Design and Manufacturing of Helical Copper Tube Heat Exchanger Winding Machine

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Abstract – *The objective of this project is to design and manufacture a helical copper tube heat exchanger winding machine. Helical coil tube heat exchangers are used widely due to their compactness, high heat transfer rates and large heat transfer areas. Helical tube heat exchangers made of 3/8" copper tube are the most popular choice. As there is no formal technique for manufacturing 3/8" copper tube into a helix, the cross-section of tube becomes elliptical rendering to lower heat transfer rates. In this study we will manufacture a machine consisting of a mandrel with a drive upon which the helix will be formed. Also, the study consists of using different techniques and different mandrel materials to acquire circular cross-section of helix. It also deals with parameters like spring back effect, thinning effect, wrinkling at corners of the copper tube.*

***Key Words*: Helical coil, Heat exchanger, 3/8" copper tube, Mandrel, Material selection, Circular cross-section, Spring back, Wrinkling, Thinning.**

1. INTRODUCTION

A 3/8" copper tube helical coil heat exchanger is used in food products, diary and refrigeration industries. For better efficiency of this heat exchanger its heat transfer rate needs to be high. But, as copper is soft, during manufacturing its circular cross-section becomes elliptical, due to which the heat transfer rate reduces. A perfectly or near perfect circular cross-sectioned copper tube has the highest heat transfer rate. Thus, the aim of this project is to keep the cross-section of the copper tube circular for high heat transfer rates.

During manufacturing of the helix tube, the tube gets deformed due to the stresses produced during the winding process. The major factors of the stresses in making the circular coil elliptical are the spring back effect, thinning effect, strain and thermal stresses.

For this project, we will be keeping the cross-section circular by trial and error method. So, the major parameters under this project are spring back and thinning effect. This helical copper tube heat exchanger has to be manufactured by winding the tube on a rotating mandrel of a softer material. Thus, a setup or fixture has to be made for taking trials on the rotating mandrel.

Wooden mandrel will be the base material onto which rubber sheet or foam material will be covered. Thus, the copper tube will be wounded onto the rubber sheet. Trials will be taken with rubber sheet mounted on the mandrel with unfilled, water filled and salt filled copper tube.

2. DESIGN OF MACHINE ASSEMBLY

The design of the machine made for winding is based on the concepts of a simple lathe machine. It consists of a headstock section with drive for the mandrel, a tail stock section for supporting mandrel on other end, a mandrel and a frame for supporting all the other elements. The components of the machine are as follows:

2.1 MANDREL

Mandrel is the rotating cylinder onto which the copper tube is to be wounded into a helix. Thus, the material of the mandrel needs to be soft to compensate for the softness of copper. Thus, wood was selected as the base material for mandrel. The wood used for mandrel is "Indian Cork Tree" also known as "Akash Neem" in Marathi. The wooden cylinder is made into a circle diameter of 75mm on a wood lathe. On one side of the wooden mandrel, a bore of around 1" diameter was drilled using a portable drilling machine with a M10 size drill. The depth of the bore from the face is about 30mm. At 25mm from the face, a hole of 10mm is drilled on the surface of the mandrel. The mandrel and the tailstock shaft were then fixed together by matching the 10mm holes and then fixing them with nut and bolt. Onto the flat face of the head of this bolt, a nut of M12 size was welded. This was done so that the copper tube could be fixed into this nut while taking the trial.

2.2 FRAME

The frame is made up by using steel angles. It consists of two parts viz. the base and the legs. The base is a rectangle of 3x2 ft. The base also consists of two angles at equal distance from center of 2 ft. angle, parallel to the 3 ft. angles. These two angles are used as guide ways for the sliding block and the headstock and the tail stock rest on them. The base is all welded together. The legs are 3 ft. high. Holes of 10mm are made on the legs and the base by drilling them with a portable drilling machine, so that they can be bolted together instead of welding, so that it is easy to carry/transport the machine anywhere easily.

