Effect Of Axial Feed In A T- Shape Tube Hydroforming Process

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Abstract :

Tube hydroforming (THF) is one of the most popular unconventional metal forming processes, which is widely used to form tubular components, in this paper a comparison between finite element method using (ANSYS11.0) program and experimental work were made to show the effect of axial compression feed in a T-shape THF process, in order to prevent excessive thinning from the internal pressure. A good agreement was obtained between experimental and numerical results. In which tube wall thickness will be gradually increase at each increasing axial feed at constant internal pressure, while the maximum stresses will be below the material ultimate stress.

Keywords: the ;FEM; internal pressure; axial feed

تأثير التغذية المحورية لأنبوب بشكل حرف T في عمليه تشكيل الأنابيب بالانتفاخ

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الخلاصة :

عملية التشكيل بالانتفاخ هي واحدة من أكثر عمليات تشكيل المعادن الغير تقليدية انتشارا، والتي تستخدم بصورة موسعة لتشكيل الأنابيب، في هذا البحث مقارنة بين استخدام طريقة العناصر المحددة اعتمادا على اللغة البرمجية المعتمدة في برنامج (ANSYS) مع الجانب العملي لمعرفة تأثير الحمل المحوري لأنابيب شكلت على شكل حرف T لعملية التشكيل بالانتفاخ لمعدن النحاس الملدن (Cu-DHP)، لغرض منع التخصر الشديد الحاصل من الضغط الداخلي. موافقة جيدة تم الحصول عليها بين النتائج العملية والنظرية. سمك جدار الأنبوب يزداد تدريجيا عند كل زيادة للحمل المحوري في حالة ثبوت الضغط الداخلي، بينما الاجهادت القصوى سوف تكون اقل من أعلى إجهاد للمعدن.

Introduction:

Hydro forming processes have become popular in recent years, due to the increasing demands for lightweight parts in various fields, such as bicycle, automotive, aircraft and aerospace industries. This Technology is relatively new as compared with rolling, forging or stamping, therefore there is not much knowledge available for the product or process designers [1].Tube hydroforming (THF) is a metal-forming process in which a tube is plastically expanded into a die cavity by the simultaneous action of fluid pressure and axial material feed, such that the tube takes the shape of the die cavity. The advantages of the hydroforming over the traditional process are: (a) light weight constructions; (b) design flexibility increase, enable new shapes; (c) stiffness increase by using no welded tubular blanks; (d) welded assembly elimination; (e) dimensional accuracy. Success of THF depends on various process and material parameters. The two most important process parameters are internal pressure given to the tube and axial material feed applied to the ends of the tube. [2] So far, many investigations on tube hydroforming have been carried out; Muammer Koc et al. [1]used the finite element analysis and design of experiments to establish design guidelines for simple hydroformed parts. M. Hashmi et al. [2] had done studies in tube hydroforming process involving combined (axial feed and internal pressure) and multi stage non-linear loading action theoretically and experimentally for a multi layered tubular blank placed in a pre-shaped die block.

M. Imaninejad et al. [3] had done research to optimize methods along with finite element simulations to determine the optimum loading paths for closed-die and T-joint tube hydroforming processes, to produce a part with minimum thickness variation while keeping the maximum effective stress below the material ultimate stress during the forming process.

P. Ray et al. [4]used X- and T-branch components in a tube hydroforming machine and experimental load paths (forming pressure and axial feed) were obtained for the processes via a data acquisition system integrated with the machine. Subsequently, the processes were simulated using LS-DYNA3D explicit FEcode using the same experimental boundary, loading conditions and the simulation results were compared with the experimental results.

S.Y. Ahmadi et al. [5] used finite element modeling along with statistical method for design of experiment T-shape tube hydroforming process to construct a model for wall thickness variation and bulge high as a function of pressure displacement curve.

Mehran Kadkhodayan et. al.[6] optimized the loading path in T-shape THF was investigated using a set of experimental data to assess the influence of loading process parameters in hydroformed geometry, all cases were simulated by using FEM and the desired outputs contain the minimum thickness and maximum height of protrusion were calculated.

