13th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2009, Hammamet, Tunisia, 16-21 October 2009

INFLUENCE OF THE TOOL ECCENTRICITY ON THE SURFACE ROUGHNESS OBTAINED IN SIDE MILLING PROCESSES

I. Buj Corral; J. Vivancos Calvet; H. González Rojas
Technical University of Catalonia (UPC). Departament of Mechanical Engineering.
School of Industrial Engineering of Barcelona (ETSEIB), Avda. Diagonal 647, 08028-Barcelona, Spain

ABSTRACT
In this paper a numerical model was used to predict the surface roughness of parts machined by contour milling processes, taking into account only the tool eccentricity or both the tool eccentricity and the runout of the tool as differences in the tool edge radii, as a function of feed per tooth and per turn f_z. The computational model allows determining the value of both average roughness R_a and peak-to-valley roughness R_t, and is based on the geometric tool-part intersection.
In a first step, the effect of only eccentricity as a function of feed f_z was studied, assuming that there is no error in the tool radii (no runout). In a second step, the influence of both eccentricity and runout as a function of feed f_z was studied.
When runout was also considered, 100000 runs were performed for each f_z value using a random runout in each run in order to get simulated roughness values. Several graphics were obtained with the maximum and minimum value of average roughness R_a and of peak-to-valley roughness R_t for each value of feed f_z.
In a previous work, the effect of runout as a function of feed f_z was studied, assuming that the tool has no eccentricity. In this work, the previous results with no eccentricity were compared with the new results obtained when taking into account only eccentricity or both runout and eccentricity, in order to determine the influence of eccentricity on surface roughness.
Keywords: surface roughness, contour milling, tool eccentricity

1. INTRODUCTION
The factors that influence surface roughness obtained by milling processes have been studied by several authors [1, 2, 3, 4]. In a previous work, 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]. In the present work, the effect of the tool eccentricity was added to the model. The model is based on the geometric tool-part intersection and allows defining the roughness profile of the part as a function of the feed. It analyzes the influence of runout, i.e. differences between the radii of the different tool edges, as well as the eccentricity of the tool on the surface roughness. Both the average roughness (R_a) and the maximum roughness height (peak-to-valley) (R_t) along a line, in the direction of the feed, were calculated. Different values for the tool eccentricity were used.

2. METHODOLOGY
A computational algorithm was used in order to simulate surface topography along a contour line in the feed direction, machined by a cylindrical milling tool with nominal diameter 6 mm and 6 teeth. The effect of the tool geometry is represented by the intersection of each one of the tool edges with the part moving with a certain feed value.

By means of the simulation, the intervals of possible roughness values were determined, as a function of the feed, of the distribution of the tool radii values of the six teeth and of the tool eccentricity. Feed values were employed corresponding to finish operations: from 0.01 mm tooth^{-1} turn^{-1} to 0.1 mm tooth^{-1} turn^{-1}. 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. Three different values of eccentricity were used: Ecc = 0 mm, Ecc' = 0.001 mm and Ecc'' = 0.01 mm. For each value of feed per tooth and per turn f_z (mm tooth^{-1} turn^{-1}) and for a given eccentricity value, 100000 different random combinations of radii were used according to a fixed value of standard deviation of the tool radii, in order to calculate 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. At the graphics, upper and lower reference roughness 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 tool had the 6 teeth (all the teeth) exactly with the same radius, without radius errors [6].

3. RESULTS

As an example, at Figures 1, 2 and 3 the results of R_a for σ=0.005 mm and different eccentricity values are shown. At Figures 4, 5 and 6 the results of R_t for σ=0.005 mm and different eccentricity values are presented.

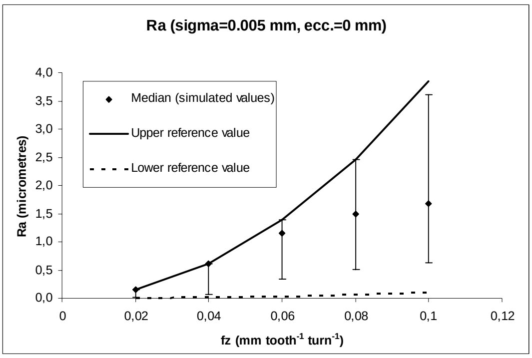

Figure 1. Intervals of variation of R_a as a function of f_z for σ = 0.005 mm and eccentricity = 0 mm

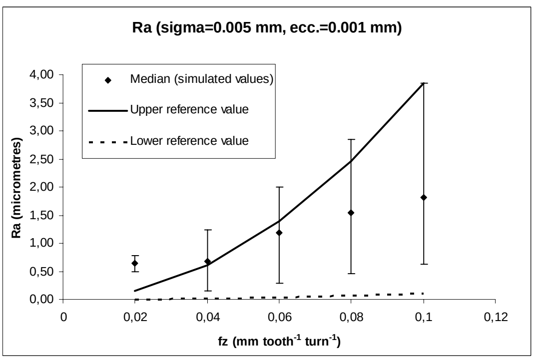

Figure 2. Intervals of variation of R_a as a function of f_z for σ = 0.005 mm and eccentricity = 0.001mm

