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INFLUENCE OF THE TOOL RATIO ECCENTRICITY/TOOL EDGE RADIUS GRINDING ERROR ON THE SURFACE ROUGHNESS OBTAINED IN SIDE MILLING PROCESSES USING TOOLS OF 6 AND 4 TEETH

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ABSTRACT
In the present work a numerical model was used to simulate the roughness topography and to determine the arithmetic average roughness R_a and peak-to-valley roughness R_t of surfaces obtained by contour milling processes, taking into account tool grinding radius error and tool eccentricity. Tools of 6 mm diameter with 6 and 4 teeth respectively were considered. 100000 runs were performed for each eccentricity value and feed per tooth value f_z, using different random radii values combinations so to determine the interval of possible roughness values to be obtained. In order to do that, numerical algorithms that allow the generation of the surface topography from the edge radii, the eccentricity and the feed values were developed. Afterwards, for each value of the ratio Eccentricity/Tool Edge Radius Grinding Error a plot was obtained. In the plot, the possible intervals of arithmetic average roughness R_a and peak-to-valley roughness R_t for each feed per tooth value f_z, as well as the corresponding median and mode values and the theoretical upper and lower reference values were represented. In addition, the histograms of R_a and R_t were obtained.
Keywords: surface roughness, contour milling, tool eccentricity, tool grinding radius error

1. INTRODUCTION
The cutting conditions influence the surface roughness obtained in milling processes [1, 2, 3, 4]. In previous works, in order to predict the surface roughness of vertical walls obtained by contour milling a numerical model was developed that studied the effect of feed and of differences in the tool radii [5, 6]. The model takes into account geometric factors that will affect surface roughness. A program calculates arithmetic average roughness (R_a) and peak-to-valley roughness (R_t) along a line, in the direction of the feed. In the present work, the effect of the tool eccentricity was added to the model. Different ratios Eccentricity/Tool Edge Radius Grinding Error (E/σ) were employed for the simulation: 0.5, 1, 2, 4 and 6. It was assumed that the distribution of possible errors of the radius values of the 6 teeth followed a normal distribution of mean value R = 2.995 mm and standard deviation σ = 0.005 mm, according to the measurement of several real tools [6]. The standard deviation of the tool radii was taken as the tool edge radius grinding error. Tools of 6 and 4 teeth were compared.

2. METHODOLOGY
In the simulation the contour milling of vertical walls was studied, using cylindrical tool of 6 mm diameter and 6 and 4 teeth respectively, for feed values of 0.02, 0.04, 0.06, 0.08 and 0.1 mm $tooth^{-1}$ $turn^{-1}$. The ratio E/σ was calculated as:

$$E/\sigma = \frac{Tool\ eccentricity\ (mm)}{Tool\ radius\ grinding\ error\ (mm)} \quad (1)$$

For each value of feed per tooth and per turn f_z (mm tooth^{-1} turn^{-1}) and for a given E/σ value, 100,000 different random combinations of radii were used for calculating the possible roughness values and their interval of variation. From the results obtained with the simulation, some graphics were created with the intervals of possible values of roughness R_a and R_t as a function of feed f_z, the median and the mode. In the graphics, upper and lower reference values were also represented. The upper reference value is defined as the theoretical or geometric roughness value that would be obtained if the tool only had (or if it only acted) one tooth per turn. The lower reference value is defined as the theoretical or geometric roughness that would be obtained if the 6 or 4 teeth of the tool had exactly the same radius (no radius error) [6].

3. RESULTS

The results for E/σ=0, for 6 teeth and 4 teeth are presented in Figures 1 and 2 respectively.

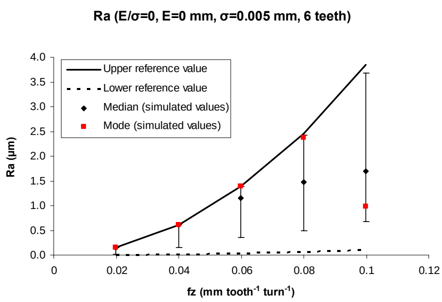

Figure 1. Intervals of variation of R_a as a function of f_z for E/σ =0, 6 teeth

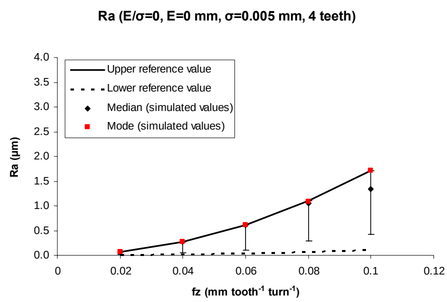

Figure 2. Intervals of variation of R_a as a function of f_z for E/σ =0, 4 teeth

The results for E/σ=2, for 6 teeth and 4 teeth are presented in Figures 3 and 4 respectively.

