CRANFIELD UNIVERSITY

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MACHINING SURFACES OF OPTICAL QUALITY BY HARD TURNING

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PhD Thesis

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ABSTRACT

The main aim of this work was the machining by hard turning of surfaces with optical surface quality. A numerical target had been set as a surface roughness $R_a = 10nm$.

It has been shown that achieving roughnesses of that magnitude by hard turning is possible. Individual work pieces exhibited the desired surface properties for short lengths at a time, but it proved to be very difficult to achieve these surfaces consistently and over longer cuts. The factors influencing the surface roughness were identified as tool defects and machine vibration in addition to the standard cutting parameters and choice of cutting tool.

A model of surface generation in hard turning has been developed and good correlation between simulated and experimentally determined surface roughnesses was achieved. By introducing a material partition equation which determines the proportional contribution of material removal mechanisms in the undeformed chip a comprehensive method for assessing the contributing factors in material removal was developed. While it has been shown that surfaces in hard turning are almost exclusively generated by chip removal and plastic deformation the developed model is versatile enough to include elastic deformation of the work piece.

With the help of the model of surface generation in hard turning it has been possible to attribute magnitudes of the influencing factors with respect to the cutting parameters such as feed rate and tool corner radius, and the main disturbances – tool defects and machine vibration. From this conclusions were drawn on the requirements for machine tools and cutting tools, which will need to be realised to make ultra-precision hard turning of surfaces of optical quality a feasible manufacturing process.

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NOTATION

Capital Letters

A_α	Flank
$A_{\alpha 1}$	Major first flank
$A_{\alpha 1}'$	Minor first flank
$A_{\alpha 2}$	Major second flank
$A_{\alpha 2}'$	Minor second flank
A_γ	Face
$A_{\gamma 1}$	Major first face
$A_{\gamma 2}$	Major second face
$F_{\gamma n}$	Force normal to the chip
$F_{\chi n}$	Force normal to the major cutting edge
$F_{\gamma t}$, $F_{\gamma t}'$	Force tangential to the chip
F_c	Cutting Force
HRc	Hardness Rockwell 'C'
HV	Hardness Vickers
L	Evaluation Length or Sampling Length
M	Reference line
P_r	Tool reference plane
R_a	Surface finish parameter (Roughness Average)
R_t	Surface finish parameter (Peak-to-Valley height)
S	Major cutting edge
S'	Minor cutting edge
S_m	Mean width of the profile elements
V_B	Wear mark width

Lower case letters

a_p	Depth of cut
f	Feed
h	Undeformed chip thickness
h_{min}	Minimum undeformed chip thickness
p_{cut}	Proportion of chip removal
$p_{elastic}$	Proportion of elastic deformation
$p_{plastic}$	Proportion of plastic deformation
r_n	Rounded cutting edge radius
r_ε	Tool corner radius
t	Time
t_c	Cutting time
v_c	Cutting speed
y_i	Profile point
y_{max}	Highest profile point
y_{min}	Lowest profile point
c_i	Calculation constants

Greek letters and symbols

Δh_{el}	Elastically deformed proportion of undeformed chip thickness
Δh_{pl}	Plastically deformed proportion of undeformed chip thickness
κ_{re}	Tool cutting edge angle
$\Phi(x)$	Heaviside Step Function
Θ	Stagnation point angle
σ	Standard deviation

Abbreviations

CBN	Cubic Boron Nitride
CGI	Compacted Graphite Iron
CVT	Continuously Variable Transmission
DSP	Digital Signal Processing
PCBN	Polycrystalline Cubic Boron Nitride