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SIMULATION WITH THE HELP OF MATLAB OF THE FORGING TECHNOLOGY FOR THE ROTOR SHAFT REFERENCE OF A WIND TURBINE INSTALLATION

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ABSTRACT

In this paper, a simulation of the forging process was carried out to obtain the rotor shaft of a wind turbine.

The simulation program used for the forging process in the referenced work is based on the mathematical formulations specific to plastic deformation during forging, integrated into a computational model that faithfully reproduces the real technological conditions.

KEYWORDS: forging, simulation, rotor shaft, wind turbines

1. Introduction

For millennia, the art of forging iron and other metals has played a crucial role in the evolution of human civilizations. Since the Bronze and Iron Ages, the ability to process and shape metals through forging has marked a major step in technological progress [1-3]. Even today, this process continues to be crucial for the production of basic materials and equipment used in strategic industries such as energy, oil and gas, construction, and the chemical and petrochemical industries [4-7]. Forging is often considered the “heart” of the metallurgical industry, due to its ability to provide a wide variety of indispensable products, such as metal pipes, fittings, sheets and profiles used in multiple industrial fields. Components obtained by plastic deformation of metals are recognized for their strength and durability, and they constitute key elements in modern industrial infrastructure.

The materials used in forging are mainly carbon steel and alloy steels, in various chemical compositions, followed by metals such as aluminium, magnesium, copper, titanium and their alloys. The raw material can have various forms, such as metal bars, ingots, metal powders or liquid metal. An important indicator in the forging process is the forging ratio, defined as the ratio between the cross-section of the material before deformation and that after deformation. The correct choice of this ratio, together with an appropriate heating temperature, an optimal holding time, the start and end temperatures of forging, as well as a well-controlled deformation and deformation rate, contribute significantly to improving the quality of the final product and reducing production costs [8-13].

Fig. 1. *Wind turbine installation* [9]

The component known as the “Wind turbine rotor shaft” is a component part of the WTG 2000 kW wind turbine rotor, used for the production of electricity from wind energy (wind energy). This way of obtaining electricity is free of polluting technological processes, is cost-effective, but is only applicable in areas of the world where the wind blows almost constantly throughout the year [14].

The primary shaft is the rotor shaft of the wind turbine; it is also called the slow shaft, because it

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rotates at speeds of approximately 20-40 rpm. Through the multiplier, it transmits the movement to the secondary shaft.

Simulation of technological processes in general consists of reproducing their evolution based on mathematical models that describe the respective process, with the aim of highlighting the evolution of the factors that characterize the final products and the technological process [15, 16].

Simulation of technological processes can be classified into several categories, depending on the nature and purpose of the study [15, 16]:

a) Real simulation – involves reproducing the analysed process through another process of a similar nature but carried out at a different scale.

b) Physical simulation – consists in reproducing the technological process using physical phenomena, preserving the characteristic interdependencies between factors. For example, the solidification process of a cast part can be simulated using electrical or hydraulic phenomena.

c) Analytical simulation – involves modelling the technological process using mathematical relationships, expressing the evolution of characteristic parameters through numerical values. This method allows analysing the behaviour of the process under different conditions through calculations.

d) Virtual simulation – is a modern simulation method that consists in representing and visualizing the technological process through computers, by transposing mathematical and physical models into software environments, in the form of image sequences.

In recent years, virtual simulation has developed rapidly, due to the numerous advantages it offers, including reduced material costs, eliminating the need to use tools, devices, installations and measuring equipment, lack of energy consumption and absence of negative impact on the environment.

2. Simulation in MATLAB of the end flange forging process by horizontal extrusion

Among the shortcomings that were identified during the design of the pair forging technology, the following can be noted:

- It is necessary to use large ingots (48000 kg);
- Handling the part during forging is cumbersome;
- Large ingots imply more pronounced segregation effects.

Since the forging of the rotor shaft in pairs (two parts in a single forged part) also has certain limitations, a new technological variant is proposed for forging this type of part.

This technology is based on the upsetting of the free end of the stretched semi-finished product in order to forge (form) the flange, with the semi-finished product in a horizontal position. To obtain the flange by retraction, the vertical movement of the upper anvil of the hydraulic press is transformed into a horizontal movement of the lower anvil.

