CALCULATION OF CUTTING FORCES FOR THE HOLE DRILL MANUFACTURING PROCESS

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ABSTRACT: Technological processes are constantly evolving due to the efforts of engineers who analyze, optimize and improve on a well-established computational algorithm. These efforts, supported by a theoretical basis and multiple experimental trials, can give rise to new, much more efficient algorithms, which can bring a considerable advance to the industry.

KEY WORDS: drill, algorithm, technological process, machining

1. Introduction

In any technological process we find different manufacturing processes. These have the role of modifying the properties of the material or semi-finished product. However, throughout history, the efforts and calculations of mathematicians and engineers have made it possible, by supporting technological advancement, the leap from the rudimentary abrasive stone to the automatic lathes and machine tools that we know today.

The cutting process is a processing process that consists in the action of a cutting tool on a semi-finished product, removing from its surface, in the form of chips, the excess material in order to obtain the designed shape and size. [1] Drilling (or drilling) is the cutting process by which holes (bores) in solid material are obtained, and the process can be performed on boring machines or lathes. This is the only method of full bore processing.

This paper focuses on the design of a computer application that helps to automate the calculation of cutting forces in the process of processing through drills, trying to optimize them on the principle of economic processing. In general, the choice of a machine tool suitable for drilling is done by analyzing the possibilities of the machine compared to the needs of the part. The main factors influencing this decision are:

- device's weight and size and part weight and size;
- the diameters and the depth of the holes (in the case of drilling , the initial diameter of the hole will always be zero, because the processing is creating a bore in a solid material);
- the required machining accuracy;
- the number of holes machined in a single clamp;
- the number of tools used for each hole;
- machine power;
- axial force, required speeds and advances, depending on the hole. [2]

These aspects are determined in advance according to the technical specifications of the chosen machine tool and are entered manually in the computer applications. To develop the algorithm and the application we need to understand the parameters involved in the cutting regime. In the process of machining a hole, the cutting edge of the tool must undergo a (main) rotational movement during the formation of the chips and a rectilinear (advance) movement to ensure the detachment of new layers of material. [3]

The speed of the main movement is determined as such:

$$v_p = \frac{\pi D n}{1000} \text{ [m/min]} \quad (1)$$

where:
D – drill diameter [mm]; n – drill RPM [rot/min]. [3]

The speed of the forward movement is calculated as follows:

$$v_a = n \times s \text{ [mm/min]} \quad (2)$$

where:
n - drill RPM [rot/min]; s – advance [mm/rot]. [3]

Another important parameter is the advance of the drill, which can be calculated using the formula:

$$s = C_s \times D^{0,7} \quad (3)$$

where:
Cs – coefficient that takes into account the processed material; D – drill diameter [mm]. [3]

Cs values are canonical tabulated values, which will be entered manually in the computer application. Another important parameter is the depth of cut. It's formula can be found below:

$$T = \frac{D-d}{2} \quad (4)$$

where:
D – final hole diameter [mm]; d – initial hole diameter [mm]. [3]

In the case studied, namely considering the optimization in economic regime, the cutting speed for drills has the following formula:

$$v = \frac{C_v \times D^{Z_v} \times k_{v_p}}{T^m \times t^{x_v} \times s^{y_v}} \quad (5)$$

where:
Cv – speed coefficient ; D – drill diameter [mm]; zv – diameter exponent ; Kvp – speed correction coefficient; T – tool durability [minute]; m – durability exponent; s – advance [mm/rot];
xv – advance exponent; t –depth of cut [mm]; yv – depth of cut exponent. [3]

The values of durability, coefficients and exponents will be entered manually in the computer application depending on the parameters. In the drilling process, the cutting force is perpendicular to the surface of the material. Therefore, axial force on drills has the following formula:

$$F = C_F \times D^{x_F} \times f^{y_F} \times K_F \text{ [N]} \quad (6)$$

in which the constants, exponents and correction coefficients are determined experimentally, for specific cutting cases. [4]

2. Current stage

In the initial phase, a LabView application (Laboratory Virtual Instrument Engineering Workbench) [5] was developed to test the cutting force measurement algorithm. The application displays, as a percentage, and locally measures the compressive force exerted by a compactor (with the role of simulating the cutting force at the drill) on a force cell type sensor. In order to allow the reading and processing of data, the use of an Arduino Mega type acquisition board was chosen, and for making connections within the application, the LINX MakerHub module was used [6]. The force cell, assembled in the experimental stand on two designed support plates, is connected to its pins.

