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The Measurement of The Three Components of The Cutting Force During The Turning Process

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Abstract: We carried out the measurement of the three components of the cutting force as a function of the modification of the depth of cut during the longitudinal turning process. The results show that if we increase the depth of cut, all three components of the cutting force shows increasing tendency, regardless of how much the cutting speed and feed speed were performed during the measurements [1] [2] [3] [4].

Introduction

The cutting force was measured at the Deciphering Laboratory of the University of Debrecen on an E-400 type universal turning machine. After evaluating the measurements, results are verified by hand calculation.

1. Methodology

Material

Work piece is a general purpose steel (42CrMo4) Ø60mm diameter shaft-like component with five separate pieces.

Table 1. Chemical composition according to EN 10083-3:2007

Si	C	S	Mn	P	Cr	Mo
0.15-0.40	0.38-0.45	0.020-0,035	0.60-0.90	0.025	0.90-1.20	0.15-0.30

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Table 2. Other properties (typical values)

Youngs module (GPa)	Poisson´s ratio (-)	Shear module (GPa)	Density (kg/m3)
210	0.3	80	7800
Average CTE 20-300°C (µm/m°K)	Specific heat capacity 50/100°C (J/kg°K)	Thermal conductivity Ambient temperature (W/m°K)	Electrical resistivity Ambient temperature (µΩm)
12	460-480	40-45	0.20-0.25

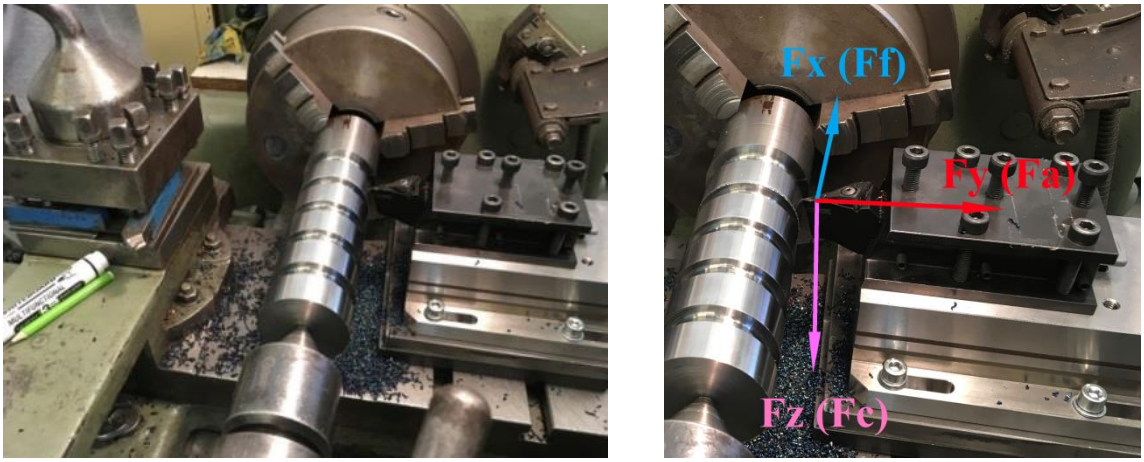

Figure 1. The lathe (E-400) and the axis coordinates

Tool

The cutting tool is a commercially available that is designed for cutting general steels.

Details of the cutting tool:

Major tool cutting edge angle: 72,5°

Tool width and height: 25x25mm

Corner radius: 0,8 mm

Figure 2. The tool / insert (plate)

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Experimental chain

A measuring device from Kistler (Kistler Group, Winterthur, Switzerland) was used to measure force components consisted of a Quartz 3-Component Dynamometer Type 9257B, multiple channel amplifier 5070A, 16-bit A / D convertor 5697A. The computer software used was Kistler Dyno-Ware (type 2825D-02; version 2.5.1.2). The cutting force measuring equipment is shown in Figure 3.

