# Experimental Determination of Relationship of Cutting Force with Cutting Parameters

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*ABSTRACT*

*Experiments have been carried out to determine the relationship of cutting force (P kg.) with cutting speed (v m/min), uncut chip thickness (a mm) and uncut chip width (b mm) In these experiments high speed steel and tin bronze were taken as the tool material and the material of the workpiece respectively. The relationship of cutting force with cutting speed, uncut chip thickness and uncut chip width was fouud as* $P = 13.27.\ a^{0.565}.\ b^{0.828}.\ v^{0.405}$ *kg. The error of performing the experimests was found as 1.77%.*

**Introduction**

The aim of this experiment was to imitate the cutting condition of worm-wheels (1). In most cases high speed steel is taken as the tool material for cutting worm-wheels. Technology of manufacturing worm is more complicated and castly than that of worm-wheels. Therefore, the material of worm-wheels should be softer, so that the surface of the worm does not wear as a result of friction with the surface of worm-wheels. For this purpose the material of worm-wheels is usually faken as tin bronze or aluminium bronze (2). Tool material of hobs for cutting worm-wheels in most cases is taken as high speed steel. No such expriments have been carried out earlier to dermite the relationship of cutting force with cutting speed, uncut chip thickness and uncut chip width for particularly this type of pair of materials of tool and the workpiece. In these axperiments the composition of the selected tool material ( P6M5-according to Russian standard ) was; 0.8-0.88 % carbon, 3.8-4.4% cromium, 5.5% tungsten, 1.7-2.1% vanadium, 5.0-5.5% molebdenum and that of the material of the workpiece (Bp OF 10-1 -according to Russian Standard) was: 9-11% tin, 0.4-1.0% phosphorous and the rest is copper. The resnlts of the experiments were used for investigating the cutting force which appears during cutting worm-wheels (bronze) with hobs (high speed steel).

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The experiments were performed as a boring process (fiq 1 a), because the worm-wheel makes a concave surface with res-respect to the hob (fiq. 1 b). The geometrical parameters of the boring tool were the same as that of tooth of the considered hob (clearance angle $\alpha = 8^{o}$, rake angle $\gamma = 0$; inclination angle $\lambda = 0$).

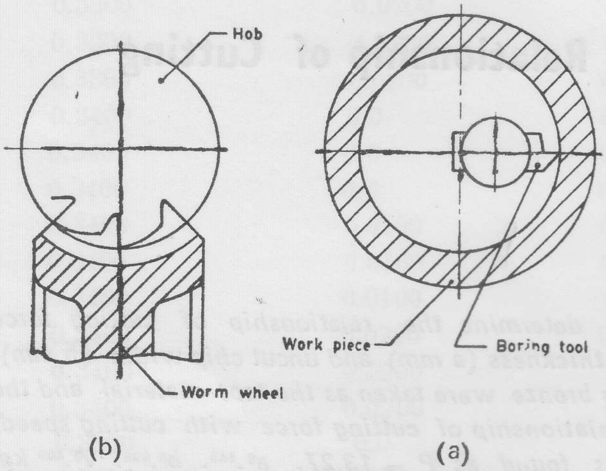


Fig. 1. Scheme of boring and hobbing worm-wheel.

**Apparatus and procedure**

The tool holder was fastened with an universal dynamometer (YDM-300, on the carriage of the lathe 1K62. The scheme of measuring force is shown in fig. 2.

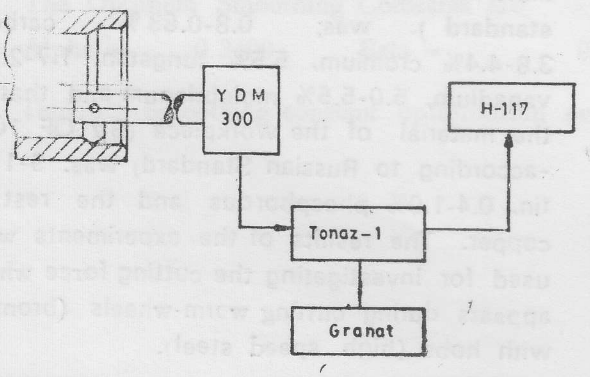


Fig. 2. Scheme of measuring cutting force.

