The determination of the relation between the drill diameter and the correction coefficient of the relative thickness of the drill core when calculating the axial force

R Daicu* and V Dițu

1Manufacturing Engineering Department, Transilvania University of Brașov, Eroilor nr. 29, 500036 Brasov, Romania

*E-mail: raluca.daicu@unitbv.ro

Abstract. When drilling metals, the determination of the axial force is necessary for multiple applications. In the literature the algorithm for calculating the axial force is quite well presented but there is an exception, namely, the correction coefficient of the axial force in relation to the relative thickness of the drill core where several iterations are needed. To determine the relationship between the diameter of the drill and the correction coefficient of the axial force, we start from the expression of the axial force developed based on the hypothesis of polytropic compression of the material to be processed where the correction coefficients are applied when practical situations require it. From the methodology of calculating the correction coefficient in relation to the relative thickness of the drill core it is found that there are three stages. In this paper we eliminate two steps by determining the relationship between the diameter of the drill and the correction coefficient for the relative thickness of the drill core and also improves the calculation both by developing a relationship that can be easily applied and by building a graph that helps upon rapid identification of the correction coefficient.

1. Introduction

The knowledge of the forces in metal cutting is particularly important due to the multitude of applications for which they are used. Since the beginning of metal cutting, researchers have paid special attention to estimating cutting forces by developing calculation relations, tables and graphs useful for practice. The sources [1-7] are just a few examples where relations for cutting forces are presented.

In paper [8] is presented a device for smooth entrance in cutting of the drill. Both for its design and for its reengineering, the axial force at drilling is needed to dimension the springs that are part of it. Research [9] and [10] are examples that show the interest for the cutting forces at drilling.

The source [1] presents, in detail, the methodology for determining the axial force at drilling and the relationship (1) was developed based on the hypothesis of polytropic compression of the material to be processed.

\[ F = C_F \times D^{x_F} \times f^{y_F} \times K_F \times 10 \text{ [N]} \]  

where:

- \(D\) [mm] – drill diameter;
- \(f\) [mm/rev] – cutting feed;
- \(K_F\) – compound correction coefficient.
where:
- sharpening coefficient;
- coefficient of oversharpening (adjustment of the transverse edge);
- coefficient for nose angle 2K (K – angle of attack);
- coefficient for the relative thickness of the drill core (the ratio between the core diameter and the drill diameter).

From the correction coefficients presented in relation (2) the coefficient for the relative thickness of the drill core (the ratio between the diameter of the core and the diameter of the drill) is determined in three steps which is time consuming.

In this paper two steps are eliminated by determining the connection between the diameter of the drill D and the correction coefficient $K_{\eta_F}$ for the relative thickness of the drill core.

That also improves the determination both by developing a relationship that can be easily applied as well as by building a graph that helps to quickly determine the correction coefficient.

2. Determination of $K_{\eta_F}$ - correction coefficient of the relative thickness of the drill core

Relative thickness of the drill core $\eta$ is the ratio between the drill core diameter $d_0$ and the drill diameter $D$.

To determinate $K_{\eta_F}$ the next steps will be followed:
- The determination of the relation between the drill diameter $D$ and relative thickness $\eta$ of the drill core using the data from [1] and [5];
- The determination of the relation between the relative thickness $\eta$ of the drill core and the correction coefficient $K_{\eta_F}$ using data from [1];
- The determination of the relation between the drill diameter $D$ and correction coefficient for the relative thickness of the drill core $K_{\eta_F}$ using the relation obtained in the previous step.

2.1. Determination of the relation between the drill diameter D and the relative thickness $\eta$ of the drill core

In the literature [1] and [5], the relative thickness of the drill core $\eta$ depending on the drill diameter is presented using intervals, as in table 1.

| D – drill diameter [mm] | $\eta$ – relative thickness of the drill core [mm] |
|-------------------------|---------------------------------|
| 0.25 ÷ 1.25             | 0.28 ÷ 0.2                      |
| 1.5 ÷ 12                | 0.19 ÷ 0.150                    |
| 13 ÷ 80                 | 0.145 ÷ 0.125                   |

The data from table 1 is processed using Curve Expert 1.4 software (figure 1 and figure 2).

Figure 1 shows the relation between the relative thickness of the drill core and the drill diameter obtained by processing the data with the Curve Expert software.

Figure 2 shows the graphical representation of the relative thickness $\eta$ depending on the drill’s diameter D processed by the same software.

Relation (3) is the resulted relation between the relative thickness of the drill core and the drill diameter.

$$\eta = \frac{0.359 + 0.332D}{1 + 2.314D + 0.005D^2}$$
Fig. 1. Using Curve Expert to determinate the relation between the relative thickness $\eta$ and the drill diameter $D$.

Fig. 2. Graphical representation of the relative thickness $\eta$ depending on the drill’s diameter $D$.

