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Experimental and Numerical Investigation of the Shearing Process Square Tube Steel

Thanh Tan Nguyen, Long Nhut-Phi Nguyen, Van Huong Hoang, Dai Gia Ton, Dai Nghia Vu, Hoang Tan Nguyen, Hong Tan Bui
Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology and Education (HCMUTE), Ho Chi Minh City, Viet Nam, 71307
Email address: tannt@hcmute.edu.vn, trontv@hcmute.edu.vn, longnnp@hcmute.edu.vn, 18143224@student.hcmute.edu.vn, 18143283@student.hcmute.edu.vn, 16144376@student.hcmute.edu.vn, 18143149@student.hcmute.edu.vn

Abstract— *Metal forming is not only used for sheet metal but also applied to tube metal. Many recent studies have shown that the parameters such as clearance, velocity cutting, blank force holder, the radius of punch and die, and friction constant have been optimized in sheet metal forming. However, the processing parameters in manufacturing square tubes are still being studied, and not many results are found in the literature. In this paper, the clearance between punch and die in forming square tube steel is computationally simulated and experimentally analyzed. The shearing punch is made of SKD11 cold-work tool steel. Simulations and experiments are carried out for tube steel with the thickness of 1.2, 1.4, 1.8, and 2 mm in 0.16 mm die clearance. The effect of clearance, dimension cross-section, and length of materials on the burr height is presented. The obtained results provide rational parameters for shearing blades working in particular conditions.*

Keywords— *Sheet metal, shearing, square tube steel, burr height, clearance.*

I. INTRODUCTION

Sheet metal working includes shearing and forming operations performed on relatively sheets of metal. Cutting of metal is accomplished by a shearing action between two sharp cutting edges. The cutting action is described in three-step actions such as plastic deformation, penetration, and fracture. In the final step, if the clearance between punch and die is suitable, the two fault lines meet, resulting in the complete separation of the work into two pieces [1]. The advantages of method shearing are a straighter edge and no material loss than traditional removal and torch cutting. However, the parameters cutting process needs to optimization to high quality. Some research involving burr height [2-5], clearance [2,6,7], cutting force [7,8], material [3,9], and tool life [4,9-10] for sheet metal forming were studied.

Various new demands in manufacturing include mechanical engineering, automobile industries, house accessories, frame structure, etc. Metal forming is not only used in sheet metal but also applied in tube metal. In the last few years, some studies have been carried out on the forming and fracture of metal tubes, such as the bending of circular tubes on a small bending radius [11], the effects of the initial thickness on the shear bending of circular tubes [12], the effect of pushing force on the shear bending process of circular [13], the effect of thickness on the shear bending process [14] shearing process of thin-walled metal tubes [15], hydro-forming square tubes with small bending radius [16], wrinkling in electromagnetic tube compression [17]. However, there are few studies involving the fracture experiment during the shearing process of square tubes. Moreover, there are still no clearance or cutting force theories to predict the shearing process of square tubes accurately. Experimental studies on the mechanical properties of shear square section steel tubes for building dampers have been studied [18].

The complex stress distribution is achieved during shearing due to the pressure on the shearing edge of the punch and the die. Depending on the process parameter, different product geometry, burr height, and tool life can be obtained at the end of the deformation of the material. The changes in the cutting square tube steel were not studied in the abovementioned manuscripts. The material area at the intersection surface, the quality of surface finish, the burr height, and tool life were important issues. The shearing of square tube steel parts is not well researched and described.

The paper presents the research results on the influence of different thicknesses, dimension cross-sections, and lengths of material on the geometrical quality of the tube steel during partial shearing with square tube steel in a die without a mandrel. The influence of clearance on the change of burr height and material deformation, made of square tube steel instead of sheet metal, was discussed.

II. MATERIALS AND METHODS

A. Material

Square tube steel is purchased from Hoa Phat steel company, Viet Nam. Table 1 shows its chemical compositions of the steel ASTM A53, and Table 2 shows its mechanical properties after heat treatment.

TABLE I. The chemical composition of the steel ASTM A53

Element	C	Mn	P	S	Ni	Cr	Mo
wt.%	0.3	1.2	0.05	0.045	0.4	0.4	0.15

TABLE II. Material properties of material ASTM A53

Mechanical Properties	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
ASTM A53	250	350	28

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B. *Press machine*

Profi Hydraulic Press C-Frame PPCM-50 from the Netherlands is used. With features are shown in Table 3.

TABLE III. Feature of machine

Name	Unit	Value
Force	ton	50
Working speed	mm/s	6,3
Approaching speed	mm/s	30
Return speed	mm/s	42

C. *Die*

The shearing process was carried out with cutting angle 120° and 5 mm thickness, SKD11 tool steel (60-62 HRC) for punch and SKD11 tool steel (58-60 HRC) for die, 0.16 for clearance. The important dimensions of the shearing punch and die are presented in Fig. 1.

