RAMP Submission: Manual Grinding Operation

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Manual Grinding Operation: Graphical Representation

Product & Process Information

Job Information

Part Description: Surface Topographical Test
Geometry: ½ ″ Square Coupon
Material: 304 Stainless Steel
Operations: Manual Grinding
Required Tool: Alumina sanding bands

Variable definitions for transformation equations

Vs = Cutting wheel rotational speed (mm/sec)
D= Wheel diameter (mm)
n= Wheel revolution per minute
b_w = Width of wheel contact to workpiece
F_t= Tangential Force
Q′ = Specific removal rate
e_c = Specific grinding energy
h_{eq} = Equivalent Chip Thickness
ρ = Density (kg/mm3)
Zi(x)=Zo(x)= Initial and Final surface height variation at x distance
υw = Workpiece velocity
Fn = Normal force
MRR= Material Removal Rate
μ= Coefficient of Grinding
ae = Depth of cut
Ra= Average surface roughness
Rt=Maximum surface roughness
P= Grinding Power

Inputs

Processing energy,
Workpiece Material i.e. steel
Tool geometry
Grinding force= *f* (Worker's Experience, Tool Wear, Manual Feed)

Transformation Equations

$$Vs = \frac{\pi Dn}{1000x60}$$

$$heq = \frac{ae * vw}{vs}$$

$$Q' = \frac{\Delta\rho\Delta Volume}{\Delta t}$$

$$ec = \frac{Ft * vs}{Q'}$$

$$P = Ft * vs$$

$$\mu = \frac{Ft}{Fn}$$

$$Pm = VI$$

$$\Lambda = \frac{Q'}{Fn}$$

$$ae = \frac{\Delta V}{L * w}$$

$$\nabla Ra = \frac{1}{L}\int_0^L | Zo(x) - Zi(x) | dx$$

$$Rt \alpha \frac{h_{eq}^{1.33}}{a_e^{0.33}}$$

Outputs

Finished part
Roughness_final = *f* (Ft)
MRR= *f* (Ft, Fn)
Waste
Heat,
Broken Chips

Resources

Operator: Jayanti Das
Machine: 4000 Handheld Dremel

Tool List: (1) 1/4″ mandrel
(2) Alumina abrasive sanding bands
(3) Piezoelectric force sensor
Fixture Details: Tool orientation,
Low cutting speed
Software: NI DAQ and Labview

Transformation Functions for Manual Grinding (in ASCII)

$V_s = (π * $D * $n)/ (1000*60)

$h_eq= ($a_e * $V_w)/($V_s)

$MRR= (diff$ρ * diff$Volume)/(diff$t)

$e_c= ($F_t * $V_s)/MRR

$P=$F_t * $V_s

$μ = $F_t/$F_n

$P_m = $V * $I

$ʌ = $MRR/$F_n

$a_e= Delta $V/($L * $W)

grad $R_a= int_0^L |quad|$Zo(x)− $Zi(x) / $L d(x)

$R_t ∞ (($h_eq)^1.33)/(($a_e)^0.33)

Description of Nomenclature

Nomenclature of the Input keys for the transformation functions in Manual Grinding Operation

Name	Meaning	Type	Unit
Machine	Name of the machine	Parameter	
Material_type	Workpiece type (Material)	Parameter	
Material_length	Workpiece length	Parameter	mm
Material_width	Workpiece width	Parameter	mm
D	Diameter of the abrasive wheel	Parameter	mm
n	Spindle Speed	Variable	Rpm
V_s	Rotational Cutting Speed	Variable	m/sec
V_w	Workpiece Velocity	Variable	m/s
a_depth	Depth of cut	Variable	mm
F_tangential	Tangential Force	Variable	N
F_normal	Normal Force	Variable	N
V	Voltage	Parameter	V
I	Current	Parameter	Amps
h_eq	Equivalent Chip Thickness	Variable	mm
Q´	Material removal rate	Variable	Kg/s

Nomenclature of the Output keys for the transformation functions in the Manual Grinding

Name	Connection to computed values
Surface roughness	= $SurfaceRoughness
Microstructure Deformation	= $MicrostructureDeformation
Microhardness	= $Microhardness
Energy	= $Energy