This paper present a finite element modeling (FEM) to produce a T- shape tube hydroforming to study the effect of axial compressive feed on material formability, and compare the result obtained with experimental investigation.

1. Tube hydroforming sequence:

The principle of tube hydro-forming is shown in **Figure.(1)** . The tube is first filled with a fluid, after which the tool is closed. The tube is then forced to adopt the inner cavity of the tool by application of an internal pressure and axial forces. In some cases, the tube is formed by the increasing internal pressure only. This means that the axial cylinders do not feed more material into the expansion zone. There are also cases in which the axial cylinders push more material into the expansion zone. In these cases, the tube is formed under the simultaneous action of the internal pressure and the axial forces. [7]

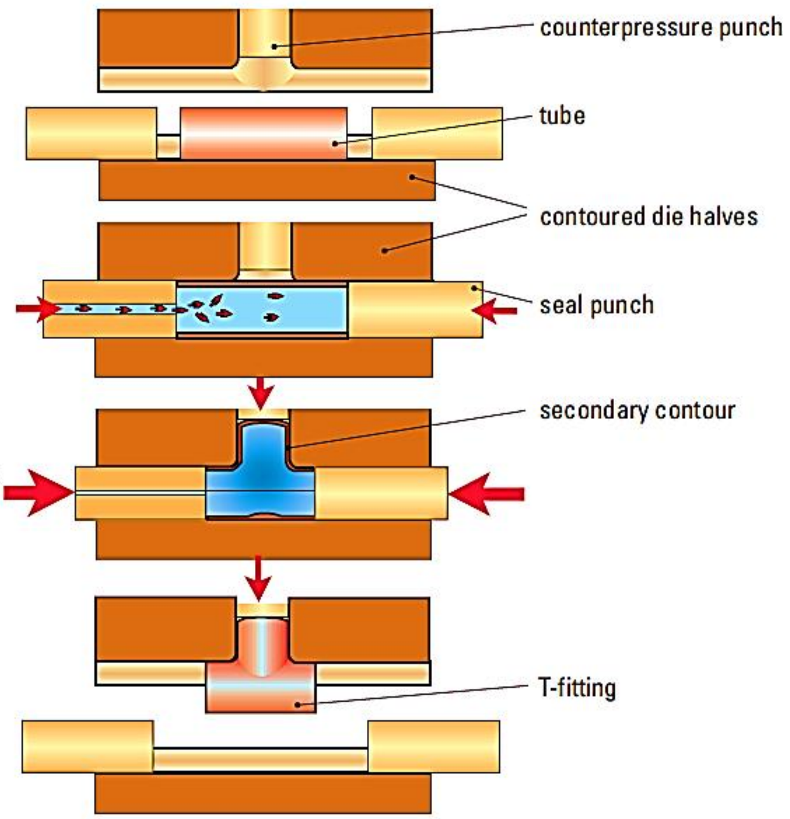

Fig. (1) tube hydroforming sequence [7]

2. Finite element modeling (FEM):

Finite element Analysis (FEA) has been used for years by the metal forming industry. Three dimensional simulations give more accurate results, but two dimensional simulations are simple to use and effective in producing accurateresults for basic simulations. Recently two dimensional simulations have been used in predicting the forming characteristics in the THF process [8].

This study focuses on a T-shape tube hydroforming, Both die and axial punch are assumed as rigid bodies in the simulations, numerical analysis was conducted using the explicit finite element code ANSYS11. PLANE42 is used for 2D modeling of solid structure. One-two model of the whole geometry consisting of the tube and the dies was adopted in consideration for symmetric property of the tube deformation **Figure (2).** The model of metal tube is assumed as nonlinear, inelastic, isotropic, bilinear model. The effects of friction, geometric parameters; tube thickness, tube length , die corner radius and diameter of bulge width and varying internal pressures only and with axial load were input data in tube hydroforming.