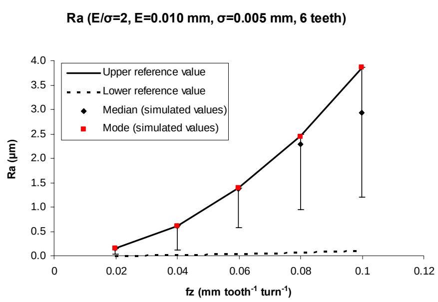

Figure 3. Intervals of variation of R_a as a function of f_z for E/σ =2, 6 teeth

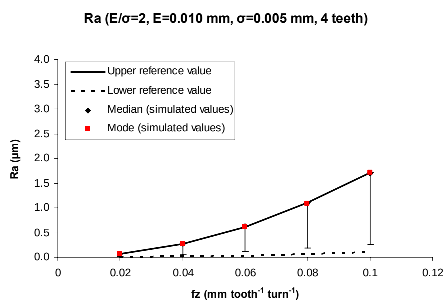

Figure 4. Intervals of variation of R_a as a function of f_z for E/σ =2, 4 teeth

The results for E/σ=6, for 6 teeth and 4 teeth are presented in Figures 5 and 6 respectively.

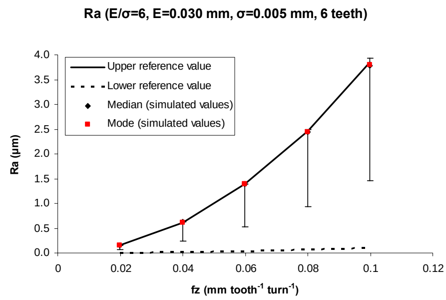

Figure 5. Intervals of variation of R_a as a function of f_z for E/σ =6, 6 teeth

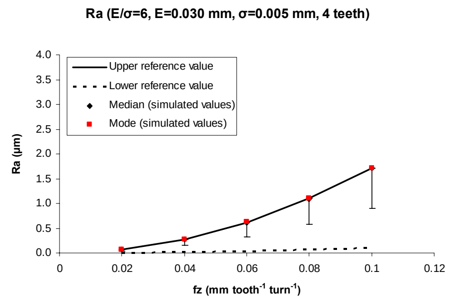

Figure 6. Intervals of variation of R_a as a function of f_z for E/σ =6, 4 teeth

For both 6 and 4 teeth, the median and the width of the interval of possible roughness values increase with feed. When the ratio E/σ increases, the median and the mode move towards the upper reference value. As the lower limit of the interval also increases, the width of the interval of possible roughness values is reduced. When 4 teeth are considered instead of 6, the upper reference values are lower, and for this reason also the width of the intervals is lower.

As an example, the frequency histograms for E/σ=2 and f_z=0.02 mm tooth^{-1} turn^{-1} are presented in Figures 7 and 8, while the frequency histograms for f_z=0.06 mm tooth^{-1} turn^{-1} are in Figures 9 and 10 and the frequency histograms for f_z=0.1 mm tooth^{-1} turn^{-1} are in Figures 11 and 12.

