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CONTENTS

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Dependance on the required power of the electric motor on the CNC Spinner EL-510 lathe according to the depth of cut for turning and facing with CNMG 120408-PM 4325 tool insert

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Abstract: *A lathe is a machine that removes metal from a workpiece to the required shape and size. A lathe operates on the principle of a rotating workpiece and a fixed cutting tool. The cutting tool is fed into the workpiece, which rotates about its own axis, causing the workpiece to be formed into the desired shape. The operation by which the excess material is removed from the workpiece to produce a cone or cylindrical shape is called turning, and the operation used to cut a flat surface perpendicular to the workpiece's rotational axis is called facing. Speed, feed, and depth of cut are important factors that have to be determined according to the power of the CNC Spinner EL-510 lathe using a PCLNR 2525M 12 shank tool and a CNMG 120408-PM 4325 tool insert.*
Keywords*: MACHINING, METAL CUTTING, CUTTING CONDITIONS, SPEED, FEED*

1. Introduction

The material removal processes are a family of shaping operations in which the removal of material from a starting workpiece results in a transformed product machined to the desired final geometry. The most important branch of that family is machining. Machining, as a manufacturing process, is most frequently applied to shape metals into convenient products, which consists of forcing a sharp cutting tool to cut away a layer of material on the workpiece blank to achieve the desired part shape and size. Actually, machining is a generic term, applied to all material removal, while metal cutting refers to processes in which the excess material is removed by a harder tool, through a process of extensive plastic deformation or controlled fracture [1].

The predominant cutting action in metal cutting involves separation of the work material to form a chip. When the cutting tool is fed along the finished contour, a new surface is generated. It is usually performed after other manufacturing processes that create the general shape of the starting workpiece, and metal cutting provides the final geometry of the resulting work surface. Metal cutting is important in the process of manufacturing (commercially and technologically) as a consequence of applying a variety of work materials for different part shapes (with regular and irregular geometry features), achieving dimensions to very close tolerances with appropriate smooth surface finishes.

In fact, metal cutting is not just an individual specific process - it is a group of certain processes. The common feature is the aim of generating the shape of the workpiece using a sharp cutting tool of harder material to form a final workpiece with precise dimensions or to improve the tolerances and quality of the surface finish of an already produced workpiece. To realize the metal cutting operations, relative motion is required between the workpiece and the cutting tool. The relative motion is performed (in most operations) by a primary and a secondary motion. The primary motion (called the cutting speed) is attained with the spinning of the workpiece, and the secondary motion (called the feed) is obtained by the linear movement of the cutting tool (Fig. 1(a)).

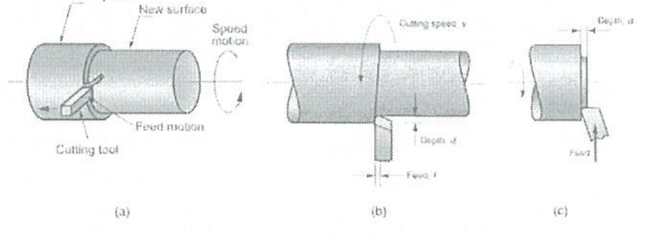

Fig. 1 *(a) Creating a shape in metal cutting by turning, (b) Turning cutting conditions, and (c) Facing cutting conditions*

Conclusively, the primary motion is accomplished at a certain cutting speed (v). In addition, the tool must be moved laterally across the work. This is a much slower motion, called the feed (f). The remaining dimension of the cut is the penetration of the cutting tool below the original work surface, called the depth of cut (d). Collectively, speed, feed, and depth of cut are called the cutting conditions [2].

Here are discussed cutting conditions for turning and facing (as one of the most common types of metal cutting) in more detail.

In turning, the workpiece revolves around its central axis. The cutting tool moves along the axis of rotation at a constant speed, removing excess material to form a cylinder, cone, or surface with a more complex profile. The rotating workpiece performs the speed motion, and the cutting tool achieves the feed motion by moving at a slow pace in a direction that is parallel to the workpiece's axis of rotation. In facing, the perpendicular movement of the cutting tool to the axis of rotation of the workpiece removes excess material from the workpiece's end and/or shoulder to create a new smooth surface. The cutting conditions for turning and facing are illustrated in Figure 1(b) and Figure 1(c), respectively. A typical unit used for cutting speed is [m/min], for feed is [mm/rev] and for depth of cut is [mm].