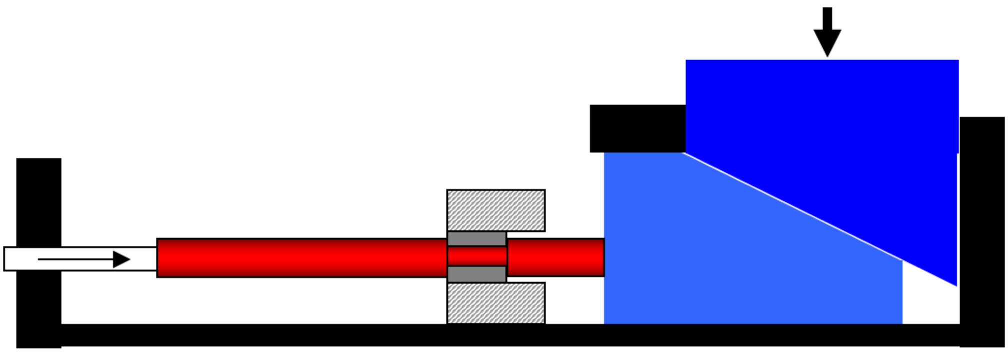

Fig. 2. Schematic diagram of horizontal end flange retraction

According to the website www.thefreedictionary.com [18], MATLAB is described as “an interactive program, developed by the MathWorks company, intended for performing high-performance numerical calculations and graphical representations. It integrates numerical analysis, matrix calculation, signal processing and graphics, in an intuitive and accessible working environment. MATLAB is based on an advanced numerical calculation core for the analysis of linear equations. Its applications cover a wide range of fields such as: applied mathematics, physics, chemistry, engineering, finance, but also other areas that involve complex numerical modelling and calculations.”

From the perspective of a computer scientist, MATLAB may be viewed as a programming language, namely an interpreter dedicated to

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implementing and running complex numerical calculations.

In this paper, a simulation of the forging process used to obtain the rotor shaft of a wind turbine was carried out.

The simulation program used for the forging process is based on the mathematical relationships specific to plastic deformation through forging, integrated into a computational model that faithfully reproduces the real technological conditions.

The simulation of the process includes the following stages:

Stage I - Initiation of the program developed in MATLAB (Figure 3).

Stage II - Bringing and Placing the Semi-finished Product on the Lower Half-Mold (Figures 4-5).

Stage III - Bringing the upper half-mould onto the semi-finished product (Figure 6).

Stage IV - Forming the flange by pressing the vertical anvil onto the horizontal anvil (Figure 7).

Stage V - Withdrawing the anvils to extract the parts (Figure 8).