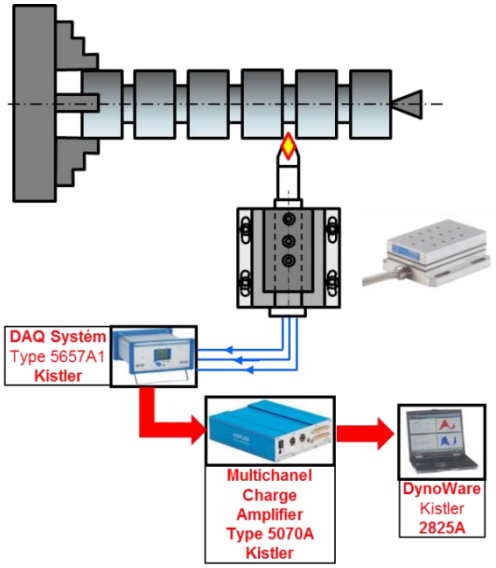

Figure 3. Measuring chain

Table 3. Choosen parameters of platform Type 9257B

Parameter		Unit	Value
Range 25 mm above top surface	Fx, Fy, Fz	kN	–5 ... 5
Overload: Fx and Fy ≤ 0.5 Fz	Fx, Fy, Fz	kN	–7.5/7.5
Fz		kN	–7.5/15
Response threshold		N	< 0,01
Sensitivity	Fx, Fy	pC / N	≈ –7.5
Sensitivity	Fz	pC / N	≈ –3.7
Linearity (all ranges)		% FSO	≤ ±1
Hysteresis (all ranges)		% FSO	≤ 0.5
Rigidity cx, cy		kN / µm	> 1
Rigidity cz		kN / µm	> 2
Operating temperature range		°C	0 ... 70
Protection class with cable Type 1687B5, 1689B5, 1677A5, 1679A5		-	IP 67
Weight		kg	7.3

2. Comparison of measured and calculated results

The following diagrams show the measuring graphs:

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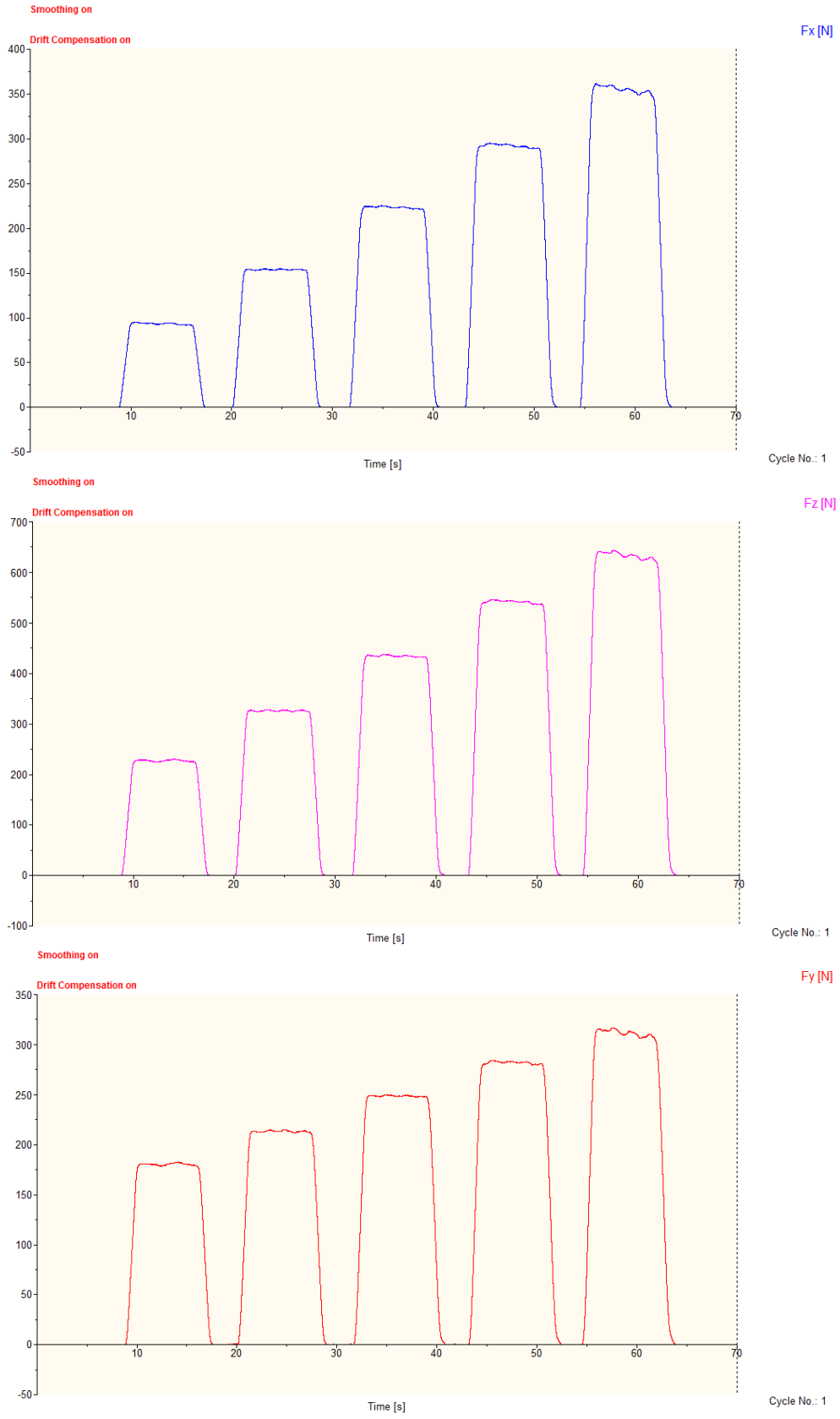