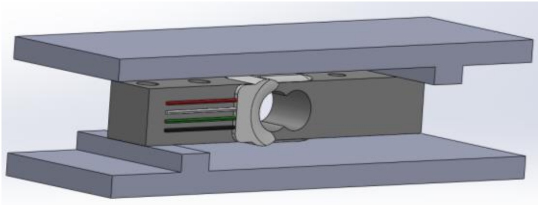

Fig. 1. Power cell mounting assembly

The Microsoft Office suite, more precisely Microsoft Excel, a spreadsheet program, was used to test the calculation algorithm. [7] This test medium was chosen because of the ability of the program to automatically calculate certain values based on certain parameters entered individually. In a spreadsheet, the formulas of the parameters of the cutting regime were introduced and adapted, the application displaying, depending on the specifications of the machine tool and the material introduced by the human operator, the minimum theoretical values necessary for the drilling process.

3. Simulation and testing

An experimental stand consisting of the following components was made to test the operation and correctness of the force measurement application:

- power source;
- drive motor BTS7960;
- strain gauge TAL220B;
- Arduino Mega pcb;
- 12 V motor;
- compactor (simulates drill forces);
- laptop.

These connected components form a test system, and the connections between them are illustrated in the principle diagram of the stand in Figure 2.

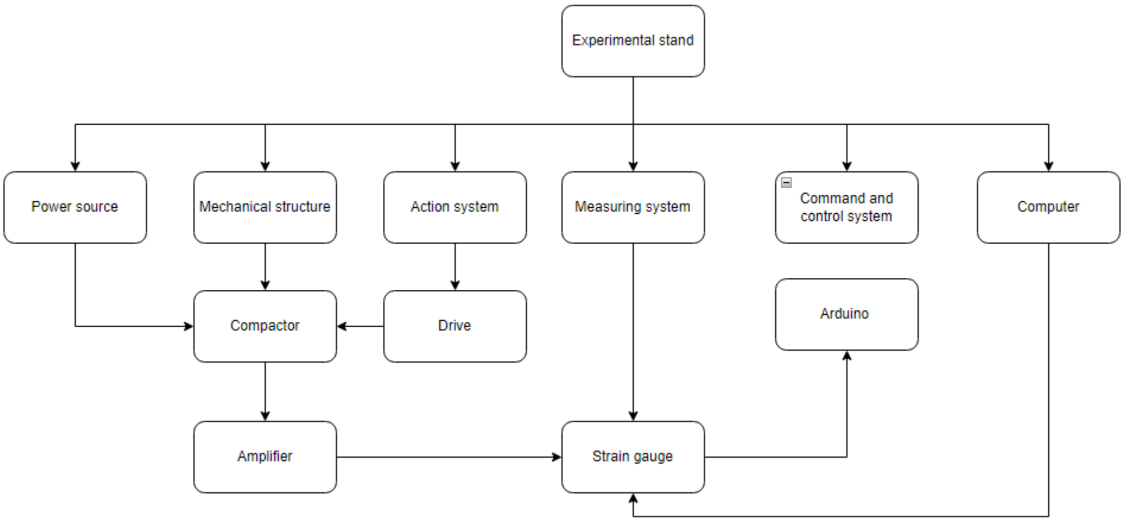

Fig. 2. Schematic diagram of the experimental stand

In the LabView power measurement application, the measurement process is initialized through the LINX Open function, which establishes the connection between the application and the Arduino board through the COM3 port of the laptop. The LINX Analog Read function is used to read the signal, and the LINX Digital Write function is called for speed control. Thus, by linking the value read by the sensor [8], multiplied by 20 to find out the percentage, at a Vertical Progress Bar, we can display the percentage of pressure of the sensor. Subsequently, it is connected to 2 LED indicators that indicate at what stage of the process we are: pressing / compacting, respectively returning to the initial position. In case of sensor overload, the application automatically changes the direction of the motor, which switches the compactor to return to the initial position. A Switch button can be pressed in the front panel of the application to initiate the compaction process. The engine speed is also manually entered into this panel, just before the start button is pressed. The application also has a stop button, which once pressed stops the application operation and engine operation.

