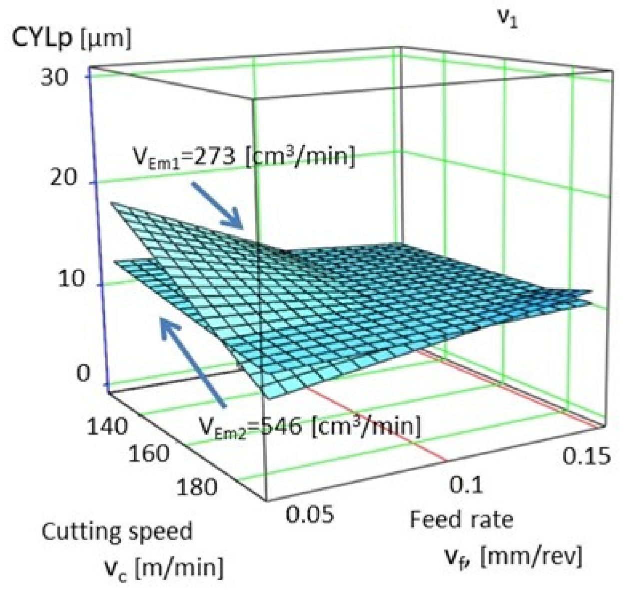

Fig.6. Change in CYLp cylindricity error depending on technological parameters and volume of emulsions for Emulsion 1

$$CYLp_{Em1} = 102.555 - 0.538v_c - 818.3v_f - 0.146V_{Em} - 4.749v_c \cdot v_f + 8.456 \cdot 10^{-4} v_c \cdot V_{Em} + 1.34v_f \cdot V_{Em} - 7.736 \cdot 10^{-3} v_c \cdot v_f \cdot V_{Em} \quad (2)$$

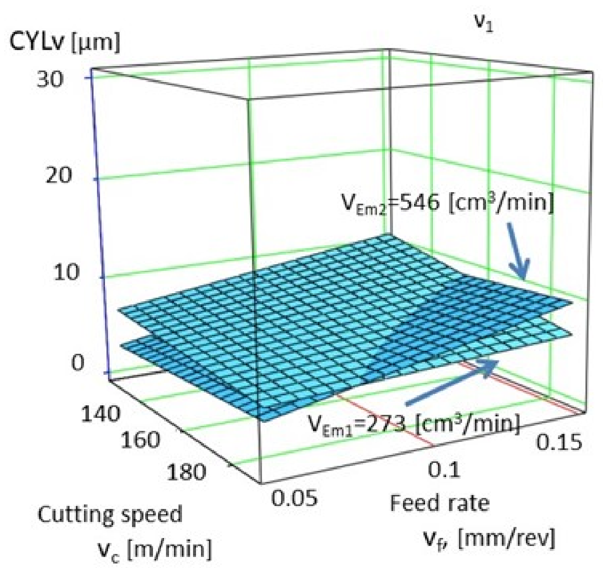

Fig.7. Change in CYLv cylindricity error depending on technological parameters and volume of emulsions for Emulsion 1

$$CYLv_{Em1} = 10.935 - 0.015v_c - 144.1v_f - 0.023V_{Em} - 0.923v_c \cdot v_f + 5.859 \cdot 10^{-5} v_c \cdot V_{Em} + 0.175v_f \cdot V_{Em} + 1.766 \cdot 10^{-3} v_c \cdot v_f \cdot V_{Em} \quad (3)$$

Examining Figs. 5-10 it can be stated that the values of CYLt are the largest.

