

Outside 3D Integral Fin on stainless steel tube forming and Multi-Factor Experimental Analysis

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Abstract. You should leave 8 mm of space above the abstract and 10 mm after the abstract. The heading Abstract should be typed in bold 8,5-point Times. The body of the abstract should be typed in normal 8,5-point Times in a single paragraph, immediately following the heading. The text should be set to 1.15 line spacing. The abstract should be centred across the page, indented 15 mm from the left and right page margins and justified. It should not normally exceed 200 words.

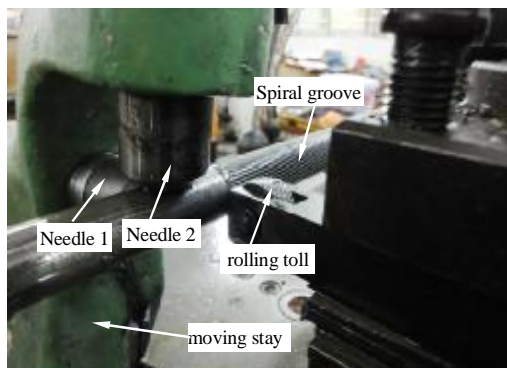
1 Introduction

High efficiency tube and shell heat exchanger has a series of advantages such as simple structure, low cost, easy cleaning, etc., they are widely used in many fields. Extended surface is a kind of heat transfer enhancement structure. The fin tube is a very effective surface heat transfer components of extended surface[1]. Integral fin tube is processed directly from the fin on the tube, and has good heat transfer effect. At present, some scholars did some study and some results were obtained on the manufacture of copper finned tube [2,3].

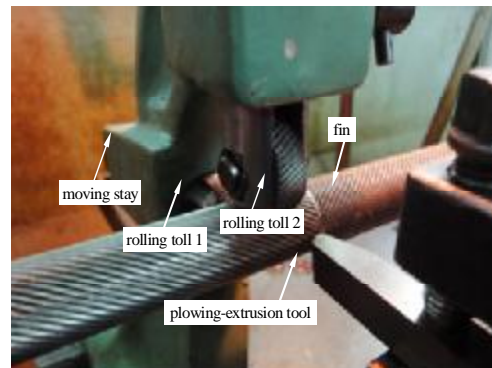
2 Experimental method and steps

The experiments were carried out on the lathe C6132, stainless steel tubes with diameter of 20.0mm and thickness of 2.0mm were used as the workpiece. outside 3D integral fin on stainless steel tube was obtained by rolling/plowing-extrusion compound forming, as shown in Fig.1[4].

Rolling/plowing-extrusion is a complex forming process, Fin height is an important factor that influence finned heat transfer, a lot of factors have influence on the fin height, a lot of parameters influence the fin height. A lot of experiments found several parameters have more influence to the fin height. through the single factor experiment and multi-factor experiment, the fin height of four main affected parameters were analyzed.



(a) Rolling equipment



(b) Plowing-extrusion equipment

Fig.1 Rolling/plowing-extrusion equipment on stainless steel tube

3 Single factor experiments

As shown in fig.2 that the fin height h changes with the plough extrusion depth a_p chart. From the fig.2 can be shown that the fin height h increase with the increase of plowing/extrusions depth a_p . When plowing / extruding depth reaches a certain value, the fin height increasing trend becomes slowed.

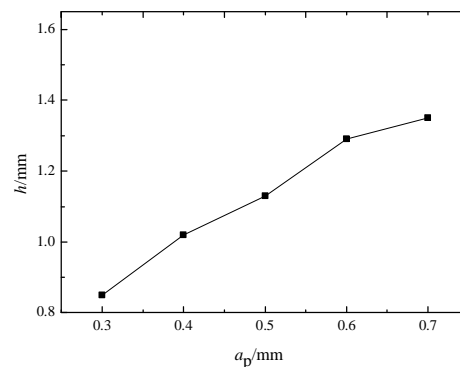


Fig.2 Influence of plowing/extrusion depth on fin height

As shown in fig.3 that the fin height h changes with the plough extrusion feed rate f chart. From the fig.3 can be shown that the fin height h increase with the increase of feed rate f .

