Numerical analysis of cold extrusion of tubes using CAx system

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ABSTRACT

This paper presents a numerical analysis of the cold extrusion of pipes with the use of DEFORM 3D software. As a result, a CAE system was obtained with the help of CAD, and diagrams of the effective stress distribution are presented. Additionally, some aspects of the quality of the final product were discussed.

Keywords: cold extrusion, tubes, friction, effective stress distribution

1. Introduction

CAx (CAD/CAM/CAE) tools are widely used in engineering fields (Łukaszewicz et al., 2018; Łukaszewicz et al. 2021). The main advantage of using CAx systems is the shortening of a product's time development. The ability to perform many types of CAE analyses (Mircheski et al. 2019; Sidun, Łukaszewicz 2017), visualizations, and technical documentations in the design phase allows us to better fit the assumptions.

Cold extrusion is defined as a compressive forming process (push-through) in which the source material is a billet (slug); the process is carried out at room temperature. The basics of cold-extrusion processes are described in Filice et al. (2008) and Stepanenko et al. (1987).

The design and manufacture of dies must be obtained by modern manufacturing methods from the appropriate die materials to ensure an acceptable die life at a reasonable cost (Dieter et al. 2003). Detailed knowledge about the process will help streamline die production processes (Hrycaj et al. 1991; Nine 1982; Oden, Pires 1983).

The friction factor μ in non-lubricated hot extrusion has a fixed value of $\mu = 1$. In lubricated hot extrusion, $0.1 \leq \mu \leq 0.4$, with an estimated average μ value of about 0.25 (Webster, Davis 1982).

Flow stress is a function of the temperature, strain, strain rate, and structure. Thus, a calculated flow stress value can be used for estimating the extrusion pressures for other extrusion ratios and shapes (Bhattacharyya et al. 1982). The possible loads are influenced by the different process variables (Dieter et al. 2003; Oden, Pires 1983) as well.

2. Die design in CAx systems

The objectives of applying CAE techniques to extrusion have been explained in several papers (Abou-El-Lail Mohsen, Farag Mahmound 1981; Bhattacharyya et al. 1982; Dieter et al. 2003; Hrycaj et al. 1991). The model of our die was created using the Deform 3D CAD/CAE system (Fig. 1).

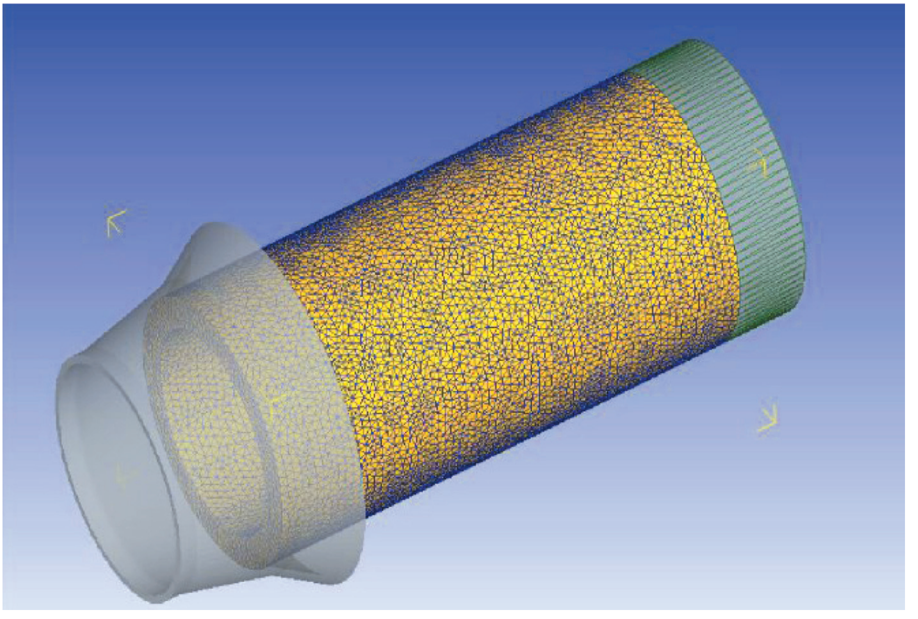

Fig. 1. Die, workpiece (tube), and punch designed in CAD/CAE system

The mesh of this model is available within this system. In the same way, the mesh of a workpiece (e.g., tube) was obtained in works (Abou-El-Lail Mohsen, Farag Mahmound 1981; Oden, Pires 1983).