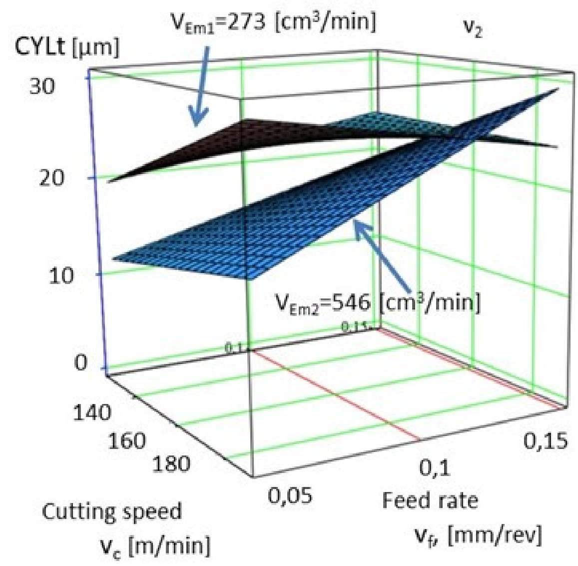

Fig.8. Change in CYLt cylindricity error depending on technological parameters and volume of emulsions for Emulsion 2

$$CYLt_{Em2} = -28.43 + 0.439v_c + 521.4v_f + 0.061V_{Em} - 4.025v_c \cdot v_f - 7.628 \cdot 10^{-4} v_c \cdot V_{Em} - 1.026v_f \cdot V_{Em} + 9.065 \cdot 10^{-3} v_c \cdot v_f \cdot V_{Em} \quad (4)$$

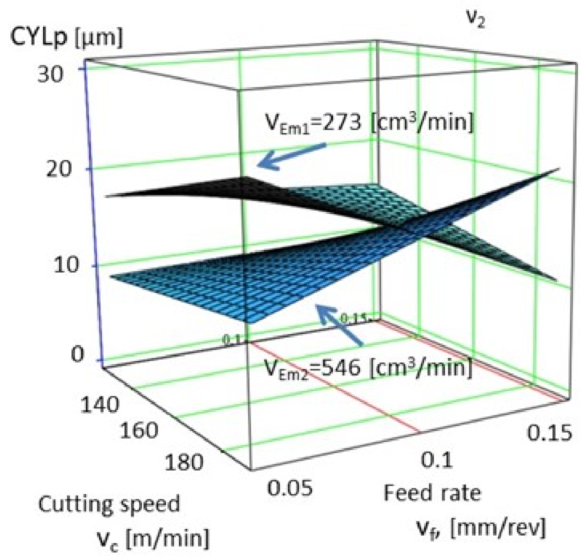

Fig.9. Change in CYLp cylindricity error depending on technological parameters and volume of emulsions for Emulsion 2

$$CYLp_{Em2} = -24.45 + 0.417v_c + 573.8v_f + 0.068V_{Em} - 4.954v_c \cdot v_f - 8.211 \cdot 10^{-4} v_c \cdot V_{Em} - 1.371v_f \cdot V_{Em} + 0.012 \cdot v_c \cdot v_f \cdot V_{Em} \quad (5)$$

The nature of CYLt and CYLp is the same. When studying Figs.5-10, the improvement values of the minimum cylindricity errors can be calculated by (7).

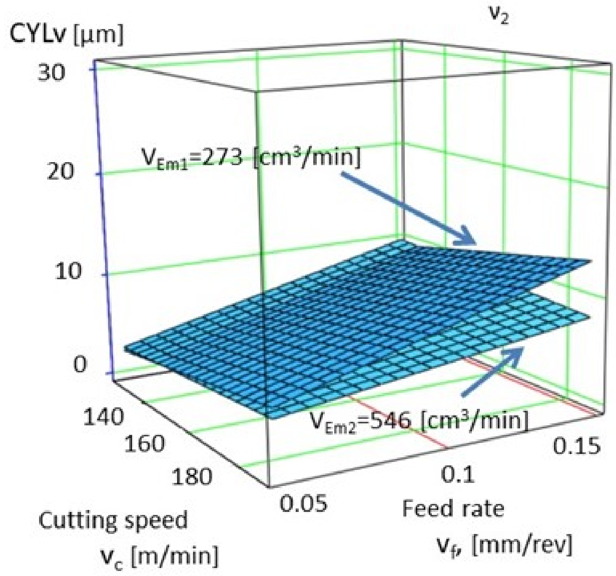

Fig.10. Change in CYLv cylindricity error depending on technological parameters and volume of emulsions for Emulsion 2