Figure 4. Measurement result

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1st. Measurement:															
	1st. piece a=0,5			2nd. piece a=0,75			3rd. piece a=1			4th. piece a=1,25			5th. piece a=1,5		
Turn [1/min]:	750			750			750			750			750		
Feed [mm/ford]:	0,2			0,2			0,2			0,2			0,2		
Depth of cut [mm]:	0,5			0,75			1			1,25			1,5		
Diamater [mm]:	60			60			60			60			60		
Diameter (after turning) [mm]:	59			58,5			58			57,5			57		
Cutting speed [m/min]:	141,37			141,37			141,37			141,37			141,37		
Fc (Fz) [N]:	223,5	227	230,2	323,2	325,6	328,1	431,1	433,9	437,4	536	541,8	545,6	622,4	632,7	643,1
Ff (Fx) [N]:	91,6	93,4	95,1	152,6	153,6	154,8	221,2	223,3	225,2	288,8	292,2	295,2	348,7	355,3	361,1
Fa (Fy) [N]:	178,3	180,3	182,5	211,3	213,1	214,7	247,1	248,4	249,7	279,2	281,9	284,1	305,65	311,15	316,45
Resulting force (average) [N]:	304,5			418,3			547,5			677,0			789,5		

2nd. Measurement:															
	1. piece a=1,5			2. piece a=1,25			3. piece a=1			4. piece a=0,75			5. piece a=0,5		
Turn [1/min]:	750			750			750			750			750		
Feed [mm/ford]:	0,2			0,2			0,2			0,2			0,2		
Depth of cut [mm]:	1,5			1,25			1			0,75			0,5		
Diamater [mm]:	59			58,5			58			57,5			57		
Diameter (after turning) [mm]:	56			56			56			56			56		
Cutting speed [m/min]:	139,02			137,84			136,66			135,48			134,30		
Fc (Fz) [N]:	688,5	708,1	721,4	585,4	589,8	594,4	477,9	480,5	484,0	364,2	366,3	367,7	254,4	257,2	259,1
Ff (Fx) [N]:	392,1	405,4	414,3	320,7	324,2	327,3	249,7	251,0	252,3	174,7	176,1	177,2	105,9	107,4	108,2
Fa (Fy) [N]:	331,4	342,3	349,9	297,0	299,9	303,0	261,3	263,5	265,7	227,6	229,2	230,4	189,5	191,4	192,8
Resulting force (average) [N]:	884,8			736,8			602,7			466,6			338,1		