3. Preparing simulation

Before commencing the simulation of the extrusion process, a number of conditions needed to be fulfilled. It was necessary to check whether all of the required files and dates were available (Altan et al. 2004; Samper, Felder 1990).

The model of the workpiece (i.e., tube) contained the following data:

- density: 7.8 e–09 kg/mm^3,
- Young's modulus: 2.1 e+05 MPa,
- Poisson ratio: 0.3,
- thickness: 4 mm.

The hardening curve of the tube material is described as a function of the stress and plastic strain:

$$\sigma_p = 976 \cdot (\varepsilon_p + 0.2)^{0.14} \tag{1}$$

The punch data was comprised of the following information:

- density: 7800 kg/m^3,
- Young's modulus: 2.1 e+05 MPa,
- Poisson ratio: 0.3,
- velocity of punch: 10 m/s.

The specified dimensions of the die and workpiece are presented in Figure 2.

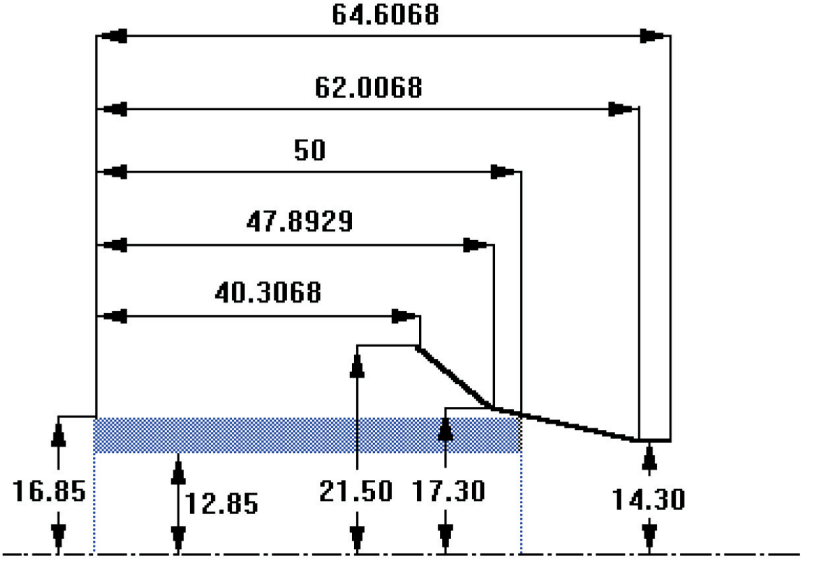

Fig. 2. Geometry of tool and workpiece

4. Discussion of results

The computer simulation of the tube extrusion considered three cases. There were three different friction coefficients that were used in each simulation: their values were as follows (Samper, Felder 1990): $\mu = 0.15$ (for example, uncoated steel); $\mu = 0.2$ (zinc-coated steel in metal forming); $\mu = 0.05$ (lubricated extrusion).

The numerical simulations in Figure 3 (initial state of extrusion), Figure 4 (advanced phase of extrusion), and Figure 5 (end of the process) are presented below.

The technical problem of the tube extrusion is almost always the final diameter of the product. It is possible to obtain these kinds of results from a numerical simulation; these are shown in Figure 6.