Signals from the dynamometer YDM-300 were received by the amplifier Tonaz-1. The amplifier got energy from a separate source of energy feeder "Granat". Oscillograph H-117 received amplified signals from Tonaz-1, where they were recorded.

Changeable parameters for the experiment were cutting speed v (m/min), uncut chip thickness a (mn) and uncut chip width b (mm). The values of the variables are shown in table 1 and the plan of the experiments are shown in table 2. Measured forces are shown in table 3.

The relationship of cutting force for the given pair of materials of work piece and cutting tool with cutting speed, uncut chip thickness and uncut chip width may be given by,

$$P = C.a^{x}b^{y}v^{z} \quad \dots \quad \dots \quad (1)$$

Where P-cutting force, C = constant, x, y and z are exponents for a, b and v respectively. In order to find the value of P, the values of C, x, y and z are to be found.

Taking the value of log P,

$$\log P = \text{Log } C + x \log a + y \log b + z \log v. \dots (2)$$

If we change any factor, say a, then the exponent x for the factor a can be found easily.

$$\text{Log } P = x \log a + (\log C + y \log b + z \log v) = x \log a + \text{constant}$$

Now, if $P_1$ and $P_2$ are two values of measured forces for two different values of $a_1$ and $a_2$ respectively, then

$$x = \frac{\log P}{\log a} = \frac{\log P_1 - \log P_2}{\log a_1 - \log a_2} \quad \dots \quad \dots (3)$$

TABLE 1

Values of a, b and v

| N | a(mm) | b(mm) | v(m/min) |
|---|---|---|---|
| 1 | 0.05 | 1 | 45 |
| 2 | 0.2 | 2 | 30 |
| 3 | 0.4 | 4 | 15 |

TABLE 2

Plan of the experiments

| ɟactors | a(mm) | b(mm) | v(m/min) | serial number |
|---|---|---|---|---|
| 1 | 0.4 | 4 | 45 | 1 |
| 2 | 0.4 | 1 | 45 | 7 |
| 3 | 0.05 | 4 | 45 | 2 |
| 4 | 0.05 | 1 | 45 | 6 |
| 5 | 0.4 | 4 | 15 | 3 |
| 6 | 0.4 | 1 | 15 | 8 |
| 7 | 0.05 | 4 | 15 | 5 |
| 8 | 0.05 | 1 | 15 | 4 |
| 9 | 0.2 | 2 | 30 | 9 |

TABLE—3

Measured values of cutting force p (kg).

| N | Values of cutting force P kg Number of measurements | | | | | Mean value |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| 1 | 122.7 | 121.4 | 118.2 | 118.2 | 121.2 | 120.3 |
| 2 | 36 8 | 35 2 | 38 3 | 36.2 | 32.7 | 35.8 |
| 3 | 38 2 | 38.1 | 36.4 | 39.2 | 38.1 | 38.0 |
| 4 | 10.7 | 10.3 | 11.3 | 11.3 | 8.6 | 10 4 |
| 5. | 66.0 | 68.2 | 68.6 | 69.2 | 72.1 | 68,8 |
| 6 | 24.6 | 25.2 | 27,2 | 22.2 | 25.3 | 24.9 |
| 7 | 22.2 | 21.2 | 22.0 | 23.3 | 21.8 | 22.1 |
| 8 | 7.6 | 7.9 | 7.9 | 7.4 | 7.1 | 7.6 |
| 9 | 39.6 | 38.4 | 39.5 | 36.2 | 37.8 | 38.3 |

TABLE—4

Values of log P, log a, log b, log v.

| N experiments | log P | log a | log be | log v |
|---|---|---|---|---|
| 1 | 2.080 | —0.398 | 0.602 | 1.653 |
| 2 | 1.554 | —0.398 | 0 | 1.653 |
| 3 | 1.579 | —1.301 | 0.602 | 1.653 |
| 4 | 1.017 | 1.301 | 0 | 1653 |
| 5 | 1.837 | —0.398 | 0.602 | 1.176 |
| 6 | 1.396 | —0.398 | 0 | 1.176 |
| 7 | 1.344 | —1301 | 0.602 | 1.176 |
| 8 | 0.880 | —1.301 | 0 | 1.176 |
| 9 | 1.583 | —0.69 | 0.301 | 1.477 |