Electroforming Process: Micro Manufacturing

Sukhswarup S. Patel
Department of Mechanical Engineering
A. D. Patel Institute of Technology, Karamsad, Anand, Gujarat India

Abstract— Electroforming is one of the main manufacturing methods of electrodeposition for the manufacture of metal parts. With the use of electroforming technique, parts can be manufactured with precision dimensions and more accuracy. Here in this paper, process principles and mechanisms of electroforming, outlining its advantages and limitations are described. The ability to manufacture complex parts to close tolerances and cost effectively has meant that electroforming has applications both in traditional/macro manufacturing and new micro-manufacturing fields. The removal of cathode (mandrel) for electroform part is difficult for complex parts. By keeping steady cathode and forcing electroform, it can be removed.

Key words: Electroforming, Copper Electrodeposition, Electroplating, Micro part manufacturing

I. INTRODUCTION

Electroforming was first observed in 1837 by Jacobi during the electrodeposition of copper onto printing plate. The American Electroplaters and Surface Finishers' Society (AESF) has provided definition of Electroforming as "the production or reproduction of an article by electrodeposition upon a mandrel or mould that is subsequently separated from the deposit". It is also known as 'the art of growing parts'. This excludes requirements for removal of mandrel, but sometimes, is more appropriate. Although it is not a universally applicable process, its ability to produce or reproduce shapes with good surface finish and superior metallurgical properties has ensured that the electroforming is a competitive process in precision manufacturing. The range of its application areas are consumer products to the highly specialized aerospace components. Recently electroforming has evolved into an extremely focused micro fabrication technique. This paper outlines the principles and practice of the electroforming process and reviews its applications in traditional macro and the new micro fabrication industry.

Most of the engineers and designers are not fully dealing with the advantages of electroforming. A main cause is that the technology is based upon the principles of electrochemistry. Though, electroforming can be subjected to a high degree of control. It can be operated with extreme precision and reliability. Electroforming should be thought of as a basic Manufacturing process when considering alternatives best suited for making any particular component. Other processes such as casting, forging, stamping, deep drawing and machining may serve well for most applications. However, when requirements specify high tolerances, complexity, lightweight and miniature geometry, electroforming is a grave contestant.

A. Basic Principles

Electroforming is type of electrodeposition process, similar to electroplating and electrorefining. In electroplating, metal is dissolved electrolytically at an anode. The basic process principle of electroplating process is shown in fig 1. The metal ions from anode transported through an electrolyte solution which usually contains a high concentration of the same metallic ions are to be deposited at a cathode. The difference between electroforming and electroplating lies in the purpose of use for the deposited metal. Electroplating is concerned with taking an existing part and applying a metallic coating to provide a decorative and/or protective surface. Electroform, however, is a metallic object that has been created by utilising the electroplating process to deposit a metal onto a master form cathode or mandrel. The purpose of electroform is to serve functionally as a separate entity or to serve as decoratively.

Electroplated deposits vary in thickness from about 7-50 μm, where electroformed thicknesses vary from 50 μm or more and very often several mm thick. After electroforming the electroformed part is physically removed from the mandrel. Thus, the deposit part must have low adhesion to the mould to facilitate its removal. In conventional electroplating the deposit is normally used to protect the base metal (for ex. from corrosion) and/or to provide a cosmetically attractive appearance. Mechanical properties and dimensional accuracy are the key features in electroforming requiring control over deposit composition, structure and internal stress.

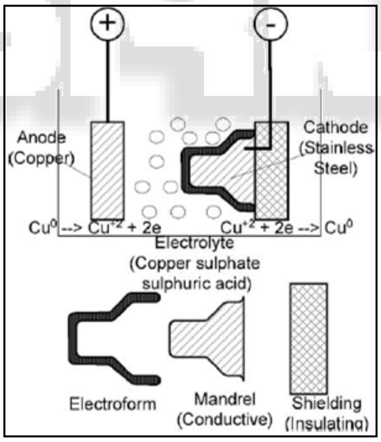

Fig. 1: The principles of electroforming

In practical, the mandrel is given the desired shape for electrodeposition, and also an exact replica of the mandrel surface is produced. This (negative) replica may itself then be used as a mandrel to regenerate the original (positive) form. Thus, a large number of identical forms can be produced from a single master.

