Electropolishing or Electrocleaning Qualification

Electrocleaning/electropolishing of maraging steel must be achieved by a process that does not leave behind black spotting or streaking on the material due to improper chemical baths. Only suppliers with proven experience performing electrocleaning work on maraging steel components are to be used. In addition post electrocleaning/electropolishing inspections must be performed prior to acceptance. Suppliers without a track history can be asked to provide coupons of LIGO supplied maraging steel processed through their electrocleaning steps prior to accepting any bids, and these coupons must pass a visual inspection by the cognizant engineer and LIGO QA Officer.

2.5.2 Electrocleaning and Nickel Plating Process

Specific thickness and heat treatments are called out below and for that reason no specific class or grade of electroless nickel plating is defined. The following process steps are suggested. Due to outgassing concerns for UHV service, the specific process steps proposed by the plating company should be submitted to LIGO for approval. Once cleaned, the springs must be kept in a clean condition, kept covered in clean stainless steel containers, or wrapped in UHV foil and handled carefully with latex gloves both prior to and after nickel plating. Cleaning should occur just prior to plating.

1. Alkaline Soak: Alkaline Soak for 30 minutes. A new batch of soak cleaner should be used and periodically replaced. Parts should remain wet with cleaning solution and not be allowed to dry out.
2. Rinse: Rinse in clean, ambient-temperature tap water. The tanks should be drained and rinsed out prior to starting. Cross rinsing or dirty rinses are not acceptable.
3. Alkaline Electrocleaning: 20 sec Cathodic / 40 sec Anodic / 20 sec Cathodic / 40 sec Anodic / 20 sec Cathodic / 40 sec Anodic; typically using 15-20 Amps/square foot. A new batch of the electro-cleaner solution (to be specified by vendor) should be used and periodically replaced. A bath with a filtration system will be accepted as an alternative to changing the fluid (after approval from LIGO) but changing the fluid is preferred.
4. Rinse in ambient temperature tap water (step 2 above).
5. Acid Clean: Place the parts in a 30 % (by volume) hydrochloric acid at ambient temperature for a minimum of 30 sec. Leave the parts in the acid until 10 sec after uniform gassing over the surface is observed, but for not more than 2 min. A new batch of the acid solution should be used and replaced at the same time as the soak and electrocleaners.
6. Rinse in ambient temperature tap water (step 2 above).
7. Repeat electrocleaning (step 3 above)
8. Rinse in ambient temperature tap water (step 2 above).

9. Electroless nickel plate with a low (<5%) phosphor bath as called out in table 1 of ASTM[3] (Type III phosphorus % wt - 2% - 4%) to a thickness of 0.5 um (microns) / [0.0000197 inches]. We will accept a tolerance on the thickness from 0.4 to 0.6 microns / [0.0000157 to 0.0000236 inches]. Use a method, as called out in section 9 of the ASTM[3] Designation B 733-97, to gauge the time required to obtain the required thickness .
10. Rinse blades with ambient temperature, de-ionized water.

2.6 Bake to prevent Hydrogen Embrittlement

The blade springs must be baked soon after plating to avoid any problems associated with hydrogen embrittlement. If the age hardening bake (see section 2.7) can begin within 4 hours of plating, then the following bake can be eliminated.

Handle the springs only with latex gloves and expose them as little as possible to the environment.

Bake the springs within 4 hours of the nickel plating for 12 hours at 150 deg C.

The bake to prevent hydrogen embrittlement must occur in a clean, non-shedding oven with stainless steel surfaces, or in a clean stainless steel box insert within the oven. The oven (or stainless steel box if one is used) must be continuously purged with Argon gas, or HEPA and carbon filtered air, at a rate of about 10 liters/min through oil-free plumbing lines and valves.

2.7 Age Hardening Bake

Prior to aging, soak the springs in a bath of iso-proponal and either ultrasonically or manually agitate for 2 minutes. Handle the springs only with latex gloves and expose them as little as possible to the environment.

The springs must be mounted in a "comb" or "wire rack with pins" fixture. The fixture is used to maintain the shape of the blades during aging and should expose most of the blades surface area. The design of this fixture should be discussed and approved with LIGO staff prior to proceeding. The fixture must be electrocleaned and baked out at 500 degrees C for 4 hours prior to initial use.

The age hardening bake must occur in a clean, non-shedding oven with stainless steel surfaces, or in a clean stainless steel box insert within the oven. The oven (or stainless steel box if one is used) must be continuously purged with heated Argon gas at a rate of about 10 liters/min through oil-free plumbing lines and valves.

[3] Standard Specification for Autocatalytic (Electroless) Nickel-Phosphorus Coatings on Metals, ASTM Designation: B 733-97

Measure the post heat treatment hardness at several locations on each blade spring. Do not take measurements at the clamp regions on either end of the springs since the upset/dimple created could interfere with proper clamping. Provide these measurements in certification documentation to LIGO.

2.7.1 Thin Blade Springs

For suspension assembly blade springs (see section 2.2):
Age harden at 815 F (435 C) for 100 hours in an inert atmosphere and air cool.

After aging the hardness should be 48 to 52 Rockwell C.

2.7.2 Thick Blade Springs

For seismic isolation assembly blade springs (see section 2.2):
Age harden at 900 F (482 C), soak for 40 minutes, then age for 4 – 6 hours in an inert atmosphere and air cool.

After aging the hardness should be 50 to 55 Rockwell C.

2.8 Post-Hardening Dimensional Check

Perform a final dimensional check on all dimensions, including, but not limited to the thickness at various positions along the length, the radius and the height. If the dimensions are not within the tolerances called out on the drawing, forward this information to LIGO for review. Provide a summary of these final dimensional checks with a certification statement of compliance with this specification.

3 Alternative

In the process outlined above nickel plating is performed before aging. However, it should be noted that plating after age hardening is also acceptable, but only with the addition of a 330 deg C for 24 hr bake, used to drive off any unbound phosphorous[4]. This additional bake step should be performed after the hydrogen embrittlement prevention bake (section 2.6) at the end of the nickel plating process. Alternatively, if this bake can be accomplished within 4 hours of plating it also serves the purpose of preventing hydrogen embrittlement.

The additional bake, outlined above, must occur in a clean, non-shedding oven with stainless steel surfaces, or in a clean stainless steel box insert within the oven. The oven (or stainless steel box if one is used) must be continuously purged with HEPA and carbon filtered air, at a rate of about 10 liters/min through oil-free plumbing lines and valves.

[4] Internal LIGO reference - LIGO-L0900024-v1 The VRB response to nickel-phosphorous plating issues.

Prior to baking to remove unbound phosphorous, soak the springs in a bath of iso-proponal and either ultrasonically or manually agitate for 2 minutes. Handle the springs only with latex gloves and expose them as little as possible to the environment.

4 Internal Steps

The following steps will be performed by LIGO staff after receipt of the blade springs:

1. Blade spring response characterization – deflection/flatness under load, internal mode frequencies, etc.
2. Cleaning and baking (150 deg C for 48 hours) for UHV service, including outagssing measurements - not under load.
3. Creep bake (150 deg C for a week) - blades remain under load