I.1: Development of beam dump for 3 MeV proton beam by electroforming

As part of proton accelerator activities, a beam dump has been developed for proton beam with energy up to 3 MeV. This involves fabrication of a thin conical structure made of copper. Electroforming technique was used for its fabrication. The task was completed in two stages. Stage-1 consisted of optimization of the electroforming technique and fabrication of the prototype end cone made of copper (~ length of 230 mm and maximum diameter 40 mm) with a 25 µm thick nickel coating on the inner side of the cone. In stage-2, electroforming of actual free standing end cone of length 760 mm and maximum diameter 140 mm, made of copper of thickness ~3 mm with 50 µm thick nickel coating on the inner side, was completed. Figure I.1.1(a) shows the mandrel and flange with conical bore in assembled condition. The conical bore of the stainless steel flange connecting the aluminium mandrel and the flange was copper plated before assembly. Its close up view is shown in Figure I.1.1(b).

(a) (b)

Fig. I.1.1: (a) Mandrel parts after assembly and (b) close up view of mandrel and flange joint.

The entire manufacturing process was completed in following steps: (a) preparation of conical aluminium mandrel and stainless steel knife edge flange with a conical bore matching with mandrel, (b) copper deposition at conical bore location of flange to a thickness of ~10 µm, (c) assembly of mandrel, flange and a fixture for electro deposition, (d) electro deposition of 50 µm thick nickel on the aluminium mandrel, (e) electro deposition of copper to a thickness slightly greater than 3 mm along the entire cone, (f) machining of the OD (the deposited copper on mandrel) in vertical turret lathe, (g) removal of the aluminium mandrel for obtaining free standing copper cone with flange, and (h) leak testing of the cone.

Preparation of Mandrel: The cleaning procedure adopted for the surface preparation of aluminium 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 DM water.

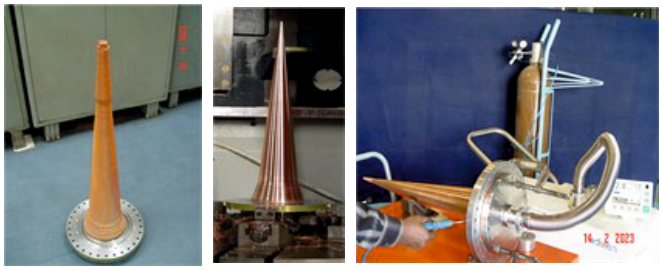
Nickel and copper electrodeposition: After chemical cleaning of the mandrel, nickel was deposited from nickel sulphamate bath at 48-50 ºC at a current density of 0.05 amperes/cm^2 to achieve a thickness of 50 µm.

Typical experimental set up used for nickel and copper plating is shown in Figure I.1.2(a). The mandrel was rotated using a motor at 15 RPM along with continuous filtration. In order to reduce the current density at the bottom of the cone, auxiliary electrodes were employed as thief. Nickel plated mandrel with thief used for reducing the current density at the bottom of cone is shown in Figure I.1.2(b).

(a) (b)

Fig. I.1.2: (a) Typical set up for nickel and copper plating and (b) nickel plated mandrel with thief.

Nickel plated mandrel was further deposited with copper from a solution containing copper sulphate and sulfuric acid (current density 0.02 to 0.03 A/cm^2) to a thickness greater than 3 mm. 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 as shown in Figure I.1.3((a) & (b)).



(a) (b) (c)

Fig. I.1.3: Electroformed copper- (a) before machining, (b) after machining, and (c) separation of cone.

The mandrel was successfully separated from the deposit to obtain a free standing cone after subjecting the mandrel to a thermal shock and by applying the required force. Leak testing of the free standing cone was done as shown in Figure I.1.3(c). This free standing cone passed the leak test with a leak rate of $2x10^{-10}$ mbar.l/s.

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