Nomenclature of the Computed values for Manual Grinding

Name	Meaning	Type	Unit
V_s	Rotational Cutting Speed	Variable	m/s
Q´	Material removal rate	Variable	mm^3/s
e_specific	Specific energy of grinding processes	Variable	J/mm^3
P_spindle	Spindle power	Variable	W
µ	Friction coefficient	Variable	Unit less
P_motor	Motor power	Parameter	W
Stock removed	Stock removal rate	Variable	(mm^3/Ns)
a_depth	Depth of cut	Variable	mm
Roughness	Roughness parameter	Variable	µm

Description of Information Sources

MODEL SOURCE

UMP Name: Manual Grinding

Source Name: Effect of Manual Grinding Operations on Surface Integrity Jayanti Das, Dr. Barbara Linke 06/19/2016

Where on the web: www.sciencedirect.com; http://dx.doi.org/10.1016/j.procir.2016.02.091

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README Section

ZIP folder directory includes:

1) RAMP Submission

Manual Grinding.pdf - PDF file completing the submission requirements (this file)

2) Code Folder

Manualgrinding.pdf-a PDF copy of a Matlab file that calls on a transformation equation to run the model

3) Resource Folder

a. ManualGrinding_reference2.pdf – a PDF copy of the primary reference used to construct

b. ManualOperation_reference1.pdf – a PDF copy of the primary reference used in description

Brief Narrative

Manual grinding operations are prominently used in repair, construction, foundries, welding to cut, remove burrs, improve surface quality, remove slag, etc. Compared to the automated grinding process, manual grinding operations are critically dependent on worker's posture, motion, gripping forces, process knowledge and personal skill level. Moreover, accidents with power tools account for 2/3 of accidents with grinding machines and cause severe health issues with irreversible medical effects (Odum et al., 2014). In addition, poor control of the machining process may influence the geometrical and physical properties of the machined surfaces, especially under dry cutting condition.

Manual abrasive finishing processes have a growing market but these sectors are under-researched. Limited researches have been reported in the literature about manual processing parameters and their corresponding effect on surface integrity. Generally, automated grinding processes are 'path controlled' processes, where abrasive cutting wheels are running under a constant rotational speed and apply a precise pressure on the workpieces. In contrast, manual grinding is a 'force controlled' process, where manual feed causes three dimensional force variations on workpieces (i.e. tangential, axial, and normal) in an unpredictable way. These three dimensional force variations have direct impact on friction, chip thickness, and on specific energy consumption of the processes (Fig 1). In addition, the operator might change the force or tool engagement area intermittently depending on the force-feedback and tool wear. The material removal rate and depth of cut result from the applied pressure. Therefore, understanding the cutting forces in manual finishing operations are challenging and required to develop process model to monitor the impact of processing parameters on surface integrity (Jourani et al., 2013).

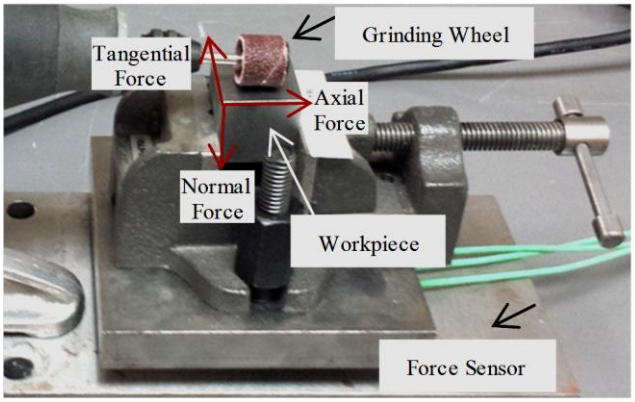

Fig. 1: Understanding Cutting Forces in Manual Grinding Processes (Das and Linke, 2016)

In order to overcome these limitations, we investigated manual grinding processes under dry cutting conditions and observed the influence of processing parameters on surfaces mechanical and metallurgical properties (i.e. hardness, force ratio, microstructure, etc.). We have analyzed the processing energy, resulting surface integrity, and prospective part performance, considering the above-mentioned variants, with the aim to give a detailed insight into manual grinding processes and fill the existing knowledge gaps.

