EFFECT OF TOOL GEOMETRY

AND NOSE PROFILE MICRO-DEVIATION

ON SURFACE ROUGHNESS IN FINISH TURNING

SUNG AUN NAA

UNIVERSITY SAINS MALAYSIA

2015

EFFECT OF TOOL GEOMETRY AND NOSE PROFILE MICRO-DEVIATION ON SURFACE ROUGHNESS IN FINISH TURNING

by

SUNG AUN NAA

Thesis submitted in fulfillment of the requirements

for the degree of

doctor of Philosophy

AUG 2015

ACKNOWLEDGEMENT

I would like to thank my supervisor, Prof. Dr. Mani Maran Ratnam. He was supervising me patiently, always guiding me in the right direction and make my Ph.D. experience productive and stimulating. I could not have finished my thesis successfully without his help. Prof. Dr. Mani Maran Ratnam is profound knowledge in image processing and his positive spirit has been a great source of inspiration to me. Special thanks are also given to my co-supervisor Dr. Loh Wei Ping for her help and encouragement in my work.

I would like to acknowledge the financial, academic and technical support of the University. This work was funded by the USM Fellowship and the Research University research grant.

Lastly, I would like to thank my family for all their love and encouragement. For my parents Sung Foo Heng and Ng Mooi See, husband William Lee Chiew Sing, brother Sung Yew Chong and Sung Yew Fong and sister Sung Aun Nee, I would like to thank for their unequivocal supports.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ALGORITHMS

LIST OF SYMBOLS

5X	the magnification of the lens
*	Convolution operator
α	Angle between left straight flank with vertical line (Figure 3.17)
κ_r	Major cutting edge angle
κ_r'	Side cutting edge angle
λ	Inclination angle
γ	Rake angle
ϵ_r	Included angle
Ω	Rotation angle to locate nose profile at appropriate side cutting edge angle
ϕ	Angle between *OL* and vertical line (Figure 3.21)
θ_e	Angle measured counterclockwise between the vertical line and the line connecting the point *O* to each nose profile point P_e (Figure 3.19)
θ_J	Start angle of rounded nose of edge profile
θ_K	End angle of rounded nose of edge profile
θ_L	Start angle of tool-workpiece interface
θ_l	Angle between left straight flank and the horizontal line (Figure 3.19)
θ_M	End angle of tool-workpiece interface
θ_r	Angle between right straight flank and the horizontal line (Figure 3.19)
ψ_1	Possibility of the data not come from a normally distributed population
ψ_2	Possibility of the data $R_{s(n_z+1)}$ will fall within the range

ΔT	Sampling interval
a	Major semi-axis of elliptical arc
a_p	Predefined value for *DFP*
b	Minor semi-axis of elliptical arc
c_t	Constant to provide 50% transmission characteristic at the cut-off wavelength
D	Diameter of workpiece
d_a	Difference between the x-coordinate (x_N) of point N and x-coordinate (x_E) of point E (Figure 2.1)
d_b	Horizontal distance between the peak and adjacent valley of the arc of the surface profile at the cutting portion produced by the rounded nose (Figure 2.1)
d_e	Difference between y-coordinate (y_e) of the nose profile and y-coordinate (y_l) of the last detected pixel at the probable edge point in a column
DFP	Difference between the y-coordinates of the first pixel at the probable edge point that detected from bottom up for two columns in image V_b
D_n	Lilliefors' test statistic
d_s	Tool cutting path in the circumferential direction
e	Euler number
E	Intersection point of the minor cutting edge and rounded nose as (Figure 2.1)
e_u	Threshold value to select the probable edge point in the tool image
f	Feed rate
g_1	Gradients of left straight flank of a tool
g_2	Gradients of right straight flank of a tool
$h(k)$	Displacement-frequency discrete signal