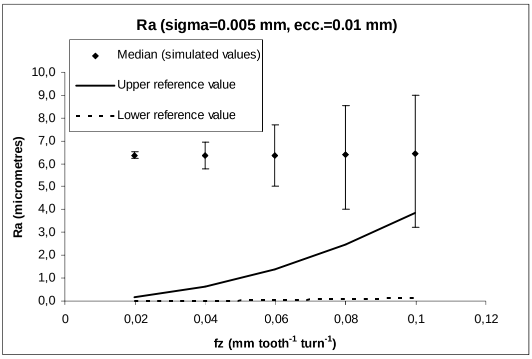

Figure 3. Intervals of variation of R_a as a function of f_z for σ = 0.005 mm and eccentricity = 0.01mm

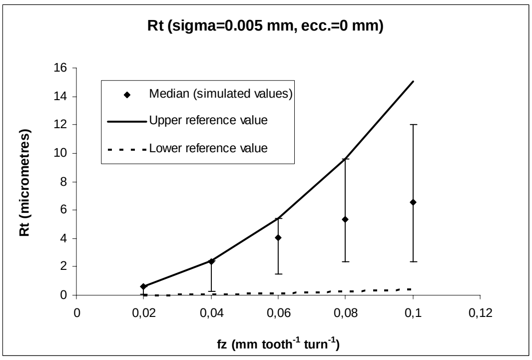

Figure 4. Intervals of variation of R_t as a function of f_z for σ = 0.005 mm and eccentricity = 0 mm

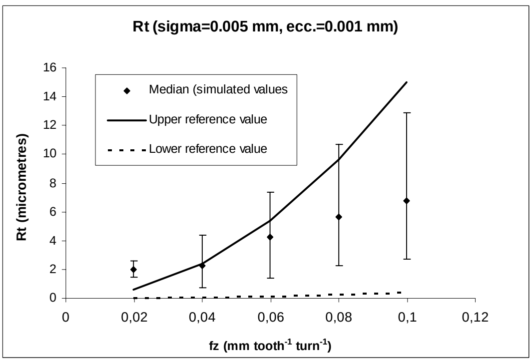

Figure 5. Intervals of variation of R_t as a function of f_z for σ = 0.005 mm and eccentricity = 0.001mm

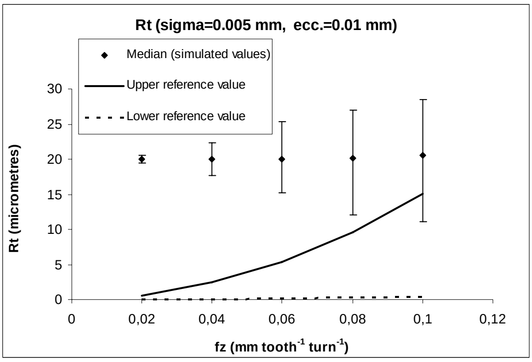

Figure 6. Intervals of variation of R_t as a function of f_z for σ = 0.005 mm and eccentricity = 0.01mm

The results show that, if low eccentricity is considered (Ecc = 0.001 mm) (Figures 2 and 5), roughness increases for low feed values with respect to the case with no eccentricity (Figures 1 and 4). For low eccentricity and higher feed values, the median of the roughness values increases with feed, in a similar way to the case with no eccentricity, showing that the effect of runout is more important than the effect of eccentricity. On the contrary, if a higher eccentricity is considered (Ecc = 0.01 mm) (Figures 3 and 6), roughness increases for all the feed values considered with respect to the case with low eccentricity, exceeding the upper reference value except for some roughness values with f_z = 0.1 mm $turn^{-1}$ $tooth^{-1}$. In addition, the medians of the roughness for the different feed values become almost equal. The effect of eccentricity is more important than the effect of runout in this case.

4. CONCLUSIONS

The main conclusions of this work are:

- A sensible increase of the tool eccentricity increases roughness. The roughness intervals exceed the upper reference roughness value for most feed values. Similar median values are obtained regardless the feed used. The effect of the eccentricity prevails over the effect of the runout.
- For low eccentricity and low feed, the effect of eccentricity on the roughness increment is more important than for higher feed values. Thus, for high feed values the effect of the tool runout prevails over the effect of the tool eccentricity.

5. ACKNOWLEDGMENTS

The authors would like to thank the Spanish Ministry of Science and Education for the financial support of Project DPI2007-66546 and Mr. Ramón Casado for the measurement of the tools.

6. REFERENCES

[1] Saï W.B., Salah N.B., Lebrun J.L.: Influence of machining by finishing milling on surface characteristics, International Journal of Machine Tools and Manufacture 41 (3) (2001) 443-450.

[2] Lee K.Y., Kang M.C., Jeong Y.H., Lee D.W., Kim J.S.: Simulation of surface roughness and profile in high-speed end milling, Journal of Materials Processing Technology 113 (1-3) (2001) 410-415.

[3] Franco P., Estrems M., Faura F.: Influence of radial and axial runouts on surface roughness in face milling with round insert cutting tools, International Journal of Machine Tools and Manufacture 44 (2004) 1555-1565

[4] Vivancos J., Luis C.J., Ortiz J.A., González H.A.: Analysis of factors affecting the high-speed side milling of hardened die steels, Journal of Materials Processing Technology Volumes 162-163 (2005) 696–701.

[5] H. González Rojas, I. Buj Corral, J. Vivancos Calvet, Numerical simulation model for the determination of surface roughness in side milling as a function of feed and of the tool edges radii, Proceedings of the 12th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology" TMT 2008. Istanbul (2008) 89-92.

[6] H. González Rojas, I. Buj Corral, J. Vivancos Calvet, Influence of runout on the surface roughness obtained in side milling processes, Proceedings of the 3rd International Manufacturing Engineering Society Conference. MESIC 09. Alcoy (Spain) (2009) 83-90.