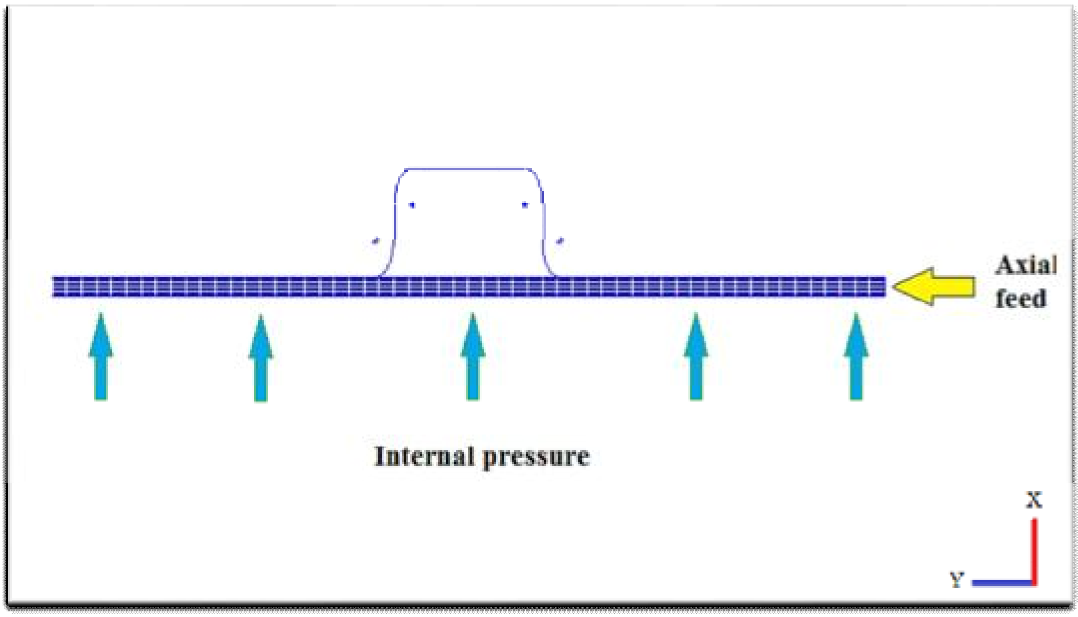

Fig. (2) axisymmetric finite element modeling for T- shape tube hydroforming (THF) and the direction of boundary condition

3. Experimental setup:

The material used in this research was annealed Copper (Cu-DHP), its chemical composition shown in **Table (1)** according to ASTM commercial standards. And **Table (2)** shows the material properties obtained from tensile test.

Table (1) chemical composition for annealed copper tube

Sample	Zn%	Pb%	Sn%	P%	Fe%	Cr%	Al%	S%	Cu%
Cu tube	0.021	0.002	0.002	0.031	0.020	0.000	0.004	0.001	99.9

Table (2) material properties for annealed copper tube

Annealed copper	Young modulus (Gpa)	Tangent modulus (Mpa)	Ultimate Stress (Mpa)	Poisson ratio	Friction coefficient	Ultimate tensile stress (Mpa)
	124	800	354	0.34	0.15	354

Copper tube has the following dimensions, (140 mm) tube length, (25.4mm) outside diameter, and (1.6mm) tube thickness. To validate the above simulation results, closed-die experiments were performed to deform the tube. Prior to the experimental testing, a series of FEA simulations were performed to get the initial condition (internal pressure and axial feed), these result were used for experimental testing.A symmetric T-shape tube hydroforming die was design using AutoCAD program, and manufactured by using low carbon steel material in overall dimensions of (210× 120 × 60mm), and (25 mm) protrusion diameter as shown in **Figure (3)** and **Figure (4).** It was designed to resist high internal pressure necessary for the forming operation, the die consists of two parts assembled together.