The cutting conditions in turning and facing generally incorporate the speed motion combined with a feeding motion and depth of cut to create the correct shape of the workpiece by the geometry of the cutting tool and its penetration into the work surface. The cutting tool has just one or even more sharp cutting edges. It is made of a material harder than the workpiece material. The purpose of the cutting edges is to separate a chip from the current workpiece in order to generate a new surface.

The surface of the tool over which the chip flows is known as the rake face. The cutting edge is formed by the intersection of the rake face with the clearance face or flank of the tool. The rake angle is measured from a line parallel to the axis of rotation of the workpiece. A positive rake angle is one where the rake face dips below the line, but the greater robustness of tools with a smaller rake angle leads in many cases to the use of a zero or negative rake angle. The tool terminates in an end clearance face, which is also inclined at such an angle as to avoid rubbing against the freshly cut surface. The nose of the tool is at the intersection of all three faces and may be sharp, but more frequently there is a nose radius between the two clearance faces [3].

Performing the operation with a positioned cutting tool relative to the workpiece requires a compatible machine tool. A machine tool, as a term, is applied to any power-driven machine that realizes a machining operation. It also indicates metal forming and metal cutting processes. The requirement of the machine tool is to provide power for the operation at the determined speed, feed, and depth of cut related to the rotating workpiece and the movement of the cutting tool. The traditional machine tools used to implement the process of turning and facing are lathes. Instead of controlling the tool machine and the operation by a human operator who changes the cutting tool and sets the cutting conditions, a modern form of control (as a form of automation) is computer numerical control (CNC), in which the operation is controlled by a program of instructions. Despite the particular operation and the level of control, appropriate power is required to accomplish the activities in order to perform the exact operation.

2. Research

The purpose of this research is to determine how the required power of the electric motor on the CNC Spinner EL-510 lathe (with a maximum power of the main motor of 13,4[kW] and a mechanical efficiency of 80%) affect turning and facing operations when the work material, cutting tool, and cutting conditions are identical. The specified work material is C1430 (corresponding to the JUS C.B9.021 Standard for Heat - treatable Steels) with a hardness of 172 HB. The applied cutting tool is a combination of a CNMG 120408-PM 4325 indexable insert mechanically clamped into a PCLNR 2525M 12 shank tool (see Fig. 2). The cutting tool has the following elements of geometry: an approach (or cutting edge) angle of 95°, an entering (or lead) angle of -5°, an orthogonal rake angle of -6°, a clearance angle of 0°, and a corner radius of 0,8[mm].

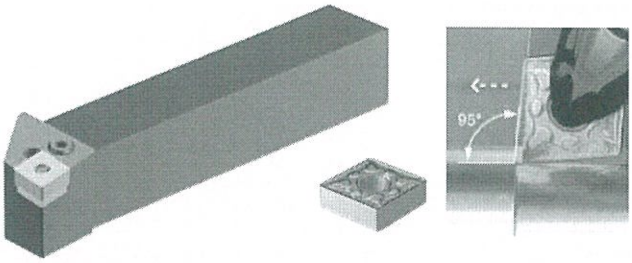

Fig. 2 The Cutting Tool

The corresponding grade number of surface roughness to the geometric tool factors is N10, and the appropriate value for the average roughness is 3,2 [μm]. The chosen cutting feed to achieve the defined surface quality is 0,83 [mm/rev]. The depth of cut is from 0,5 [mm] to 3 [mm] and it changes every 0,5 [mm] in order to calculate the essential motor power for turning and facing operations. The proper cutting speed is 180 [m/min] up to 1 [mm] depth of cut, and as the depth of cut increases from 1÷3 [mm], the cutting speed decreases to 140 [m/min].

The power required to operate the machine tool is greater than the power delivered to the cutting process because of mechanical losses in the motor and drive train in the machine [4].

The total product of the depth of cut, cutting speed, feed and the specific power coefficient for a particular operation gives the power required to perform the turning operation, while half the product gives the power required to perform the facing operation.