B. Features of Electroforming

1) Advantages

a) High-Dimensional Precision

Electroforms can be produced all having precisely the same dimensions due to its made to the required dimensions to replicate it precisely, provided the deposited metal is without internal stresses. The technique is therefore suitable for producing components where such exactness of form is required for such as moulds and dies.

b) Precise reproduction of surface detail

This process can be used to give extremely high accuracy of surface detail which is very fine detail compared to match with other production processes.

c) Production of complex-shaped components

Parts with complex shapes which required such processes as pressing, drilling, machining, deburing and welding in order to be manufactured, can be made in a single operation using electroforming process.

d) Production of thin-walled components

The main advantage of this process is its capability to produce very thin walled cylinders without joint line. Thin walled cylinders represent the high commercial use of electroforming.

e) Mass production

Multiple mould cavities can be electroformed at an electrolyte bath at the same time to reduce mould-making cycle time, thus one master mould can be reused many times for making identical moulds easily and then it can be reused to make little environmental impact.

2) Limitations

a) Long deposition times

To increase deposition rate, the distance &velocity between mandrel and electrolyte which increases current density but it also increases deposition time.

b) Material restrictions

Properties such as brittleness, oxidation and internal stresses, that's why only copper, nickel and iron can be used in practical.

c) Electroform/Mandrel separation

The separation process is normally achieved by mechanical, chemical or thermal means. For removal of electroform undamaged, the careful design process is required.

d) Non-uniform thickness

Multifarious methods are applied to obtain uniform thickness of electroformed.

3) Applications of Electroforming:

- Thin foils
- Perforated products
- Record stampers
- Moulds and dies

II. Electroforming Process

First of all, the electroforming process requires tank which is selected as per if electrolyte solution is acidic or basic. Then, for dc current and voltage, rectifier is being used to flow current through the electrolyte bath to deposit ionic solution on cathode. Normally in electroforming process, Copper, Nickel, Aluminum is used for their conductivity towards electricity & they are easily electroformed on cathode/mould regarding conductive or non-conductive material.

Here, 3D setup for electroforming process is shown as in Figure 2. Electroforming setup is consists of tank, anode, cathode, electrolyte soliution. Here, red is anode and the blue is the cathode as mould. Cathode is made from materials such as wax, plastics, ceramics, glasses & metals, etc as in form of non-conductive dissolvable mould and other is metals such as tin, lead, aluminium are conductive metals which are al.so materials such as steel or mild steel for permanent conductive mould. Moulds are normally two type based on its condutivity [1] Conductive moulds [2] Non-Conductive Mould and other type is based on its usefulness for process [1] Temporary Mould & [2] Permanent Mould. The anode materials are selected based on the requirement of the electroform material.

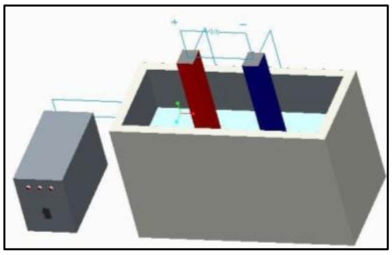

Fig. 2: Electroforming Experimental 3D Setup

In practical, the use of plane anodes does render difficult the deposition of metals in recessed areas of the mould such as edges or corner of mould, as a consequence of the locally lower current density in those regions. This difficulty is usually overcome by use of a shaped anode, whose form is complementary to that of the mould. A uniform current density over the final electrode, and hence a continuous metal breadth is then obtained. When an undistributed (insoluble) anode such as graphite or glass is used, the deposition action depends on its metal supply from the electrolyte solution. As electroforming proceeds, these materials dissolve electrolytically and maintain a constant concentration of metal salts in the electrolyte solution.

III. Results and Conclusions

After doing review study on electroforming process, it is said that electroforming process can be controlled by using input parameters such as voltage, current and current density. The uniform breadth thicknesses can be obtained by using current – voltage different ratios. With uniform metal deposition, it can achieve in making small sized components such as valves, gears, diaphragm, bellows; and more decorating things such as plated ring, jewellery, etc. The increasing in voltage-current ratios, the thicknesses can be varied.

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