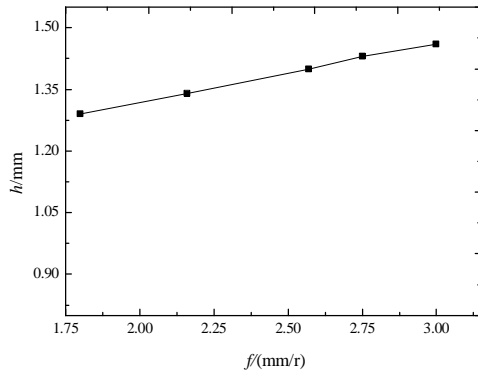


Fig.3 Influence of feed rate on fin height

As shown in fig.4 that the fin height h changes with the main angle K_r chart. From the fig.3 can be shown that the fin height h reduce with the increase of the main angle K_r .

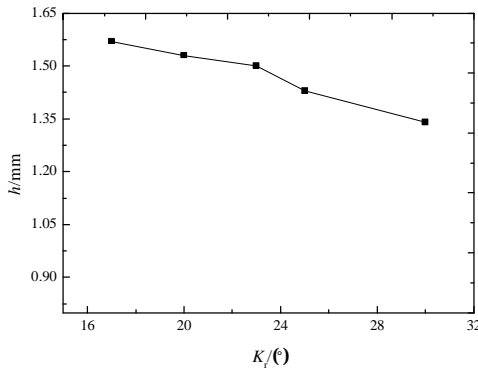


Fig.4 Influence of main angle on fin height

As shown in fig.5 that the fin height h changes with the arc radius of tool tip r_e chart. From the fig.5 can be shown that the fin height h increase with the increase of the arc radius of tool tip r_e .

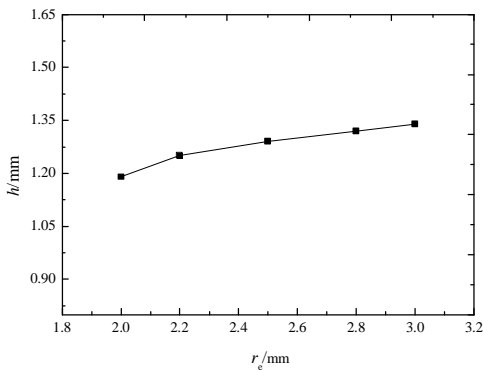


Fig.5 Influence of arc radius of tool tip on fin height

The fin height is an important characteristic parameter three-dimensional outer finned tube, the fin is higher, the heat transfer effect is better, so the fin height has been expect it is higher. The single factor Experimental results were shown that the higher fins are obtained with bigger plowing/extrusion depth, feed rate, arc radius of tool tip and smaller main angle.

4 Multi-factor experiments

Form the single factor experiment, it can only see the effect of various factors on the fin height, but they cannot been seen that fully reflect the various factors on the fin height.

In order to fully analyze the impact of these parameters, they require a lot of experiments to determine. In order to reduce the experiments and improve the accuracy of the prediction model, the need for reasonable experimental program designed to achieve the intended purpose, Multivariate experiments has been carried to achieve this goal.

4. 1 Multi-factor experiment results

Due to the limitation of experimental conditions and some uncertain factors, it is impossible to consider all influence factors. in order to reduce the number of factors to examine, the experiment should omit secondary, unpredictable human factors and equipment factors.

In this experiment, several parameters are analyzed, including: a_p , f , K_r , r_e .the experiment results are shown that in table1.

Poor refers, also known as the range of error or full range is the difference between the maximum and minimum values.it is presented with R. R is the biggest range of symbol value changes, it is the most simple indicator to the determinate value.

In the process of multiple linear regression, according to R, it is determined that the relation of the parameters and the experimental results basing on the range of R.

factors number	a_p	f	r_e	K_r	h
1	0.50	1.80	2.0	20	1.13
2	0.50	2.16	2.5	25	1.15
3	0.50	2.57	3.0	30	1.17
4	0.60	1.80	2.5	30	1.21
5	0.60	2.16	3.0	20	1.34
6	0.60	2.57	2.0	25	1.29
7	0.70	1.80	3.0	25	1.33
8	0.70	2.16	2.0	30	1.32
9	0.70	2.57	2.5	20	1.48
K_1	3.45	3.67	3.74	3.95	
K_2	3.84	3.81	3.84	3.77	
K_3	4.13	3.94	3.84	3.70	
R	0.68	0.27	0.10	0.25	
Influence factors	A>B>D>C				

From the table 1 can be shown that the three dimensional integral fin outside the plough cut/extrusion forming process, There is a sequence of influence factors on the fin height: the plough cut/extrusion depth a_p have the most influence on fin height. The second influence factor is the feeding time f , the third influence factor is the main angle K_r , the last influence factor is the arc radius of tool tip r_e .