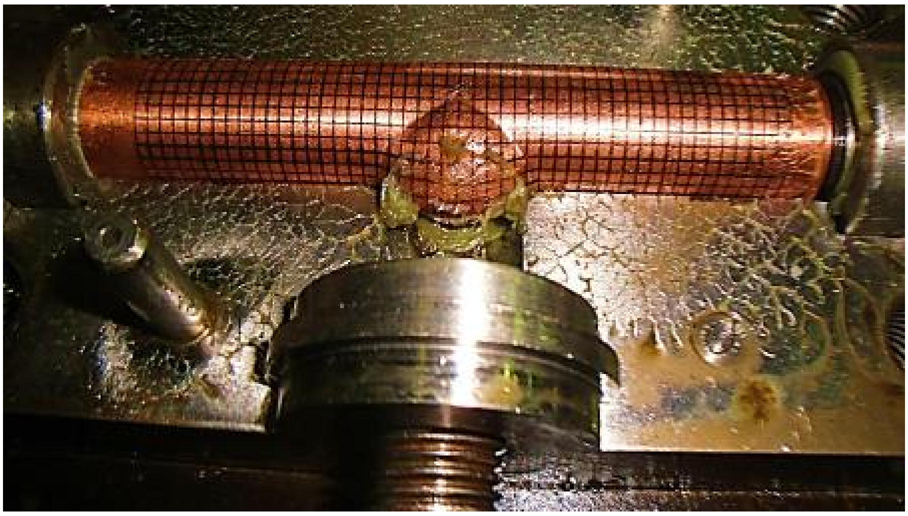

Fig. (3) final T-branch height without experiencing any failure.

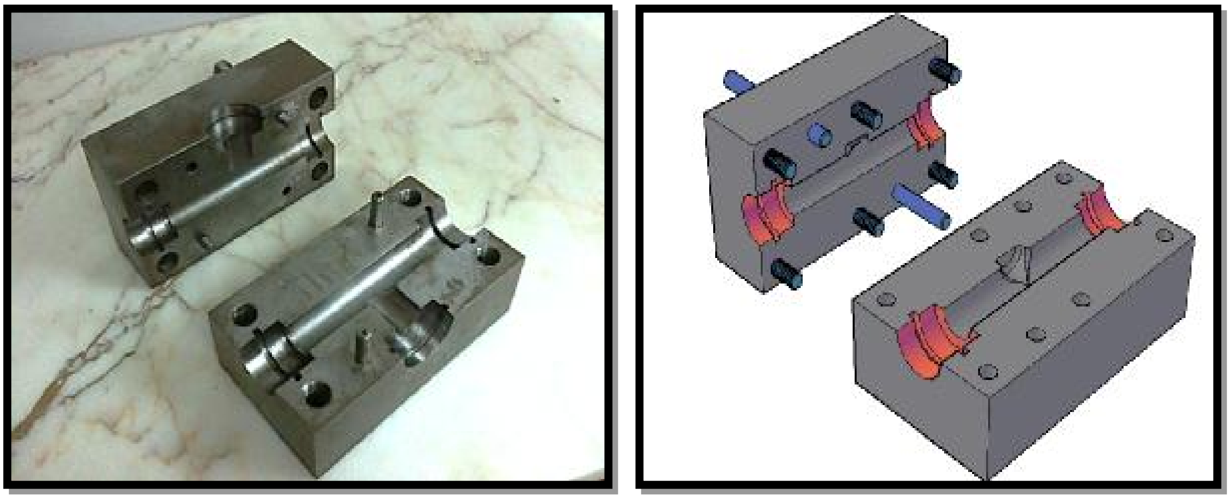

Fig. (4) T- shape die used in experimental and design in AutoCAD program

A car jag of (50 ton) is redesign to pump high fluid pressure to the internal forming operation **Figure (5-A),** the piston of this jack is pressed by hydraulic press name (every), it's a tension compression device with total capacity of (250 ton) as shown in **Figure (5-B),** the primary function of this device is to press the piston of hydraulic jack with a speed of (10 mm/min).

A B

Figure (5) A- Hydraulic pump (car jag), B- Hydraulic press

Axial feed was varied in seven tests from (1-7mm), to show how the thickness of the tube mat rial increasing gradually at each increasing of axial feed, especially in the bulge area (forming zone), and compare the result with the tube have same amount of internal pressure (400 bars) but with no axial feeding (A.F=zero). In addition to increase tube wall thickness, the tube length decrease at each increasing in axial compression feeding as shown in **Figure (5).**