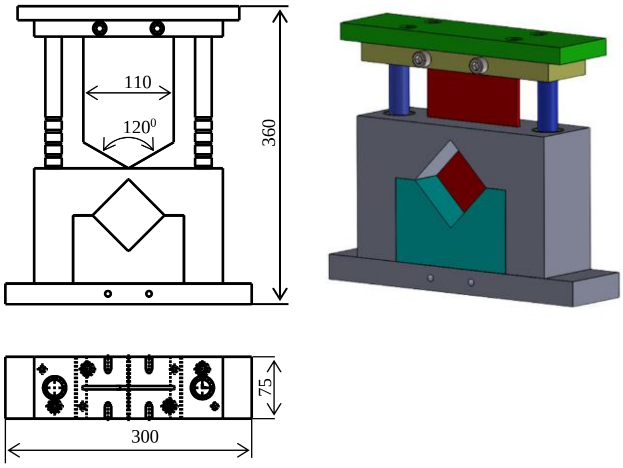

Fig. 1. Shearing die

D. *Method*

First, simulation was performed using Deform software with parameters such as 5 mm in punch thickness, 120° for angle cutting, rigid material for die, 1.16 mm in clearance, and 0.12 for friction coefficient (Fig. 2). Then the experiment was conducted in the laboratory.

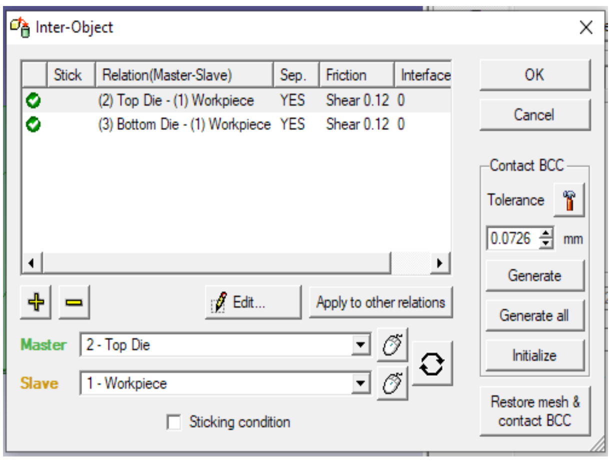

Fig. 2. Simulation parameter

During the tests, the punch movement rate was set as 6,6 mm/s. The machine with the die is showed in Fig. 3. The results were collected and evaluated in the experiments.

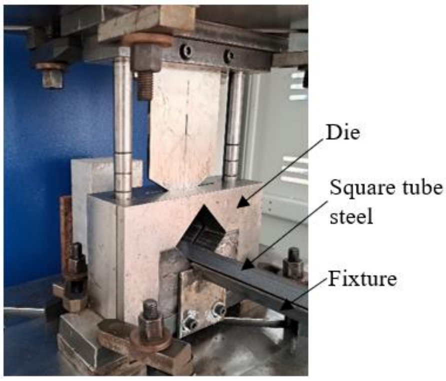

Fig. 3. Die and test sample

III. Results and Discussion

A. *The effect of clearance on burr height in shearing square tube steel*

The clearance between the punch and the die is an important parameter in the shearing and forming process. The clearance mainly affects the shearing load and the quality of the surface. In this study, CAE simulations and experiments of the shearing process were operated with thicknesses between 1,2 mm (13.5%.t) and 2 mm (8%.t).

The simulated cutting force indicated that an increase in the thickness of material from 1.2 mm to 2 mm led to an increase in stress from 1317 MPa to 1797 MPa (Fig. 4 and table 4).

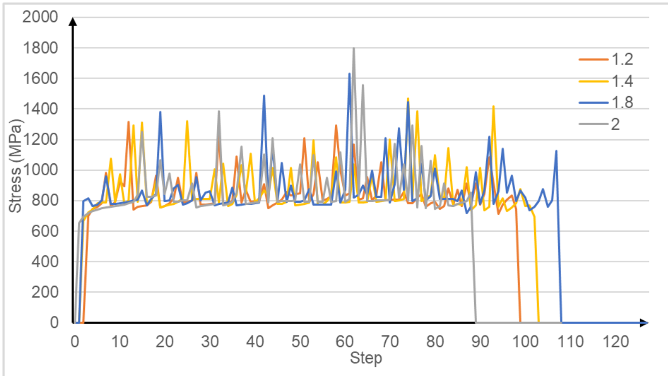

Fig. 4. Stress with difference thickness

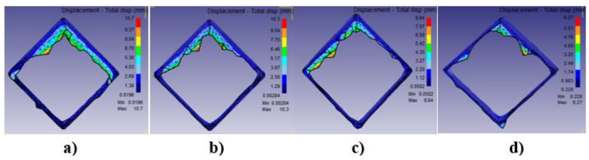

Fig. 5. Simulation result with difference thickness
a) 1.2 mm, b) 1.4 mm, c) 1.8 mm, d) 2.0 mm