2.3 HEADSTOCK/FIXED BLOCK

The headstock is used to give rotary feed to the mandrel. The headstock mainly consists of the rotating shaft on which the mandrel is to be mounted for giving rotary feed. The shaft is made up of steel polish bar. The steel bar used is of 1" diameter. One side of the shaft has been faced to achieve desired length. This side is inserted in the wooden mandrel to give the rotary feed to the mandrel. At a distance of 25mm a hole of 10mm has been drilled using a radial drilling machine. This drill was made so that the mandrel could be fixed onto the shaft with the help of nut and bolt, while the mandrel consisted of a 10mm hole to match with the shaft drill.

On the other end of the shaft, two small steel bar were welded together to make "L" shape. This L shaped bar is used to give manual rotary feed. The shaft is supported onto two pedestal bearings. The distance between centers of the two bearings is about 150mm. These bearings have a bore of around 1". Thus, the bar is passed through the bearings and then clamped by using two Allen screw each on the two bearings. These bearings are mounted on wooden block of 210x150mm dimensions and 70mm thick. This, is so done to give a considerable height to the shaft and to match the center line of the machine headstock, tailstock and the mandrel. The nut and bolts of M10 size are used to affix the wooden block to the frame.

2.4 TAILSTOCK/SLIDING BLOCK

The tailstock is used to only support the rotating mandrel onto the other end. It also uses a polished steel bar of 1" diameter. The rear end of the bar is turned while the mandrel supporting end is tapered. This shaft is mounted on a single pedestal bearing which can carry 1" diameter bar. The shaft is clamped to the bearing using two Allen screws. The bearing is mounted on a wooden block of 140x150mm dimensions and 70mm thickness.

The tailstock is the sliding block. Thus, it cannot be fixed onto the guideways. So, two plates of 4mm thickness were welded together using lap joint to make a "+" shape. The plate perpendicular to guide way is just smaller than the gap between the outer ends of the angle. At the center of the plate, a hole of 10mm thickness is drilled using a radial drilling machine. Also a hole of 10mm thickness is drilled on the wooden block. A bolt of M10 dimension and 4" length is passed through the hole on the plates and the welded together. Thus, the bolt is now passed through hole on wooden block and by using a M10 nut it is fixed.

After these arrangements, the sliding block still moves along the vertical axis. To stall this degree of freedom, two angles of 3" length were lap welded. One angle is flat faced to the block while the other angle is flat faced to the guideway angle. Thus, now the tailstock could slide onto the guideways without shifting the center line of the tailstock with respect to the headstock and the mandrel. Also, the sliding block compensates for the length of the mandrel.

Table – 1: Components of Machine

Sr. No.	Name of Component	Dimensions	Quantity
1.	Frame Base	3x2 ft.	1
2.	Frame Legs	3ft long	4+3(support)
3.	Frame Base Guide Ways	3ft long, 135mm width	2
4.	Headstock Shaft	Diameter 1 inch, 400mm long	1
5.	Bearings	Hole diameter 1 inch	3
6.	Headstock Wooden Block	210x150x70mm	1
7.	Tailstock Shaft	Diameter 1 inch, 120mm long, taper 30 degrees	1
8.	Tailstock Wooden Block	140x150x70mm	1
9.	Tailstock Fixing Plates	80x30x4mm	2
10.	Tailstock Guide Plates	3ft long angles	4
11.	Mandrel	Diameter 75mm	1
12.	Nut & Bolt	M10, 5 inches	5
13.	Nut & Bolt	M10, 4 inches	3
14.	Nut	M12	1

Figure 1: Fabricated Machine

3. SPECIFICATIONS OF COPPER TUBE

3.1 MATERIAL

Copper phosphorous deoxidized (Cu-DHP), having minimum copper content 99.90% and phosphorous content 0.015% - 0.040% as per ASTM B280/B68/JIs H3300 standard.