We represented the input-output stream and other necessary processes in MATLAB. The models are based on existing physics-based model from grinding operations. Figure 2 represents the screenshot of input parameters and transformation equations.

```
clc
clear all
% Process Type: Manual Grinding Operation
%Material: 304 Stainless Steel Type
%Input Parameters
%Dimension of parameters, All dimensions are in mm
L=12.7; %Length of workpiece in mm
W=12.7; %Width of workpiece in mm
H=12.7; %Height of workpiece in mm
D=6.35; %Diameter of cutting wheel in mm
n=5000; %Rotational cutting speed of cutting wheel in rpm
Vw=0.5; %Workpiece feed in m/s
row=0.008; %Density of 304 Stainless Steel material in g/mm3
del_vol=3.2258; %Volume removed per rotation of grinding in mm
del_t= 60; %Grinding time in sec
F_t=0.25; %Tangential force in N
F_n=2; %Normal force in N
% Output Parameters
Vs= ((pi*D*n)/(1000*60))%Cutting speed of abrasive wheel in mm/s
ae=((del_vol)/(L*W)) %depth of cut per grinding cycle in mm
heq=((ae*Vw)/Vs) %Equivalent chip thickness in mm
Q=(del_vol/del_t) %Material removal rate in mm3/s
ec=((F_t*Vs)/Q) %Specific grinding energy in J/mm3
P=F_t*Vs %Grinding power in Watt
meu= F_t/F_n  %Friction Co-efficient
s_r= Q/F_n %Stock removal rate in mm3/Ns
syms x
Ra= (x/8) %Average roughness in um
int (Ra,x,2.6,4.1)
```

Fig 2: Expression for input parameters and transformation equations in Matlab.

The dry cutting conditions increase the possibility of thermal damages during machining processes (Zhu et al., 2015). We are investigating on the energy consumption, force variation, rate of removed volume, specific cutting energy, roughness variation, microstructure and microhardness variation for 304 stainless steel surfaces.

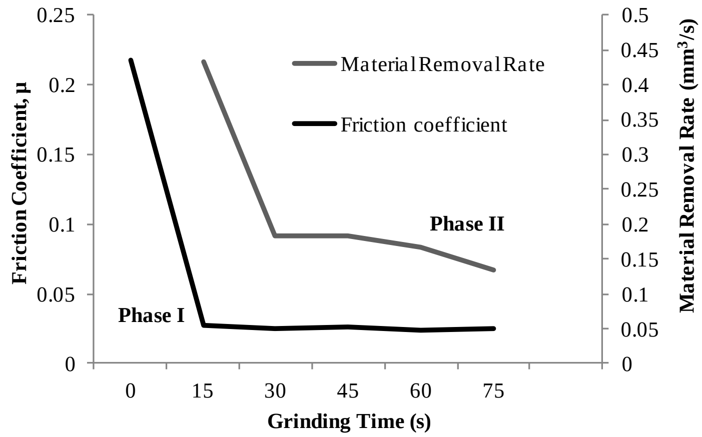

Fig.3. Relationship between Specific Energy with Material Removal rate (Das and Linke, 2016)

The experimental results showed that under dry cutting condition, for a certain volume of material, manual grinding operation consumes lower specific energy while increasing the material removal rate. By increasing the processing time, tool wear, frictional energy losses, chip thickness increases. The dry cutting condition causes localized heat generation and results plastic deformation on the surface and subsurface region. This thermal damage also impacts the metallurgical properties of the machined surfaces and changes microhardness properties of the ground surfaces.

References

Das, J., Linke, B., 2016. Effect of Manual Grinding Operations on Surface Integrity. Procedia CIRP 45, 95-98.

Jourani, A., Hagège, B., Bouvier, S., Bigerelle, M., Zahouani, H., 2013. Influence of abrasive grain geometry on friction coefficient and wear rate in belt finishing. Tribology International 59, 30-37.

Odum, K., Castillo, M.C., Das, J., Linke, B., 2014. Sustainability Analysis of Grinding with Power Tools. Procedia CIRP 14, 570-574.

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