TABLE IV. Stress and burr height with difference thickness

Thickness (mm)	Burr height max (mm)	Stress (MPa)
1.2	2.33	1317
1.4	1.94	1469
1.8	1.18	1631
2.0	0.79	1797

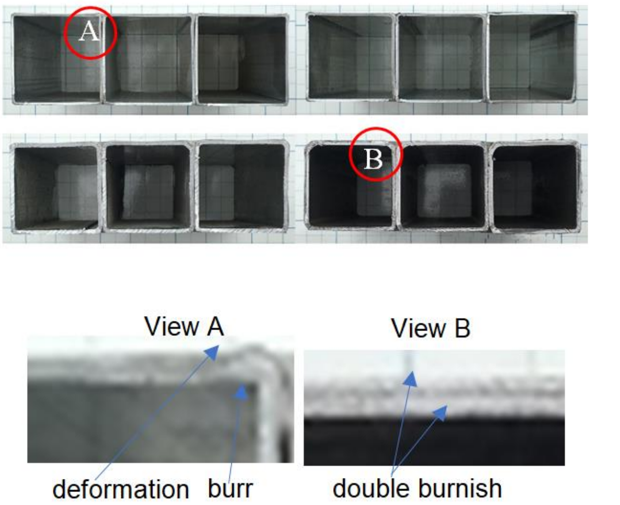

Fig. 6. Surface finish cutting with 40 × 40 (mm × mm) steel a) 1.18 mm, b) 1.36 mm, c) 1.8 mm, d) 2.0 mm

TABLE V. Burr height with difference thickness

Thickness (mm)	Burr height (mm)			
	Sample I	Sample II	Sample III	Average
1.18	1.48	1.43	1.45	0.27
1.36	1.59	1.60	1.64	0.25
1.80	2.08	2.00	1.96	0.21
2.00	2.20	2.14	2.17	0.17

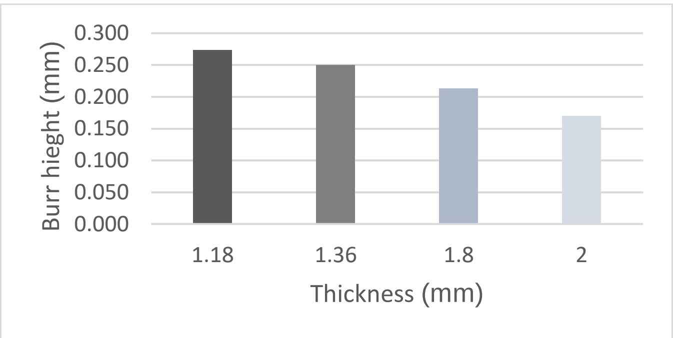

Fig. 7. Burr height with difference thickness

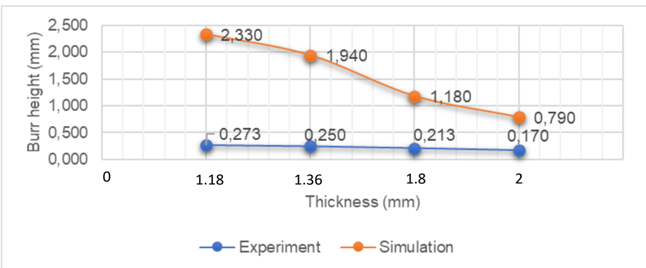

Fig. 8. Experiment and simulations

If the clearance is too tight, the fracture lines tend to through each other. It causes double burnishing and requires larger cutting forces. If the clearance is too loose, the metal becomes pressurized between the punch and die, and it causes excessive burr height. In special operations requiring optimal clearance and tool life, clearance is from 9% to 11% of raw thickness material in Fig. 5-6.

It can be known that the burr height in the simulation is similar to that in the shearing experiment. The burr height of the simulated results is a little larger than the experimental results (Fig.7), but they decrease during thickness increase, as illustrated in Fig. 8. The main reason is that the wall thickness of the shear zone may be thinner than the simulated standard value due to manufacturing error. Thus, larger deformation is reasonable for the burr height. Experiments show that with increased material thickness, burr height decreases (0.273/1.18 mm to 0.170/2 mm). Since the thickness of the material is large, the clearance is tight. Thus, the moment appearance is small (Fig. 9). The thinner the material wall is, the more distorted the square tube is.