2.2. Determination of the relation between the relative thickness $\eta$ of the drill core and the correction coefficient $K_{\eta_F}$

Relation (4) is the resulted relation between the relative thickness of the drill core and the correction coefficient $K_{\eta_F}$.

$$K_{\eta_F} = 0.085 + 6.115 \times \eta$$  (4)
Table 2. Determination of relation between relative thickness $\eta$ of drill core and correction coefficient $K_{\eta F}$.

| No. | $\eta$ | $K_{\eta F}$ | No. | $\eta$ | $K_{\eta F}$ |
|-----|--------|-------------|-----|--------|-------------|
| 1   | 0.12   | 0.82        | 8   | 0.19   | 1.25        |
| 2   | 0.13   | 0.88        | 9   | 0.20   | 1.31        |
| 3   | 0.14   | 0.94        | 10  | 0.21   | 1.37        |
| 4   | 0.15   | 1.00        | 11  | 0.22   | 1.43        |
| 5   | 0.16   | 1.06        | 12  | 0.23   | 1.49        |
| 6   | 0.17   | 1.12        | 13  | 0.24   | 1.55        |
| 7   | 0.18   | 1.19        |     |        |             |

Figure 3. Graphical representation of the correction coefficient $K_{\eta F}$ depending on the relative thickness $\eta$.

2.3. Determination of the relation between the drill diameter $D$ and correction coefficient for the relative thickness of the drill core $K_{\eta F}$

The last step in determining the relationship between the diameter of the drill, $D$, and the correction coefficient for the relative thickness of the drill core, $K_{\eta F}$, is to use the relationships (3) and (4) to generate the table 3.

Having created table 3 it is easy to use the Curve Expert software to see and graphically the dependency stated above.

The data presented in table 3, processed using the Curve Expert software, give both figure 4 and relation (5).
Table 3. Connection between drill diameter D and the correction coefficient $K_{\eta F}$.

| D [mm] | $\eta$ | $K_{\eta F}$ | D [mm] | $\eta$ | $K_{\eta F}$ |
|--------|--------|-------------|--------|--------|-------------|
| 1      | 0.208  | 1.357       | 9      | 0.151  | 1.008       |
| 2      | 0.181  | 1.181       | 10     | 0.150  | 1.002       |
| 3      | 0.170  | 1.124       | 11     | 0.149  | 0.996       |
| 4      | 0.164  | 1.087       | 12     | 0.148  | 0.990       |
| 5      | 0.159  | 1.057       | 13     | 0.147  | 0.984       |
| 6      | 0.156  | 1.039       | 14     | 0.146  | 0.977       |
| 7      | 0.154  | 1.026       | 15     | 0.145  | 0.971       |
| 8      | 0.152  | 1.014       |        |        |             |

Relation (5) is the resulted relation between the correction coefficient $K_{\eta F}$ and the drill diameter.

$$K_{\eta F} = \frac{2.926 + 4.112 \cdot D}{1 + 4.176 \cdot D + 0.012 \cdot D^2}$$

Relation (5) determines directly the correction coefficient $K_{\eta F}$ depending on the diameter of the drill, the drill being sharpened according to the conical method and without over sharpening.

As a rule for choosing a value from the intervals shown in table 1 is not indicated, the error in determining the axial force compared to the proposed method depends on the adoption of the value in the range. Thus, for the drill diameter of 1 mm, where table 3 indicates for $\eta$ the value of 0.208 which corresponds for $K_{\eta F}$ the value of 1.357 it can be taken $\eta = 0.28$ and the correction coefficient gets the value of 2.235. In this situation the error is +64.7%. If $\eta = 0.2$ is chosen from table 1, it results $K_{\eta F} = 1.24$ and the error is -8.6%.
If the drill diameter of 6 mm is chosen for the calculation of the axial force, based on the previous reasoning, it results that the error is between +13.4% and -0.5%. For the 15 mm drill the error is in the range 0 ÷ -20.2%. It is found that the error depends on the diameter of the drill and the smaller the diameter of the drill is, the higher the error gets.

3. Conclusions
When determining the axial force at the drilling of metals the most commonly used relationship is determined based on the hypothesis of polytropic compression of the material to be processed.

When the concrete working conditions differ from the conditions in which the constants and exponents in the relation have been determined, correction coefficients are needed.

For one of the correction coefficients, namely the coefficient for the relative thickness of the drill core (the ratio between the core diameter and the drill diameter) the direct relation between the drill diameter and the coefficient was developed, which simplifies its determination and also builds a graph that can be used to quickly determine the analyzed correction coefficient.

The proposed method eliminates the errors that could be committed when determining, by calculation, the axial force at the drills by the classical method.

References
[1] Picoş C et al. 1992 Design of mechanical machining technologies vol 1 and (Chişinău: Universitas)
[2] Fetecău C 2001 Parametric relations in machining (Bucharest: Technical)
[3] Cristian I 2015 Generation of surfaces by cutting (Brasovi: Lux Libris)
[4] Şteţiu G et al 1994 Theory and practice of cutting tools. Elements of metal cutting theory vol I (Sibiu: University)
[5] Minciu C et al 1995 Cutting tools. Design guide vol 1 (Bucharest: Technical)
[6] Cozmîncă M et al 1995 Cutting basis (Iaşi: Gheorghe Asachi)
[7] Cordebois JP et al 2003 Machining manufacturing (Paris: Dunod)
[8] Diţu V, Oancea G and Daicu R 2017 MATEC Web Conf. 94 02005
[9] Pirtini M and Lazoglu I 2005 Int. J. Mach. Tool. Manu. 45 11
[10] Hamade R F, Seif Ç Y and Ismail F Int. J. Mach. Tool. Manu. 46 3