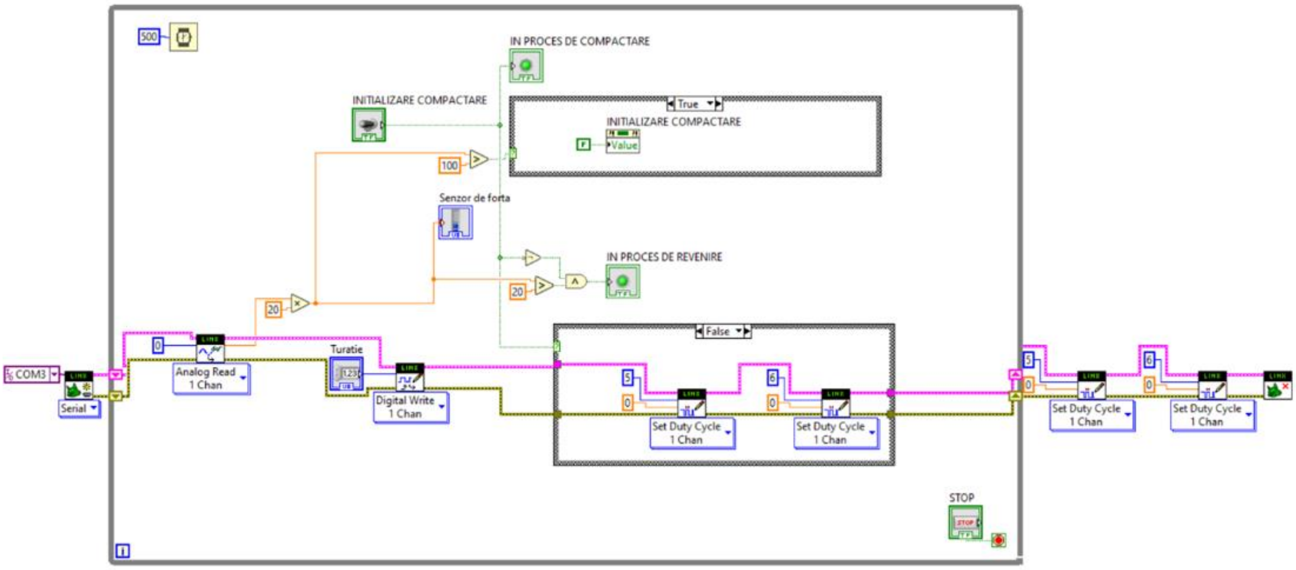

Fig. 3. Program's block diagram

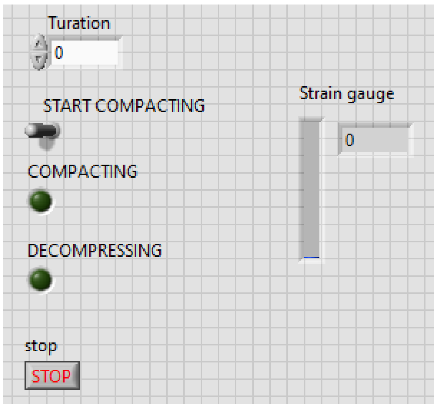

Fig. 4. Program's front panel

The Excel spreadsheet has introduced and adapted the calculation parameters of the cutting parameters. [9] The operator will enter the drill speed and diameter, and then select the hole size and material from the predefined list. The program automatically takes the tabular data of the coefficients specific to the entered parameters and calculates the theoretical values of the main parameters of the drilling process.

Parameters	Values	
Material specific Brinell hardness (HB)	160	
Cs coefficient	0.085	
Drill diameter	8	
Drill turation	20	
Hole diameter	8	
Material	Steel	
Cutting speed	0.5024	[m/min]
Depth of cut	4	
Advance	0.36	
Advance speed	7.29	[mm/min]
Axial force during drilling	3.097144111	[kgf]

Fig. 5. Calculation of parameters

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=(P10*((C4)^P12)*P8)/((R3)^P11)*((C10)^P13)*((C12)^P14)
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Fig. 6. Model for adapting the formula for calculating the axial force to drills

4. Conclusions and further developments

The applications have been developed as test environments for the future computer application that will include both components: measurement and calculation. Their operation is an important step towards solving the proposed problem, namely to optimize the parameters of the drilling process.

The theoretical calculation process presents a basis for the development of an optimization algorithm according to a certain principle, such as: minimum energy consumption; of the minimum cutting force (which ensures the avoidance of excessive deformations); of optimizing the drill path on the part (if more holes are made) and others.

This will be done by adjusting the parameters and adapting the canonical formulas so as to arrive at a set of optimal parameters for the machine tool used in the case of processing a specific blank. The algorithm can be tested at the University, but the application can be developed to be used on a larger scale. This makes it easier to take into account the technical specifications of the various machine tools available in a factory by comparing the calculated data with their catalogs, resulting in an increase in productivity without increasing the cost of production.

In the following period, we will look for a way to integrate the two applications, but also to adjust the algorithm in order to more efficiently calculate the minimum axial force required for drilling certain semi-finished products, as the ultimate goal to reach a more efficient processing process..

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