$h(p)$ Displacement-time discrete signal

$h(q)$ Displacement-frequency continuous signal

$h(t)$ Displacement-time continuous signal

i Imaginary number

j Row in image

L Start point of tool-workpiece interface

l_e Surface roughness evaluation length

l_m Total row in image

l_n Total column in image

l_r Length of the tool cutting path in one revolution

l_s Surface roughness sampling length

l_w Length of machined part of a workpiece

M End point of tool-workpiece interface

$\overline{m_c}$ Moments along the pixels at the probable edge points in image V_b, c is 1, 2 or 3

N Lowest point of the nose profile (Figure 2.1)

n_d Number of independent predicted data

n_p Point of workpiece

n_r Number of nose profile points P_e restricted in the rounded nose

n_s Number of selected points at the straight flanks

n_x Number of the pixels at the probable edge points in each column

n_z Sample size

p_1 Ratio d_e to n_x

P_d Rotated nose profile

P_{df} Nose profile contains the nose profile micro-deviation and nose wear

P_{dn} Rotated nose profile from new tool nose

P_{dw} Rotated nose profile from worn tool nose

P_e Nose profile

P_m Mean line workpiece profile

P_r Roughness workpiece profile

P_u Unmodified workpiece profile

r Nose radius

R_a Arithmetic average roughness

r_e Radial distance

R_{max} Highest peak roughness

R_{min} Lowest valley roughness

r_n Nominal nose radius

r_{opt} Optimum nose radius

r_p Predefined nose radius

R_q Root-mean-square roughness

R_s Average Surface roughness data of a workpiece obtained from simulation

R_t Maximum peak-to-valley roughness

R_w Surface roughness data in each workpiece obtained from simulation

R_z Ten-point roughness

s_1 First Sobel operator

s_2 Second Sobel operator

s_k Sampling frequency

s_R Standard deviation of the average surface roughness values of different workpiece

s_w Standard deviation of the surface roughness values of different points at workpiece

t Time

T Time period

$t.v$ Translation value

$t_{0.975,n_z-1}$ 97.5% quantile of a Student's t-distribution with n_z-1 degrees of freedom

u Spindle speed

U_m Image that having pixels with value represent the gradient of gray level in the x- and y-directions of the corresponding pixel in image V_{gs}

U_x Image that having pixels with value represent the gradient of gray level in the x-direction of the corresponding pixel in image V_{gs}

U_y Image that having pixels with value represent the gradient of gray level in the y-direction of the corresponding pixel in image V_{gs}

V_b Image consists of nose edge band

$v_c(k)$ Clean velocity-frequency discrete signal

$v_c(p)$ Clean velocity-time discrete signal

$v_e(k)$ Noise velocity-frequency discrete signal

$v_e(p)$ Noise velocity-time discrete signal

V_{gs} Gray-scale image

$v(p)$ Velocity-time discrete signal

$v(q)$ Velocity-frequency continuous signal

$v(t)$ Velocity-time continuous signal

$v_y(k)$ Noisy velocity-frequency discrete signal

$v_y(p)$ Noisy velocity-time discrete signal

w Weighing function

W_n Cutting edge normal plane

W_r Main reference plane

W_s Tool cutting edge plane

x_d x-coordinate of a point on the rotated nose profile P_d

x_e x-coordinate of a point on the nose profile P_e

x_i Number of a column in an image

x' Distance from the center (maximum) of the weighting function

y_d y-coordinate of a point on the rotated nose profile P_d

y_{df} y-coordinate of a point on the nose profile P_{df}

y_{dw} y-coordinate of a point on the nose profile P_{dw}

y_{dn} y-coordinate of a point on the nose profile P_{dn}

y_e y-coordinate of a point on the nose profile P_e

y_J Approximate y-coordinate of the point J

y_i Number of a row in an image

y_K Approximate *y*-coordinate of the point *K*

y_{min} Minimum *y* value

y_N Maximum *y*-coordinate of a point on the nose profile P_e