4. 2 the establishment of Experience mode

Fin height as the research object, the four influence factors including a_p , f , K_r , r_e . the index relationship is established:

$$h = C_1 a_p^{a_1} f^{a_2} r_e^{a_3} K_r^{a_4} \quad (1)$$

Where C_1 is determined by the workpiece material parameters, and is the Correction parameters ; $a_i (i=1,2,3,4 \text{ are indexes.})$

On both sides of the exponential of type 1:

$$\ln h = \ln C_1 + a_1 \ln a_p + a_2 \ln f + a_3 \ln r_e + a_4 \ln K_r \quad (2)$$

If $M = \ln h$, $N = \ln h$, $P = \ln h$, $C_{01} = C_1$, $C_{02} = C_2$, $C_{03} = C_3$, $x_1 = \ln a_p$, $x_2 = \ln f$, $x_3 = \ln r_e$, $x_4 = \ln K_r$.

$$M = C_{01} + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4 \quad (3)$$

In this paper, the fin height equation is expressed with matrix.

$$M = X b \quad (4)$$

The parameter β is estimated the parameters by using the least square estimation, if b_0 , b_1 , b_2 , b_3 , b_4 are Separately the least squares estimation of a_0 , a_1 , a_2 , a_3 , a_4 , therefore, the regression equation is

$$M = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 \quad (5)$$

Where M is Statistical variables, b_0 , b_1 , b_2 , b_3 , b_4 are regression coefficients.

According to the experimental results and using The formula of 5, The regression coefficient of the fin height can be expressed:

$$b = [2.2155 \quad 0.5233 \quad 0.1587 \quad 0.0933 \quad -0.1521]^T \quad (6)$$

The regression formula of the fin height can be expressed:

$$h = 2.2155 a_p^{0.5233} f^{0.1587} r_e^{0.0933} K_r^{-0.1521} \quad (7)$$

4. 3 the examination of experience mode

The model of formula 7 is established on the basis of assumptions, there is not a theoretical basis for supports, between processing parameters and the fin height whether the relation is existence. The existence of model and the measured data are needed on the relationship between the fitting effects of statistical tests.

(1) The total sum of squares:

$$SS_T = \sum_{i=1}^n (M_i - \bar{M})^2 = 0.1031 \quad (8)$$

(2) Regression sum of squares:

$$SS_R = \sum_{i=1}^n (M_i - \bar{M})^2 = 0.0995 \quad (9)$$

(3) The sum of squared residuals:

$$SS_e = \sum_{i=1}^n (M_i - M_i)^2 = SS_T - SS_R = 0.0036 \quad (10)$$

F test have been proposed by Fisher who is a English statistician, if the accuracy of the two sets of data is a significant difference by Comparing their variance S^2 . F test is a method of hypothesis testing which is used to check the overall variance of two normal random variable, it is often used to check The significance of regression equation. If $H_0: \beta_i = 0 (i=1,2,3,4)$, and the statistic can be computed as follows:

$$F = \frac{SS_R / p}{SS_e / (n - p - 1)} \quad F(p, n - p - 1) \quad (11)$$

Where n is the experimental group number, and this experiment is a 9. P is the number of variables, and this experiment is a 4.

$$MSS_R = SS_R / p = 0.0995 / 4 = 0.0249 \quad (12)$$

$$MSS_e = SS_e / p = 0.0036 / 4 = 0.0009 \quad (13)$$

$$F = MSS_R / MSS_e = 27.67 \quad (14)$$

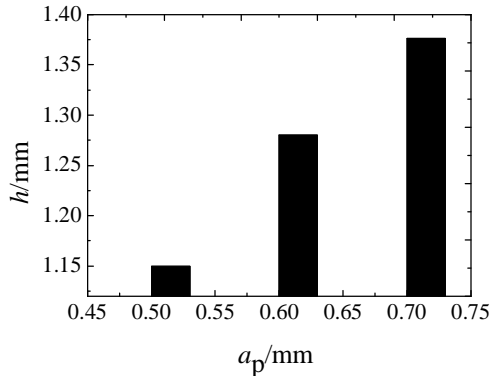
Table 2 analytical experience model of fin height