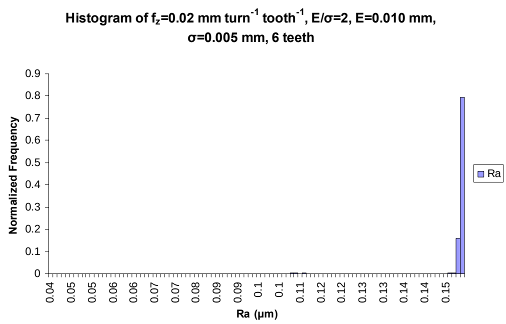

Figure 7. Histogram of f_z=0.02 mm tooth^{-1} turn^{-1} for E/σ =2, 6 teeth

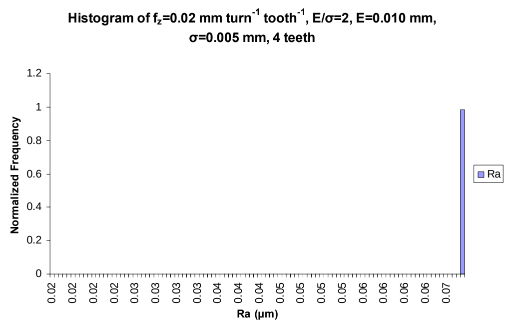

Figure 10. Histogram of f_z=0.02 mm tooth^{-1} turn^{-1} for E/σ =2, 4 teeth

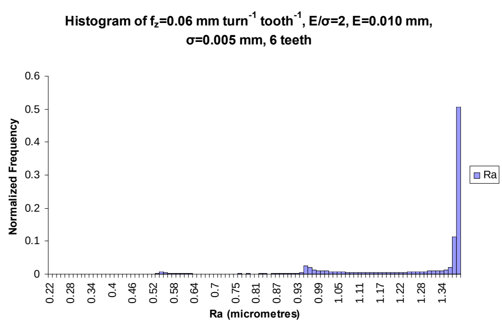

Figure 9. Histogram of f_z=0.06 mm tooth^{-1} turn^{-1} for E/σ =2, 6 teeth

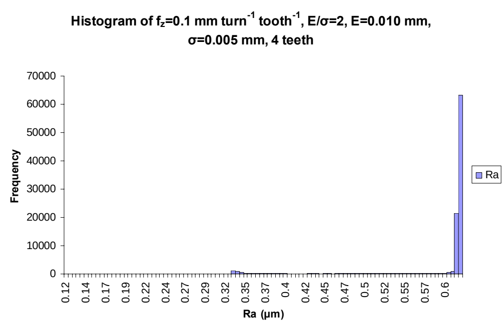

Figure 10. Histogram of f_z=0.06 mm tooth^{-1} turn^{-1} for E/σ =2, 4 teeth

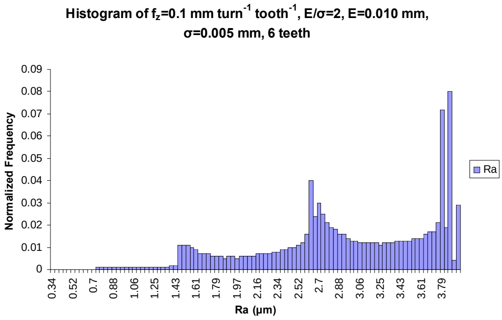

Figure 11. Histogram of f_z=0.1 mm tooth^{-1} turn^{-1} for E/σ =2, 6 teeth

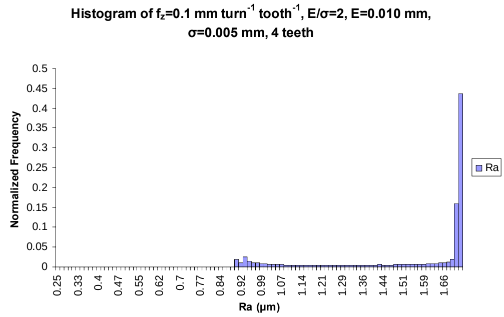

Figure 12. Histogram of f_z=0.1 mm tooth^{-1} turn^{-1} for E/σ =2, 4 teeth

For low feed values, the most frequent roughness value or mode is close to the upper reference value, both for tools with 6 and 4 teeth. The distribution is clearly asymmetrical. On the contrary, for higher feed values, the distribution becomes more symmetrical and other possible roughness values appear.

4. CONCLUSIONS

The main conclusions of this work are:

- The median and the width of the interval of possible roughness values increase with feed in all cases. As a general trend, the mode also increases with feed, although for low E/σ values and high feed the mode is near the lower limit of the interval.
- If the same feed value is considered, the higher the ratio E/σ, the higher the median of the interval of possible roughness values. The upper value of the interval remains on the upper reference value. The lower value of the interval increases with the ratio E/σ. Therefore, the width of the interval of possible roughness values decreases.
- When 4 teeth are considered instead of 6, the upper reference values are lower, and for this reason the width of the intervals is lower.
- The frequency histograms show that, for low feed values, the most frequent roughness values correspond to the upper reference value. Therefore, the distribution is asymmetrical. For higher feed values, other possible roughness values appear, leading to a more symmetrical distribution.

ACKNOWLEDGEMENTS

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5. REFERENCES

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