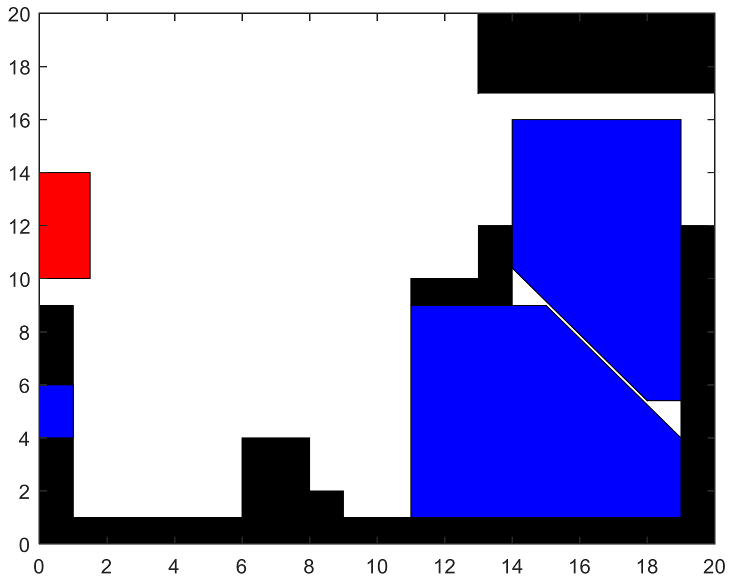

Fig. 3. *Initiating the simulation program made in MATLAB*

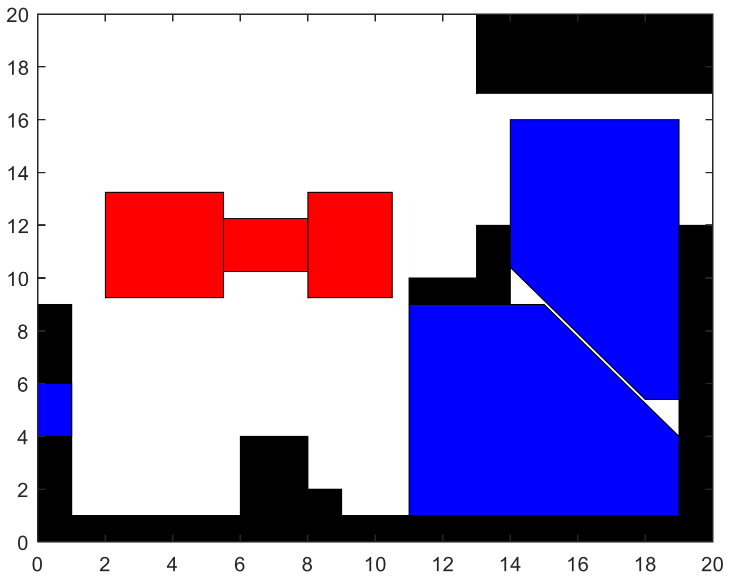

Fig. 4. *Bringing the blank onto the lower half-die*

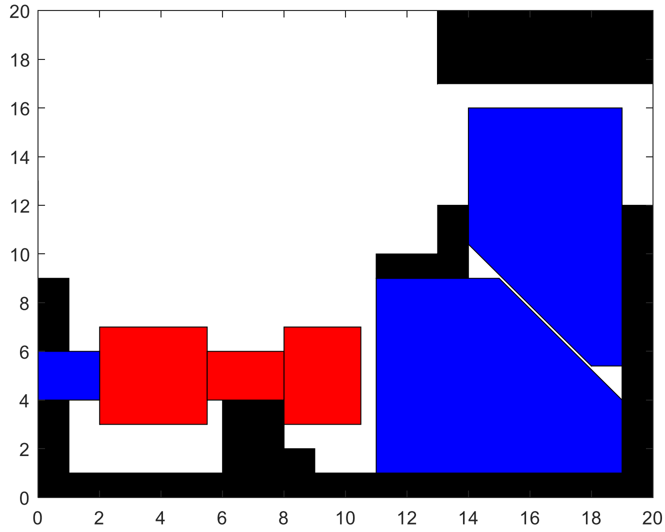

Fig. 5. *Placing the blank on the lower half-die*

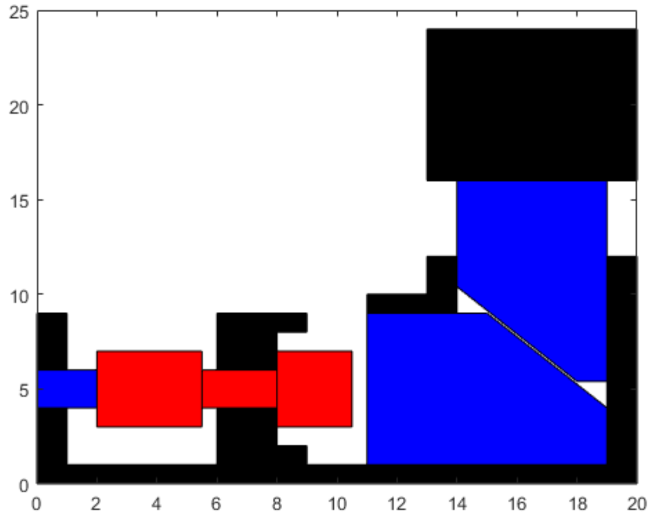

Fig. 6. *Bringing the upper half-mould onto the blank*

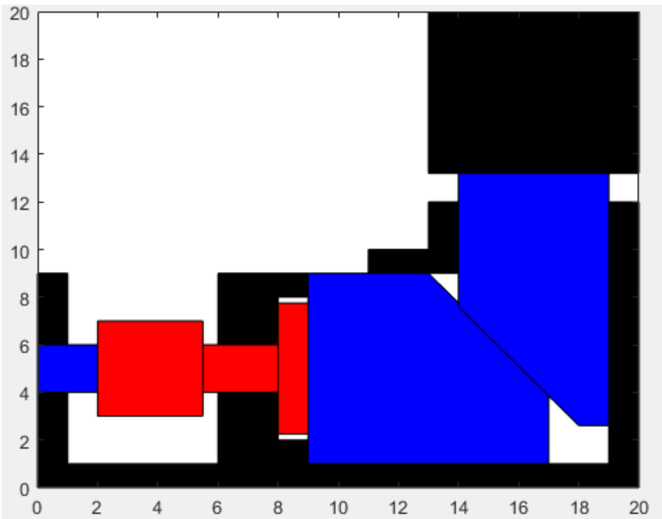

Fig. 7. *Flange retraction by pressing the vertical anvil onto the horizontal anvil*

