A.7: Development of electroforming technology for 3 MeV beam dump

For proton beam up to 3 MeV, a beam dump is under development as part of proton accelerator activities. Making thin conical structure in copper using conventional manufacturing techniques is difficult. Electroforming is a technique for fabricating parts that cannot be produced by other manufacturing methods. It is the process of electrodepositing a metal on a mandrel, which when separated from the mandrel produces an independent, free standing object. Optimization of the technique of electroforming was taken up at Chemical Treatment Laboratory (CTL), Design and Manufacturing Technology Division (DMTD), in collaboration with Linac Component Development Section (LCDS). Studies were carried out for fabrication of end cone made of copper having approximate length of 230 mm and maximum diameter of 40 mm with a 25 micron thick nickel coating in the inner side of the cone. Figure A.7.1, shows the photograph of mandrel and other insert materials used during electroforming of the above mentioned cone.

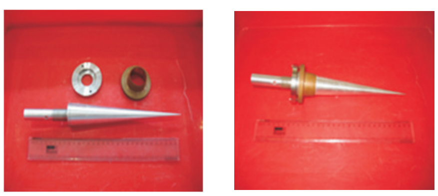

Fig. A.7.1: Mandrel parts before and after assembly.

The entire work was carried out in following 07 different stages : (a) preparation of mandrel surface (b) electrodeposition of 25 micron thick nickel (c) assembly of stainless steel (SS) and copper flanges (d) electrodeposition of copper to a minimum thickness of 2 mm along the entire cone (f) machining of the external surface of the deposited copper, and, (g) removal of the aluminum mandrel for obtaining free standing copper cone with flange. Following is a brief description of the important stages of the process:

Preparation of Mandrel: The cleaning procedure adopted for the surface preparation of aluminum mandrel to obtain non-adherent deposit for easy removal is as follows; (i) Degreasing with trichloroethylene (ii) Immersion cleaning in 10% NaOH for 45 seconds followed by rinsing with water and (iii) Immersion cleaning in 20% HNO_3 for 30 seconds followed by rinsing with water and de-mineralized (DM) water.

Nickel Electrodeposition: Nickel Sulphamate based solution that produces a stress free deposit was chosen for nickel plating. Pre-conditioning of the electrolyte after its preparation is an important step during electroforming. Activated carbon and low current density dummy treatment were carried out to remove any organic and inorganic impurities present in the electrolyte. The solution was filtered using Whatman qualitative filter paper of 10-micron pore size and adjusted to the required pH value. After chemical cleaning of the mandrel, nickel plating was carried out in this solution, at 48-50 ºC for 50 minutes (current density 0.05 amperes/cm^2). The experimental set up used for nickel plating is shown in Figure A.7.2(a). Nickel plated mandrel was washed with water, DM water and deposited with copper for 10 minutes at a current density of 0.02 A/cm^2. After copper deposition for 10 minutes, the mandrel was taken out, attached with flanged copper insert and SS flange as shown in Figure A.7.2 (b).

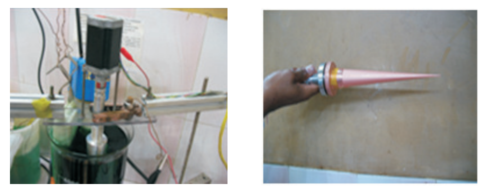

Fig. A.7.2: (a) Nickel plating of mandrel, and, (b)assembled mandrel with copper and SS flanges.

Copper Electrodeposition: The assembled mandrel was cleaned in 10% sulfuric acid for 30 seconds and copper plating was continued for 125 hours from a solution containing copper sulphate and sulfuric acid at current density between 0.02 and 0.03 A/cm^2, in the set up shown in Figure A.7.3(a).

Fig. A.7.3: (a) Electroforming set up. (b) Electroformed copper. (c) Machined free standing copper cone.

The mandrel was rotated using a motor at 15 rpm along with continuous filtration. Dynatronics make pulse periodic reversal power supply was used for electrodeposition. A 20 second forward current followed by 4 second reverse current was maintained throughout the plating process to produce a smooth deposit. Coating thickness was measured and found in the range of 2.3 mm near the flat base of the cone to 4.0 mm just above the vertex. Machining of the mandrel was carried out to remove excess copper coating at the tip of the cone and to achieve the required external dimensions with uniform surface finish. The mandrel was successfully removed from the deposit to obtain a free standing cone as shown in Figure A.7.3 (c). The cone will be further tested for its suitability in meeting the functional requirements.

Reported by:
P. Ram Sankar (prs@rrcat.gov.in)