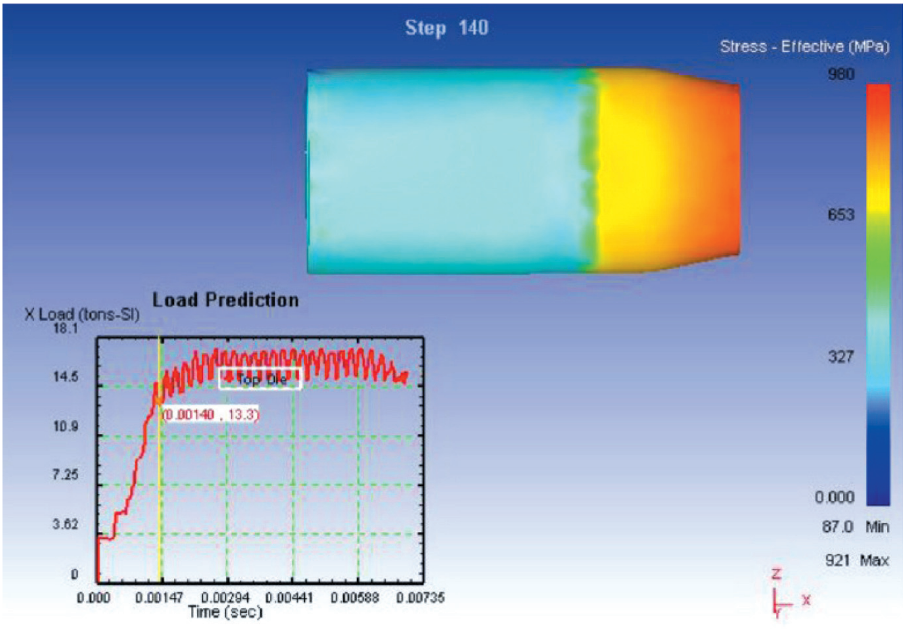

Fig. 3. Effective stress during cold tube extrusion – initial phase of process

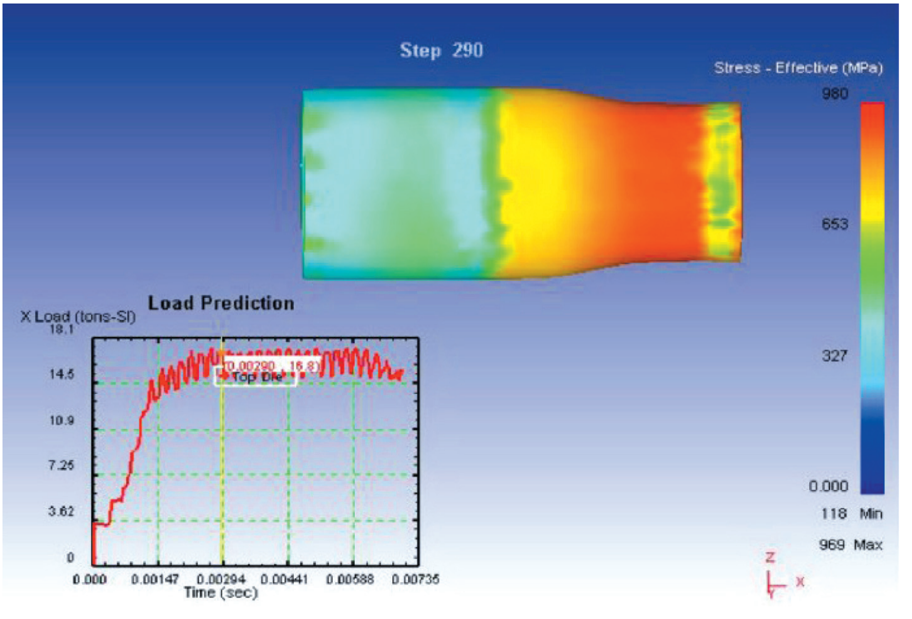

Fig. 4. Effective stress during cold tube extrusion – advanced phase of process

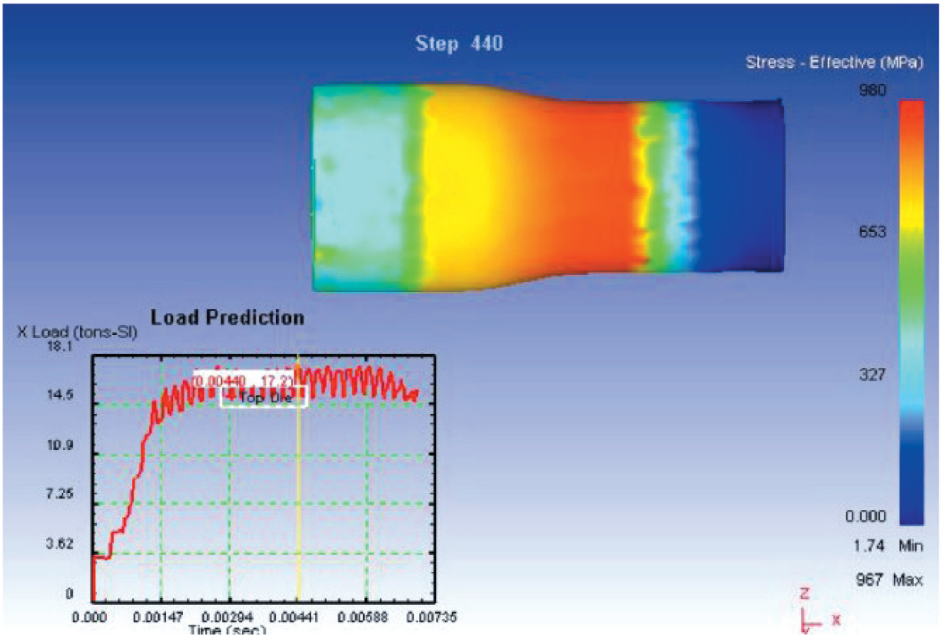

Fig. 5. Effective stress during cold tube extrusion –
end of process

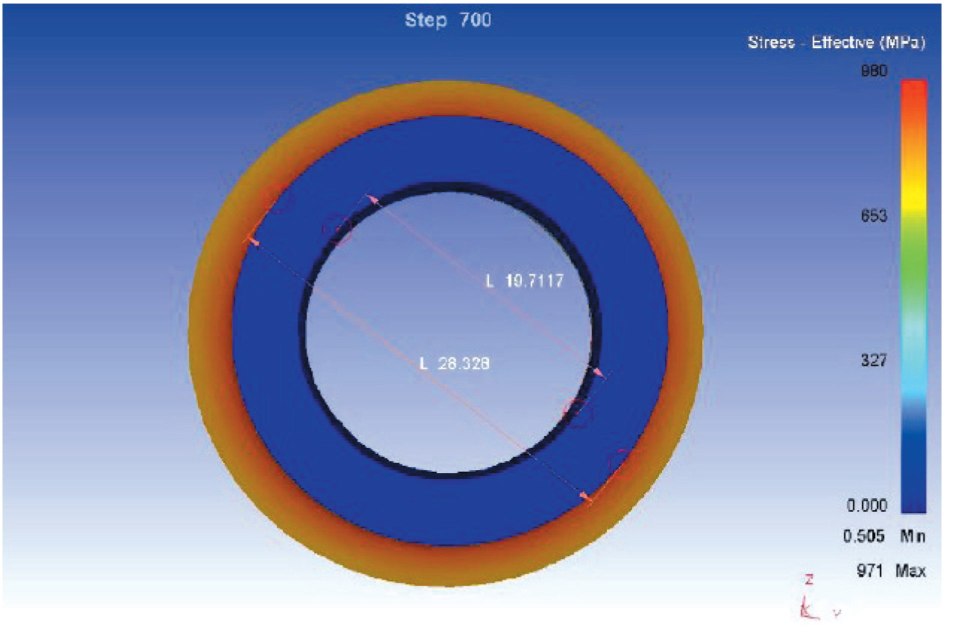

Fig. 6. Final diameters of extruded tube

5. Concluding remarks

It is a very short duration time of cold tube extrusion; therefore, numerical methods are almost the only means of obtaining the solution of pressure distribution on a die's surface. It seems necessary to know the value of the friction coefficients during the extrusion process and their distribution. The friction coefficient ranged from 0.05 to 0.15 in the presented simulation.

On the other hand, it seems to be impossible to obtain the results of contact stresses by using the DFORM 3D system only (with all of its functional constraints). The unknown distribution of stresses that is described above does not allow for die design; only the load and effective stress for choosing the technological parameters of the process are available. Some type of result is disabled because the material of the tool is defined as a rigid body of necessity; thus, only the solution that is described above has been worked out. The test was made using the Deform 3D system. During the test, a friction coefficient of $\mu = 0.12$ was assumed as a recommended parameter for the extrusion of steel tubes. The results of effective stress (Figs. 3–5) also showed the possible load of the punch. The max value of this result (X Load) was near 18 e+3 kg. Thus, this is preliminary approximate information about the kind of press that should be used. Additionally, the computer simulation allowed us to check the possible inner and outer diameters of the extruded tube. This is shown in Figure 6.

So, the computer simulation of the described extrusion process may be very useful for defining the precision load of a die. Using even similar theoretical or experimental methods to obtain this data may be more complex. The pressure load from a computer simulation to calculate the contact stress distribution may be obtained as well. The results of a numerical analysis are, thus, of great importance, as they make it possible to (approximately) estimate the die's load. Even though the actual extrusion process is accomplished within a split second, the setting up of a workplace that is equipped with all of the required measurement sensors to register the die load poses a very complicated problem and often requires significant outlays.

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