Sources of variance	SS	fs	MS	F	$F_{0.01(4,4)}$	significance
Return	0.0995	4	0.0249	27.67	15.98	**
Residual	0.0036	4	0.0009			
Sum	0.1031	8				

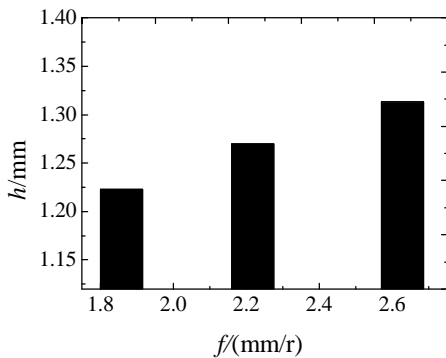
F of table 2 Obey the degrees of freedom ($p, n-p-1$) for distribution. When $\alpha=0.01$, it Meet the situation: $F > F_{0.01(4,4)}$.

4. 4 the analysis of experiment results

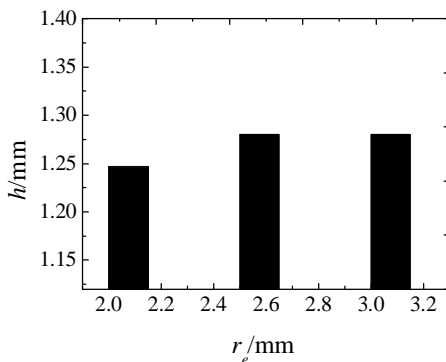
Fig.6 for various factors in the experiment on the relationship between the fin height trend chart. As shown in Fig. 6, A relation was expressed between four factors) a_p, f, K_r, r_ϵ . and fin height h . From fig.6 (a) 、 (b) can be shown that With the increase of the plough /extrusion depth and feed rate ,the fin height increases.



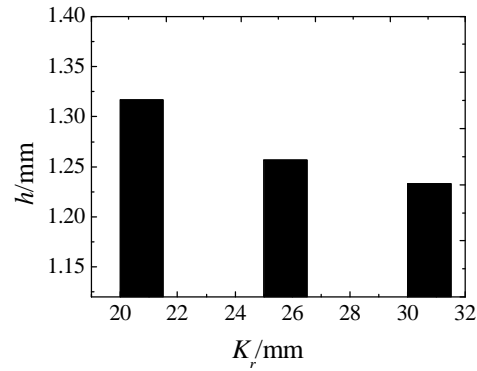
(a) a_p h



(b) f h



(c) r_ϵ h



(d) K_r h

Fig.6 Relation trend between technological parameters and finned height

5.conclusion

In this paper, a method of rolling/plowing-extrusion is presented. Through the method, outside 3D integral fin stainless steel tube is obtained, and according to the single factor experiments. It is shown that with the increase of plowing/extrusions depth, feed rate and arc radius of tool tip ,and the decreases of main angle ,the fin height increases.

According to the multi-factor experiments, the main factors influencing of the fin height is the plowing /extrusion depth, the second influence factor is feeding rate, the third influence factor is the main angle, the last influence factor is arc radius of tool tip.

References

- [1] Li Zhang, Mimi Tian, Jianhua Wu, Heat Transfer Performance of the Shell Side of Double-Pipe Heat Exchanger Enhanced with Helical Fins ,Journal of Chemical Engineering of Chinese Universities, 2011, 25(1): 24~29
- [2] Qilong Yuan, Yan Li, Jianming Zheng. Research on Cutting-press Shaping Process of Fin Tube, Chinese Journal of Mechanical Engineering, 2005, 16(17): 1550-1553 (in Chinese)
- [3] Zhenping Wan, Hui Yan H, Yong Tang. Forming mechanism of integral serrated high fins by plowing-extruding based on variational feed [J]. Transactions of Nonferrous Metals Society of China, 2010, 20(3): 400-404
- [4] Xiaoxia Zhang, Xiuli Qiu. Research on compound forming of outside 3D integral fin on stainless steel tube [J]. applied Mechanics and Materials. 2014, 670-671: 565:568