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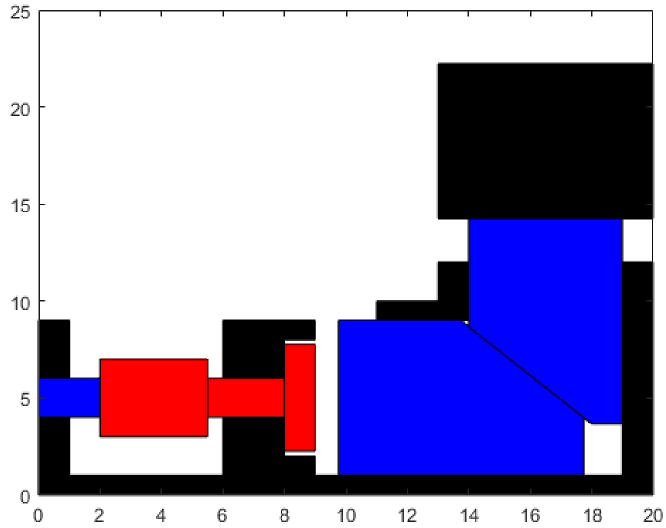
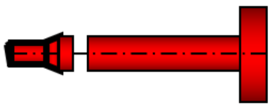
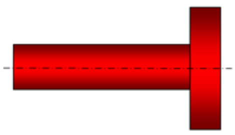


Fig. 8. Retracting the anvils to extract the parts

The semi-finished product subjected to reflow on this device must continue to follow the next operation plan described in Table 1, in order to achieve the proposed objectives.

Table 1. *Operation plan of end flange forging by pushing*

Nr. Crt.	Surgery	Operation outline	Equipment and S.D.V.s	Instructions
1	Forging the section		PH 31500 KN; Mixed anvils; Handling sleeve Compass, tape measure	-
2	Cutting the piece to size		PH 31500 KN; Mixed anvils; Handling sleeve Compass, tape measure Hot cutting axe	-
3	C.T.C., Marking Delivery		-	The external appearance is checked dimensionally and organoleptically.

3. Conclusions

From the analysis of the design of the open pair forging technology and horizontal extrusion of the wind turbine rotor shaft, it can be stated that each of the processes has both advantages and disadvantages. Among them, the following are identified:
FREE FORGING (a piece from an ingot)
Advantages:

- Ingots of relatively small size and mass are used.
- Handling of ingots during forging is easy.
- Segregation is less pronounced.

Disadvantages:

- From small ingots, the part can only be made by introducing in the operations plan, the ingot push-back, an operation that requires prior reheating and is the most energy-consuming, as it requires the greatest force (12000 tf) of all forging operations.
- The technological allowance in the flange area is large, due to the small length of the flange (160 mm) which also leads to appreciable metal consumption.

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- The technological allowance is eliminated by machining, which is also a low-productivity and energy-consuming operation.
- Can only be performed on hydraulic presses with nominal forces greater than 12,000 tf = 120,000 kN;

FREE PAIR FORGING

Advantages:

- The ingot pressing operation is eliminated.
- The ingot stretching operation is eliminated.
- The metal utilization coefficient is better than when forging a part from an ingot;
- Due to the large mass of the ingots used, a large amount of heat is stored, which makes reheating unnecessary.

Disadvantages:

- It is necessary to use large ingots (48 t);
- Handling the ingots during forging is more difficult.
- Segregation is more pronounced in large ingots.
- Separating the two parts from the forged piece is difficult.
- The heating rate for forging is slow.

FORGING BY HORIZONTAL FLANGE PRESSURE

Advantages:

- Ingots of relatively small size and mass are used.
- Handling of ingots during forging is easy.
- Segregation is less pronounced.
- The metal utilization coefficient is better than when forging apart from an ingot;
- The pressure force is acceptable, since the pressure is performed with the successive rotation of the punch, which has a small width.
- A corresponding (continuous) fiber is created.

Disadvantages:

- It requires a dedicated special device.

As a general conclusion, it can be said that horizontal pressure of the end flange combines the vast majority of the advantages of the other processes but has the disadvantage of requiring a special device.

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