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Development of Novel Spinning Process for Forming Axillary Capillary Grooves for Heat Pipes

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***Abstract*: This paper present on Development of Novel Spinning Process For Forming Axillary Capillary Grooves For Heat Pipes. In spinning, a high pressure oil-film, which squeezes the tube outer-wall, is formed as the spinning speed increases. A floating mandrel extrudes the tube inside wall to form the micro-grooves/fins continuously The key factors influencing the configurations of micro-grooves were analyzed. When the spinning depth varies between 1 mm and 0.9 mm, drawing speed varies from 60 mm/min to 100 mm/min, rotary speed is beyond 850 r/min and working temperature is less than 50 □, the grooved tubes are formed with high quality and efficiency. The ball spinning process uses full oil-filling method to set up the steady dynamic oil-film that reduces the drawing force and improves the surface quality of grooved copper tube.**

***Keywords*: ball spinning, micro groove, heat pipe, multi-tooth mandrel**

1. Introduction

Recently, the thermal management of electronic systems has become a key technique in many products. At present, silicon, diamond, copper or other materials with high thermal conductivity are mainly used for producing the radiators for electronic products with high heat flux density. Due to the better thermal conductivity, temperature uniformity and faster response, the copper heat pipes are of broad prospects for application. There are several types of cross-section of grooves inside grooved copper heat pipes, such as triangular, rectangular, trapezoidal, and inverse trapezoidal types, which results in different heat transfer capability. How to produce ideal inner micro grooves is the crucial problem to the copper heat pipes. Ball spinning, a special process to manufacture wall-thinned high-precision tubes with small diameters has been used widely in recent years. In this work, an oil-filled ball spinning process to machine the axially inner micro grooves by extruding the copper tube with fixed multi-tooth mandrel is presented. The effects of the mandrel geometry and spinning process parameters are studied to find out the optimum machining conditions. Compared with the conventional ways of machining micro grooves, such as extruding, mechanical notching and chemical etching, this process is simpler and easier, as well as requires less equipment's.

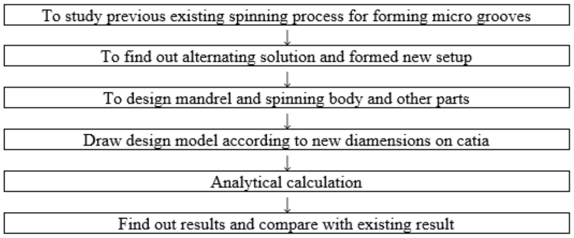
A. Problem statement

Axial grooves are used as one of the types of wicks in heat pipes along with screen mesh and sintered metal powder. The benefit of grooved wicks is that the total manufacturing time of heat pipes is reduced due to reduction in manufacturing steps. Moreover, since the wick is wick is an integral part of the container material, the thermal resistance is lower in grooved heat pipes. Since manufacturing grooves by regular extrusion method requires large order quantities of the same dimensions and for manufacturing heat pipes in smaller quantities and variable diameters, it is required to develop a novel method of producing capillary grooves on heat pipes by a process which is cheaper and does not demand larger quantities.

B. Objective

- The primary objective of the project is to develop a spinning tool which can be used to produce capillary grooves for a heat pipe. The design of the grooves shall be provided by the heat pipe manufacturer as per their heat transfer requirements.
- To design a such a setup to give inner groove heat pipe in minimum cost. Inner groove heat pipe is used in day today life.
- The main aim is to develop a system in which internal grooves heat pipe is manufactured.

2. Methodology



3. Experimental Setup

A fully oil-filled high-speed spinning machine is developed and employed as the experimental setup, as illuminated in Fig.1. This manufacturing process includes extruding and drawing processes. High-speed motor drives the spinning body,

Table 1
Literature review

S. No.	Paper title	Author	Conclusion
1	Fabrication of inner micro grooves Pipes(2008)	Y. Chi R. Du	Depth to width ratio increases significantly
2	Experimental study of oil-filled high-speed spin forming micro-groove fin-inside tubes(2007)	CHI Yong TANG Yong	Improve the stability of spinning and surface quality
3	Influence of drawing process parameters on forming of micro copper tube with straight grooves	TANG Yong OU Dong-sheng	Die angle increases the value of wall thickness decreases as α increases.

which makes steel balls rotate. Meanwhile, the steel balls and multi-tooth mandrel extrude the raw Aluminum tube that is drawn by working workbench in axial direction. During machining process, the multi-tooth mandrel only forms the inner micro-grooves and does not produce any chip, therefore, the mandrel is different from the conventional cutting tools, and can be classified as a forming tool. The fixed multi-tooth mandrel and the spinning balls work together to make the arced teeth of the mandrel split the inner metal of the aluminum tube. With the increase of drawing force and the spinning depth, the deformed metal flows in axial, radial and tangential directions. The plastic deformation in axial direction prolongs the aluminum tube. The plastic deformation in radial direction forms teeth and grooves. Due to the dramatic deformation of the metal, a great deal of heat is produced. To solve this problem, the chamber among radius regulation die, radius reduction die and spinning body is filled with pressured lubrication-oil. Thus, the wall metal of the raw Aluminum tube can be smoothly extruded, prolonged and finally developed into inner grooves and teeth (fins).