3.2 DIMENSIONS

Copper tube external diameter: 3/8 inch or 9.52 mm.
Copper tube wall thickness: 0.032 inch or 0.81 mm.
Weight: 0.198 Kgr/m

3.3 MECHANICAL PROPERTIES

Maximum operating pressure: 108 bar.
Minimum Tensile strength: 200 N/sq. mm
Yield strength (0.2%): 35-80 N/sq. mm
Elongation: > 40%

4. TRIALS

For taking trials, 3/8" copper tube is fixed on the mounting arrangement made on the mandrel. The drive required for rotating the mandrel is given by hand. As mandrel rotates copper tube is wound around the mandrel to form a helix. The pitch and helix angle are adjusted by manual feed to the tube. It makes sure that mandrel is being rotated at around 5-10 rpm. After taking the trials, the major and minor diameter of helical coiled copper tube have been noted. Trials are taken on different mandrel materials such as wooden mandrel, EPE foam and rubber. Also trials are taken by using filler material like salt and water, which are filled inside the copper tube while taking the trials.

Figure 2: Wooden Mandrel (Cork Wood)

Figure 3: EPE Foam

Figure 4: Rubber Mandrel

5. RESULTS

After performing different trials, the produced helical copper tube readings were taken. A Vernier calliper was used to measure the major and minor diameter of the tube at various sections and noted down.

Table – 2: Observations

Trial Setup	Major diameter (mm)	Minor diameter (mm)
Cork Wood	10.50	7.10
EPE Foam	10.20	8.10
Rubber mandrel	10.60	8.10
Tube filled with water (Rubber mandrel)	10.50	8.40
Tube filled with salt (Rubber mandrel)	9.96	8.84

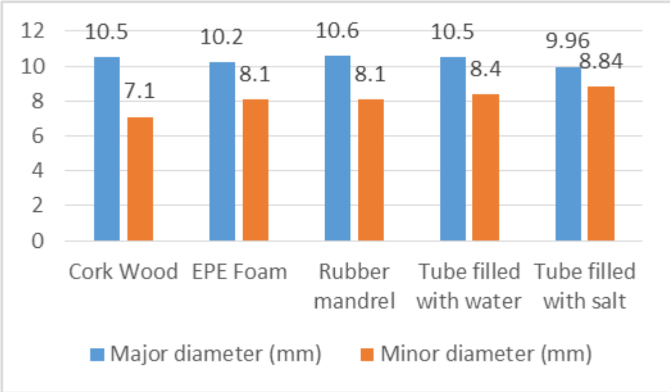

Chart – 1: Variation of major and minor diameter of copper tube

Figure 5: Result on wooden mandrel

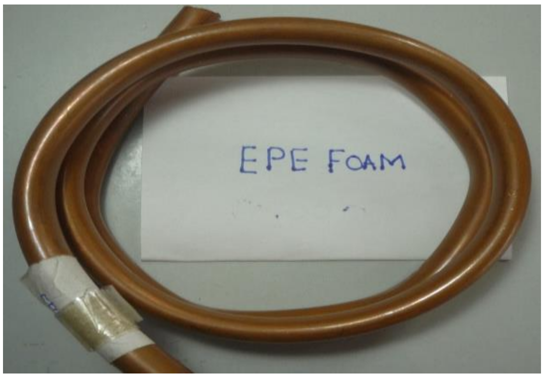

Figure 6: Result on EPE Foam

Figure 7: Result on rubber mandrel

Figure 8: Result with water filled tube on rubber mandrel

Figure 9: Result with salt filled tube on rubber mandrel

6. CONCLUSION

The observations show that the copper tube winded on rubber mandrel using salt as filler material gave the best results. The cross-section of the tube was very close to that of the circular tube cross-section. If the salt is filled up evenly and rammed with proper pressure, the deformation can further be reduced. Also, it was found that the wrinkling defect on the inner surface of the copper tube were eliminated when softer rubber mandrel was used. From the results it is clearly seen that the elliptical cross-section of the helical copper tube was reduced to near circular cross-section.

7. REFRENCES

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