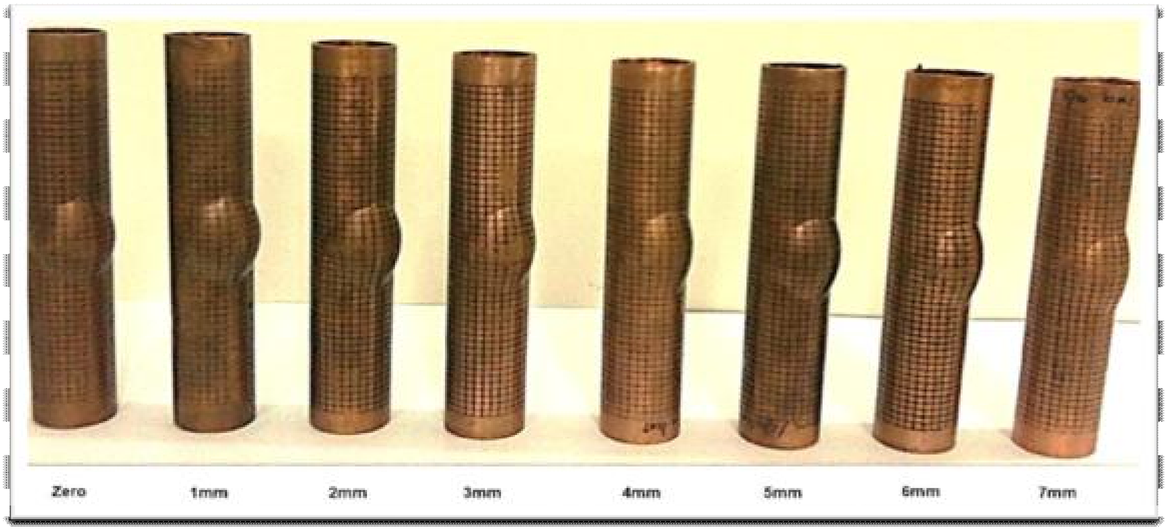

Fig. (5) T- shape tube hydroforming from (0 to 7mm) axial force at (400 bar) internal pressure for annealed copper.

The formed tubes then will be cut along the axial direction to get the thickness distribution along the tube, as shown in **Figure (6).**

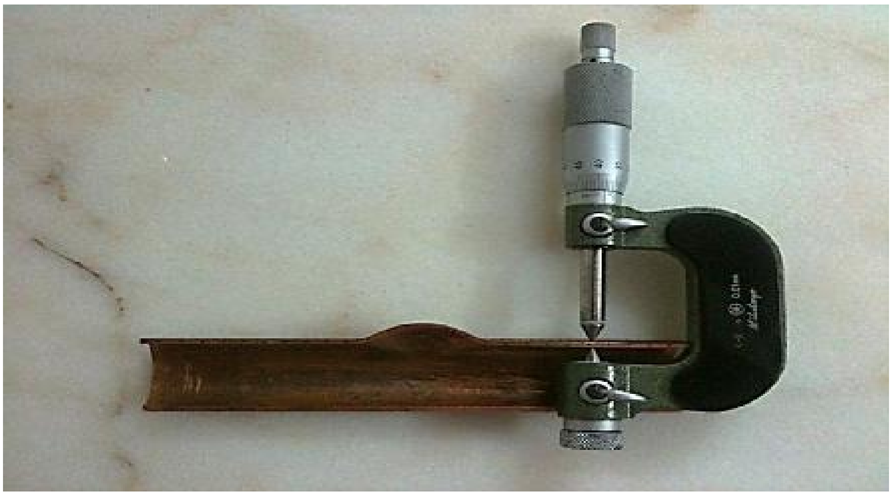

Fig. (6) tube cut along axial direction

4. Results:

Eight different tests was made in experimental work and compared the result obtained with numerical simulation result using (ANSYS 11.0 PROGRAM) in different amount of axial compressive feed starting from (0 to 7mm) at constant internal pressure (400 bars), these increasing in the axial feeding causes an increase in tube wall thickness, especially in the bulge area**, Table (3)** showing the thickness variation in the apex point for each tube and the percentage of error between experimental and numerical result. It can be concluded that the tube material will be able to withstand high internal pressure since axial feeding reduces the danger of thinning and bursting. Also the maximum stress for each tube will be decrease gradually at each increase in material axial feed and kept below the ultimate tensile stress for tube material (annealed copper) as shown in **Figure (8)** Von Mises (stress – strain) at each axial feeding.

