

End Formation of a Round Tube into a Square Section with Reduced Forming Loads

Chin Joo Tan^{1, 2, a}

¹Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia.

²Centre of Advanced Manufacturing and Material Processing (AMMP Centre), Level 8, Engineering Tower, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

^atancj1@yahoo.com / tancj@um.edu.my

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Abstract. Low formation loads are desirable in metal stamping industries as it reduces the press capacity of the machine and the tooling cost. In the previous study, the author had successfully developed a 2-stage end formation process of a round tube into a square section having small corner radii. However, the formation load in this process increased linearly with the punch stroke in the 1st stage due to the continuous expansion of the tube end by the conical die. Hence, buckling and cracks occurred at the circular section and the bottom end of the square section respectively when the punch stroke was excessive. In this study, the author proposes a circular die having a conical bottom replacing the conical die for the expansion of the tube end. Although the formation load increases when the tube end is expanded at the conical bottom, the amount of increase becomes small when the tube end reaches the circular section of the die due to its constant diameter. At the circular section, the tube end curls and wraps over the die when the punch stroke is increased. In the 2nd stage, the squaring process is performed with a conical bottom square punch and a taper square die for the two different expanded tubes i.e. the one formed with the conical die and the one formed with the conical bottom circular die. Both Finite Element Method (FEM) simulation and experiment were performed to evaluate these two processes. The distribution of plastic strains, forming loads and product appearances are investigated. With the circular die, the maximum forming loads are successfully reduced by 20% and 33% in the 1st and the 2nd stages respectively in the experiment when compared to the ones formed with the conical die. No buckling and cracks are observed for the tube formed with the circular die.

Introduction

In past years, the plastic shaping of a round tube into a square section had been reported by many researchers. Alves et al. expanded the tube end with a square punch [1]. Local thinning and cracks of tube occurred around the punch corners due to stretching. The author developed a 2-stage end formation process of a round tube into a square section having small corner radii with an improved square look [2]. Although the square section's height increased when the punch stroke in the 1st stage is increased, the formation load increased linearly with the punch stroke due to the continuous expansion of the tube end with a conical die. Necking and cracks occurring at the bottom end of the square sections due to excessive punch stroke in the 1st stage had limited the increase in height of the square section.

In this study, a 2-stage end formation process of a round tube into a square section with low formation load is proposed. In the 1st stage, a conical bottom circular die is employed to expand the tube end to a diameter slightly larger than the diagonal length of the target square. In the 2nd stage, a conical bottom square punch holds and pushed the expanded conical tube end through a taper square die to form a square section.

Experimental procedures

The comparison of the detailed forming conditions in the 1st stage of the end forming process between the conical die [2] and the conical bottom circular die is shown in Fig. 1. API seamless tubes measuring an outer diameter of 48mm and an initial wall thickness of 3.5mm are expanded with the