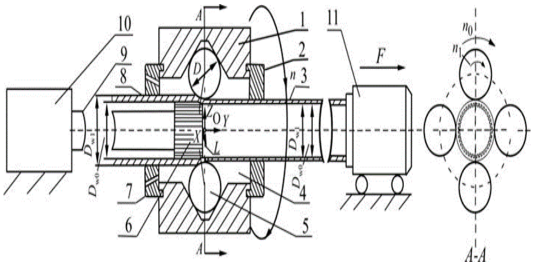


Fig. 1. Schematic diagram of experimental setup of spinning process: Spinning body; 2 Radius regulation die; 3 Axially inner grooved copper tube; 4 Oil-filled chamber; 5 Steelball; 6 Multi-tooth mandrel; 7 Radius reduction die; 8 Raw coppertube; 9 Mandrel shaft; 10 Mandrel fixture; 11 Moving workbench (n Spinning body planetary rotation speed; n_0 Steel ball planetary rotation speed; n_1 Steel ball revolution speed; D_{wl}Outer diameter of raw copper tube; D_{w0} Inner diameter of raw copper tube; D_{dl} Outer diameter of grooved copper tube; D_{d0} Inner diameter of grooved copper tube)

Table 2
Mandrel specification

	GCr15	W18Cr4V
Groove configuration	Longitudinal	Longitudinal
Shape of grooves	Rectangular	Rectangular
Mandrel hardness (HRC)	58-62	58-62
Out diameter (mm)	14.4	14.4
Overall length (mm)	25	25
Width of grooves (mm)	0.5	0.5
Depth of grooves (mm)	0.7	0.7
Teeth (Fin) width (mm)	0.6	0.6
Total number of grooves	30	30

4. Calculations

True Strain:

$$RA = \frac{A_I - A_F}{A_F} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$RA = \frac{18^2 - 16^2}{18^2}$$
$$= 0.2$$
$$= 20\%$$

$$\varepsilon = \ln\left(\frac{1}{1-RA}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\varepsilon = \ln\left(\frac{1}{1-0.2}\right)$$
$$= 0.2231$$

Where,
RA = Reduction in area
A_F *=Final Area of Heat Pipe*
A_I *=initial Area of Heat Pipe*

- Average Flow stress

$$\sigma_0 = \frac{K \times \varepsilon^{n+1}}{n+1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\sigma_0 = \frac{530 \times 0.2231^{0.26+1}}{0.26+1}$$
$$= 63.5352\ {}^{N}\!/_{mm^2}$$

Where,
K=strength coefficient(index)=530MPA
n=strain hardening exponent=0.26

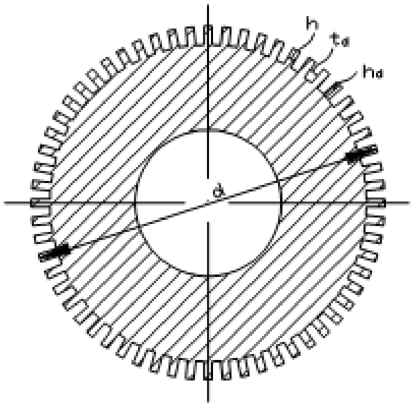


Fig. 2. Cross-section of Mandrel

- Draw Stress

$$\beta = \frac{\mu_1+\mu_2}{\tan\alpha} \qquad \ldots\ldots\ldots\ldots\ldots(4)$$

$$\beta = \frac{0.03+0.03}{\tan 4}$$
$$= 0.85804$$

$$\sigma_{ax} = \sigma_0 \times \left(\frac{1+\beta}{\beta}\right) \times \left[1-\left(\frac{h_a}{h_b}\right)^{\beta}\right] \qquad \ldots\ldots\ldots(5)$$

$$\sigma_{ax}$$
$$= 63.5352 \times \left(\frac{1+0.85804}{0.85804}\right)$$
$$\times \left[1-\left(\frac{1.5}{1}\right)^{0.85804}\right]$$
$$= 57.2476\ {}^{N}\!/_{mm^2}$$

Where ,

$$\mu = \mu_1 + \mu_2$$
$$\mu_1 = \mu_2 = 0.03\mu_1 \& \mu_2$$

α =*cone angle*
h_a =*Initial width of Heat Pipe*
h_b =*Final width of Heat Pipe*

- Draw Force

$$F_d = DrawStress \times A_F \qquad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$
$$= 57.2476 \times \frac{\pi}{4} \times (18^2 - 16^2)$$
$$= 3.057\ KN$$

- Power $= 3.057 \times 10^3 \times 0.5 \times 10^{-3} = 1.5287\ W$

5. Scope for future work

- For manufacturing variable diameter, long length of heat pipe with minimum setup cost.
- Cost of manufacturing internal groove heat pipe is minimized by this setup. And will be use in regular day to day life.
- Internal groove heat pipe requires less maintenance and more durability since it will used in more space applications where replacement is not possible.
- By using this setup, we can obtain more efficiency in less cost instead of regular extrusion process.

6. Summary

At this stage we develop new Experimental setup and from theoretical analysis and we calculate the drawing force and power required to forming axial internal grooves inside heat pipe.

7. Conclusion

This paper represented development of novel spinning process for forming axillary capillary grooves for heat Pipes.

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