For turning:

$$P_R = d \cdot v \cdot f \cdot p \tag{1}$$

where P_R is the power required to perform the turning operation, d - depth of cut, v - cutting speed, f – feed, p - specific power coefficient for a particular operation.

For facing:

$$P_R = \frac{d \cdot v \cdot f \cdot p}{2} \tag{2}$$

where P_R is the power required to perform the facing operation, d - depth of cut, v - cutting speed, f – feed, p - specific power coefficient for a particular operation.

As a result of mechanical losses in the motor and drive train in the machine, the total required power is greater than the required power to perform the operation, and these types of losses can be estimated with the mechanical efficiency of the lathe:

$$P = \frac{P_R}{E} \tag{3}$$

where P is the total required power, P_R - power required to perform the operation, E - mechanical efficiency of the lathe.

3. Results and discussion

Considering the specified work material, cutting tool, cutting conditions, and mechanical efficiency of the lathe, Table 1 lists (and Fig. 3 shows) the required power to perform turning and facing operations.

Table 1: Required power for turning and facing operations

d [mm]	0,5	1	1,5	2	2,5	3
f[mm/rev]	0,83	0,83	0,83	0,83	0,83	0,83
v[m/min]	180	180	140	140	140	140
P_R [kW] – Turning	4,78	9,56	11,16	14,87	18,59	22,31
P[kW] – Turning	**5,98**	**11,95**	**13,95**	**18,59**	**23,24**	**27,89**
P_R [kW] – Facing	2,39	4,78	5,58	7,44	9,3	11,16
P[kW] – Facing	**2,99**	**5,98**	**6,98**	**9,3**	**11,63**	**13,95**

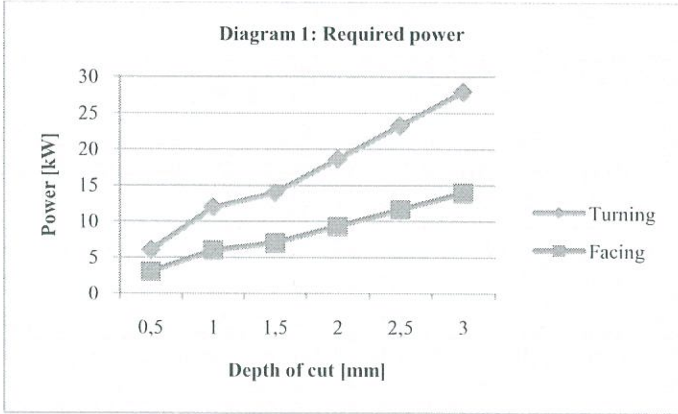

Fig. 3 Required power for turning and facing operations on the CNC Spinner EL-510 lathe

Turning and facing, as different types of metal cutting processes, require various values of motor power to perform the removal of a unit volume of metal during the process. Using this measure, turning and facing can be compared in terms of power requirements for identical work material, cutting tool and cutting conditions. The required power to accomplish a particular turning and facing operation (considering the results presented in Table 1 and Diagram 1) depends on the value of the depth of cut.

With the intention of increasing depth of cut, increasing motor power is required in performing these operations. The essential motor power is different in the two cases.

Considering that turning is a process of material removal with a cutting tool parallel to the rotation axis of the workpiece and facing is a process of material removal with a cutting tool perpendicular to the rotation axis of the workpiece, with turning the diameter of material is removed and with facing the length of material is removed.

The turning operation reduces the diameter of the workpiece from its original diameter to a final diameter, also known as the depth of cut. Actually, the depth of cut is the radius of the workpiece around which excess material is removed.

The total removed material during the process of turning is the sum of the two radiuses, i.e., it is a process of removing material from both sides of the workpiece, which results in a duplicated value of the depth of cut. On the other hand, in a facing operation, the cutting tool moves from the outer diameter of the workpiece towards the center (or inner diameter), removing a single value of the depth of cut.

Therefore, the power required to perform the turning process is two times higher than the power required to perform the facing process.

4. Conclusion

For the specified CNC Spinner EL-510 lathe's motor power of 13,4 [kW], it is recommended to perform turning up to a maximum of 1 [mm] and facing up to a maximum of 2,5 [mm] depth of cut. It is important to emphasize that to complete turning and facing operations in the same circumstances for higher values of the depth of cut, it is crucial to apply a higher power rating electric motor.

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