Figure 5. Mesurement details

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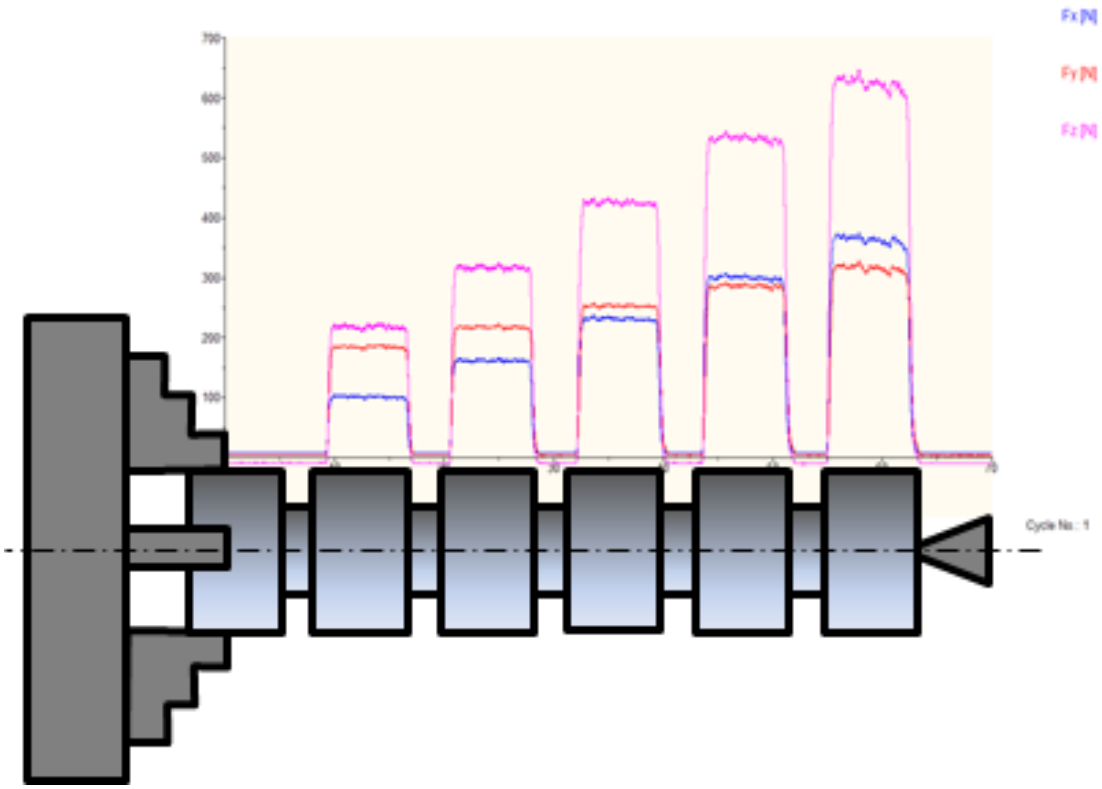

Figure 6. Schematic illustration

$$F_r = \sqrt{{F_a}^2 + {F_f}^2 + {F_c}^2}$$

where:

$$F_r = reduced\ cutting\ force$$
$$F_x = F_f = feed\ force$$
$$F_y = F_a = passive\ force$$
$$F_z = F_c = main\ cutting\ force$$

The formula for calculating [6]:

$$\mathbf{F = C_1 \cdot {a_p}^x \cdot f^y \cdot \sigma^n \cdot R^p \cdot \kappa^s \cdot {v_c}^b \cdot K_\gamma \cdot K_k \cdot K_h \cdot K_a \cdot K_\lambda}$$

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We made a total of six measurements. Comparison of measured and calculated results can be seen in the following diagrams:

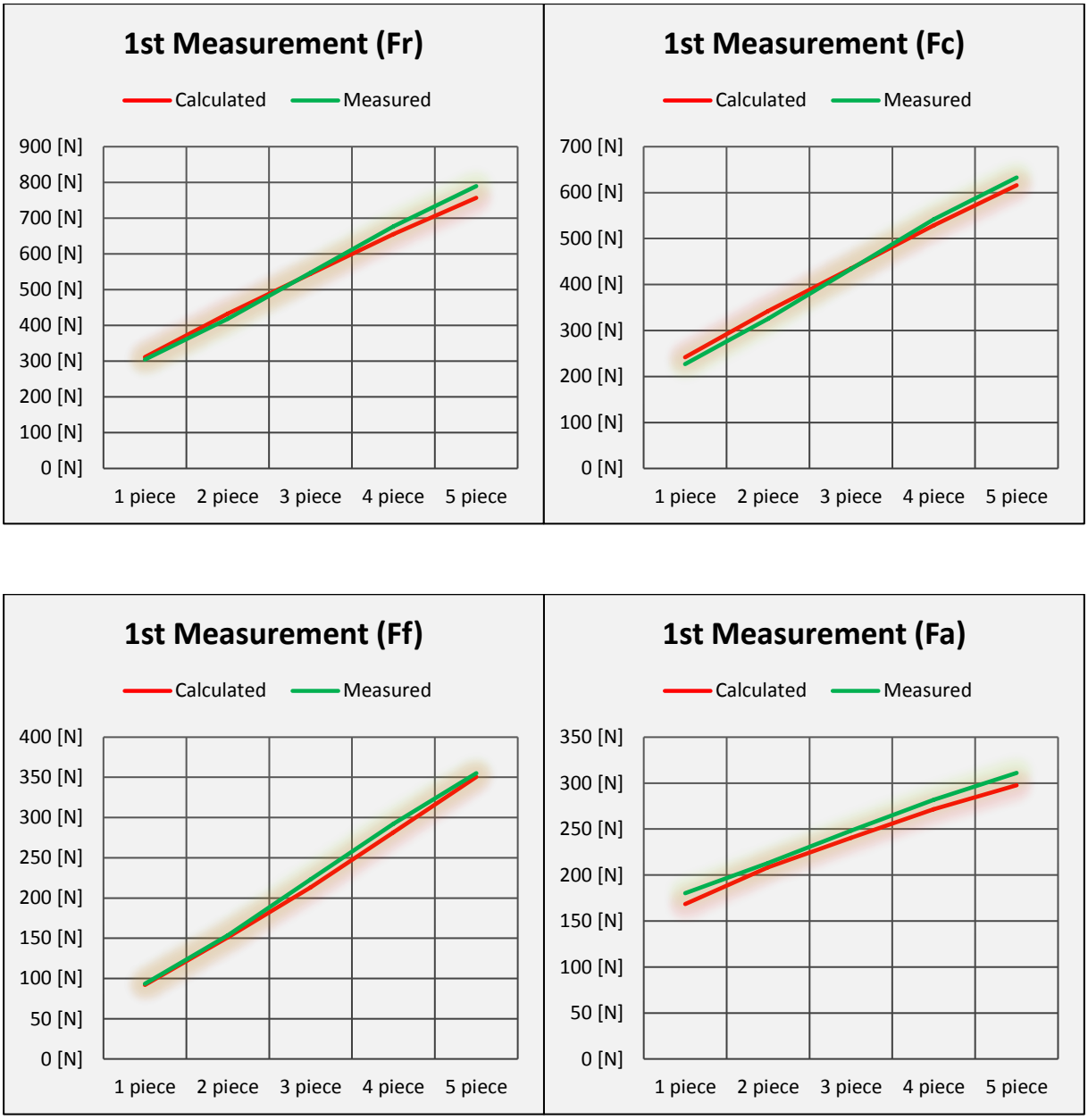

Figure 7. Comparison of measured and calculated results

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