Table (3) Thickness variation in the apex point of tube

Material type	Axial feed(mm)	Apex in Experimental test (mm)	Apex in Numerical test (mm)	Percentage of error %
annealed Copper	Zero	1.31	1.152	13.7
	1	1.33	1.189	11.8
	2	1.255	1.221	2.7
	3	1.46	1.274	14.5
	4	1.41	1.31	7.6
	5	1.275	1.353	5.7
	6	1.45	1.395	3.9
	7	1.48	1.449	2.1

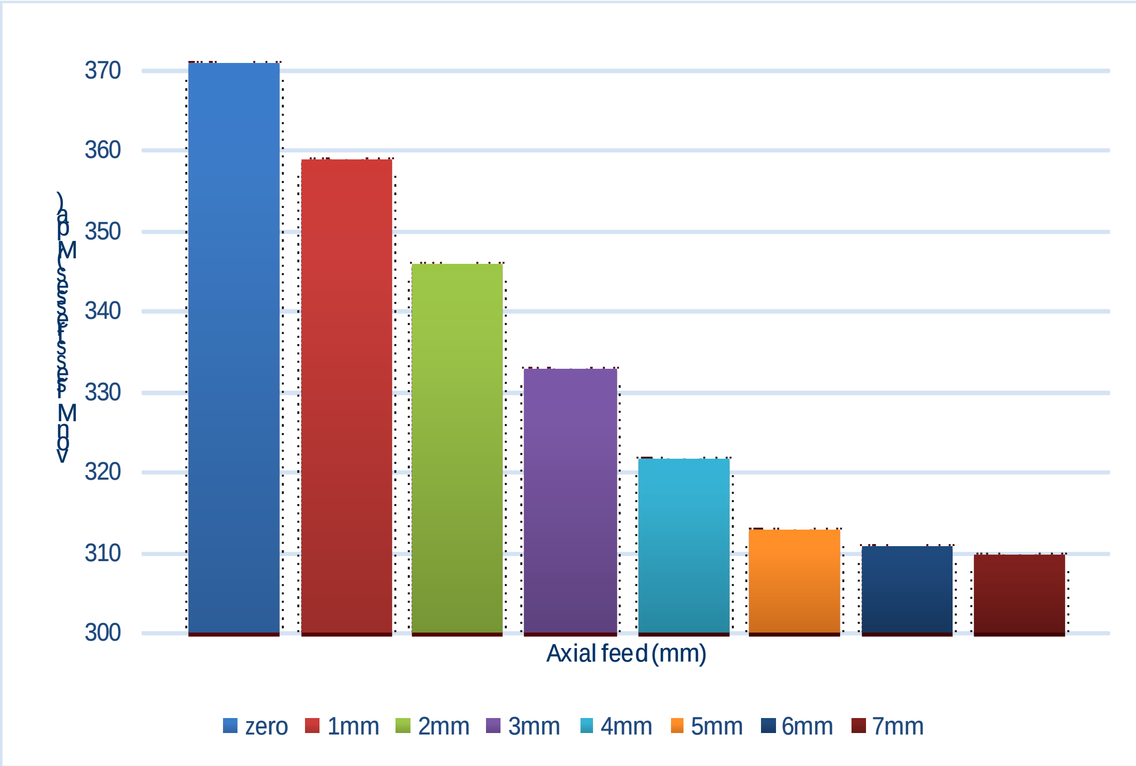

Fig.(8) maximum Von Mises stress for each axial feed at constant internal pressure (400 bars) for annealed Copper tubes

5. Conclusion:

- Tube wall thickness increase at each increasing in axial compressive feed, therefore, axial feeding reduces the danger of thinning and bursting, in addition, thickness distribution becomes more uniform.
- Maximum stresses are reduced when applying the axial compressive feed, keeping the tube material below the ultimate tensile stress now one can apply more internal pressure before the material start thinning, and hence improving its formability.
- The experimental results of wall thickness distribution along tube length validate the numerical simulations reasonably well.

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