$$CYLv_{Em2} = -4.015 + 0.022v_c - 51.7v_f - 6.502 \cdot 10^{-3}V_{Em} + 0.925v_c \cdot v_f + 5.772 \cdot 10^{-5}v_c \cdot V_{Em} + 0.342v_f \cdot V_{Em} - 2.647 \cdot 10^{-3}v_c \cdot v_f \cdot V_{Em} \quad (6)$$

$$I_{CYLx} = \frac{CYLx,g - CYLx,l}{CYLx,g} \cdot 100 \text{ , \%} \quad (7)$$

where:

CYL*x*	*x* can be: *t*, *p* or *v*
CYL*x*,*l*	lower value of the CYL*x*
CYL*x*,*g*	greater value of CYL*x*, next to the lower value

The results of the calculations of the improvements can be found in Table 7. Calculations were made with the measured values of Tables 4-5.

Table 7, Improvements of cylindricity errors

Improvements	Changes	Applied parameters		Emulsion
I_{CYLt}=49.88%	$v_{c2}\rightarrow v_{c1}$	v_{f1}	V_{Em1}	Emulsion 1
I_{CYLp}=60.76%	$v_{c2}\rightarrow v_{c1}$	v_{f1}	V_{Em1}	
I_{CYLv}=64.69%	$v_{f2}\rightarrow v_{f1}$	v_{c1}	V_{Em2}	
I_{CYLt}=39.88%	$v_{f2}\rightarrow v_{f1}$	v_{c1}	V_{Em2}	Emulsion 2
I_{CYLp}=13.49%	$v_{c2}\rightarrow v_{c1}$	v_{f1}	V_{Em2}	
I_{CYLv}=74.01%	$v_{f2}\rightarrow v_{f1}$	v_{c1}	V_{Em1}	

Table 7 shows improvements in cylindricity errors when reducing the value of one parameter while retaining the others on the same level. The first row of Table 7, for instance, means in the case of a ν_1 = 2.4557 mm^2/s kinematic viscosity emulsion (Emulsion 1), if the cutting speed is reduced to v_{c1} = 25.7 m/min from v_{c2} = 188.5 m/min, while the feed rate v_{f1} = 0.05 mm/rev and V_{Em1} = 273 cm^3/min remain unchanged, the CYLt cylinder error will be reduced by 49.88%. The other lines in Table 7 can be interpreted similarly.

There are no big differences between values of the total cylindricity error (CYLt) for the lubricants having different kinematic viscosity:
Emulsion1 $CYLt_{min}$ =12.42 µm, V_{Em1}=273 cm^3/min
Emulsion2 $CYLt_{min}$ =11.64 µm, V_{Em2}=546 cm^3/min.
The outer boring is strongly influenced by the cutting speed and feed rate. So, in selecting the parameter combination recommended for use, the volume flow rate of the coolant and lubricant was crucial. With the use of V_{Em1}=273 cm^3/min flow rate, the ambient environment load is lower than when using double flow rate. Thus, the recommended parameter combination is:

- Emulsion 1
  (ν_1 = 2.4557 mm^2/s kinematic viscosity),
- V_{Em1} = 273 cm^3/min flow rate,
- v_{c1} = 188.5 m/min cutting speed,
- v_{f1} = 0.05 mm/rev feed rate.

6 Conclusion

The paper deals with the experimental examination of outer boring. Using the measurement data of the experiments carried out based on the parameter combinations determined by the Factorial Experiment Design, empirical formulas were determined to examine how the cylindricity error of the machined surfaces is influenced by the changes in the technological parameters. It was also examined how the various coolants and lubricants (emulsions having different kinematic viscosities) and different flow rates influence the values of the different cylindricity errors CYLt, CYLp and CYLv.

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