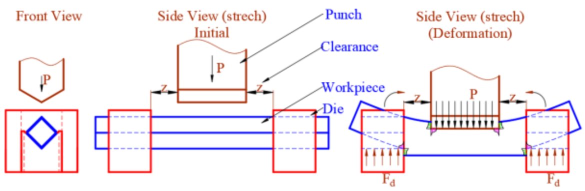

Fig. 9. Schematic diagram of shearing square section tube steel

B. The effect of dimension tube steel on cutting ability

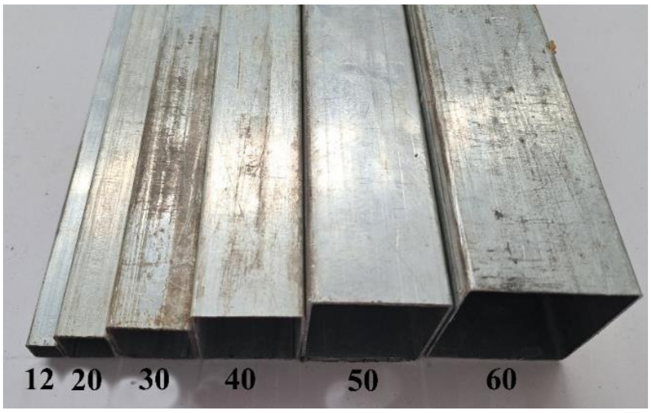

Fig. 10. Dimension of square tube type

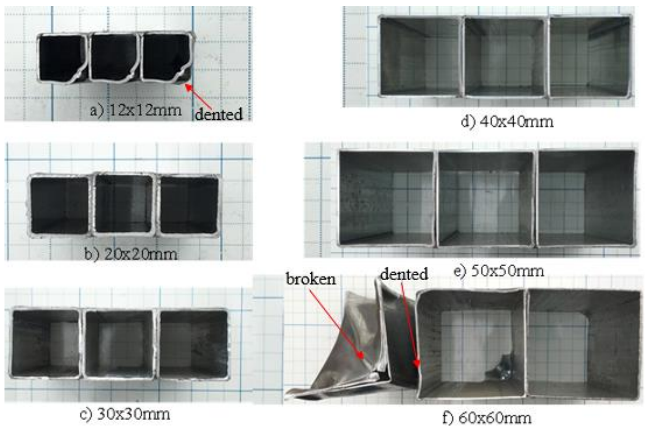

Fig. 11. Surface finish with various dimensions

With cross-section dimension as 12 × 12, 20 × 20, 30 × 30, 40 × 40, 50 × 50, 60 × 60 (width × height (mm × mm)), 1.2 mm thickness material in 0.16 mm die clearance. Experiments show that good quality cutting is from 20 × 20 to 50 × 50 (mm × mm) (Fig. 11b-e). Lower 20 × 20 (mm × mm) section dimension with

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dented in the corner (Fig. 11a) and upper 60 × 60 mm withstand more deformation (Fig. 11f).

C. The effect of cutting length on shearing ability

The experiment shows that the upper 20 mm length is better for shearing (Fig.12). The smaller 20 mm length is easy to dent because the workpiece tends to be pulled down in die without a blank-holder (Fig. 9). A mandrel is placed inside the square tube can prevent collapsing [19], but it needs more equipment.

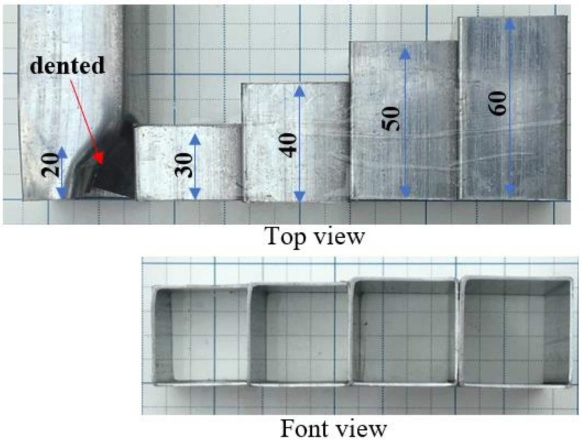

Fig. 12. Surface finish with various length

IV. Conclusion

In this study, the relationship between material thickness, clearance, cutting length, and quality surface of square tube steel was examined by the experiment and simulation. The square tube was cut in the die without a mandrel. The big collapse problem in shearing square tube steel was solved. The following results were found:

- When the clearance decreased, the burr height decreased, and the quality of the cutting edge improved. But the cutting force and the punching pressure were larger; thus, the tool life was shorter. Therefore, for cutting edge quality and tool life, it was recommended that the thickness of workpieces was less than 1.8 mm, with a clearance of 0.16 mm (~8.8% of the thickness material).

- With 1.2 mm of thickness, the cross-section from 20 × 20 (mm × mm) to 50 × 50 (mm × mm) was suitable for surface finish.

- With 1.2 mm of thickness, 40 × 40 (mm × mm) in cross-section, upper 20 mm length cutting was the best for shearing.

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