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## “FORCE ANALYSIS OF GRINDING WHEEL ON DIFFERENT MATERIAL”

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### Abstract

Grinding is an important manufacturing process and it is traditionally regarded as a final machining process in the production of components requiring smooth surfaces and tight tolerances. Despite its industrial importance, the productivity of grinding is comparatively less and the operating cost is higher compared to other machining processes. Therefore, there has always been a strong need for improving the productivity and reducing the cost of grinding processes.

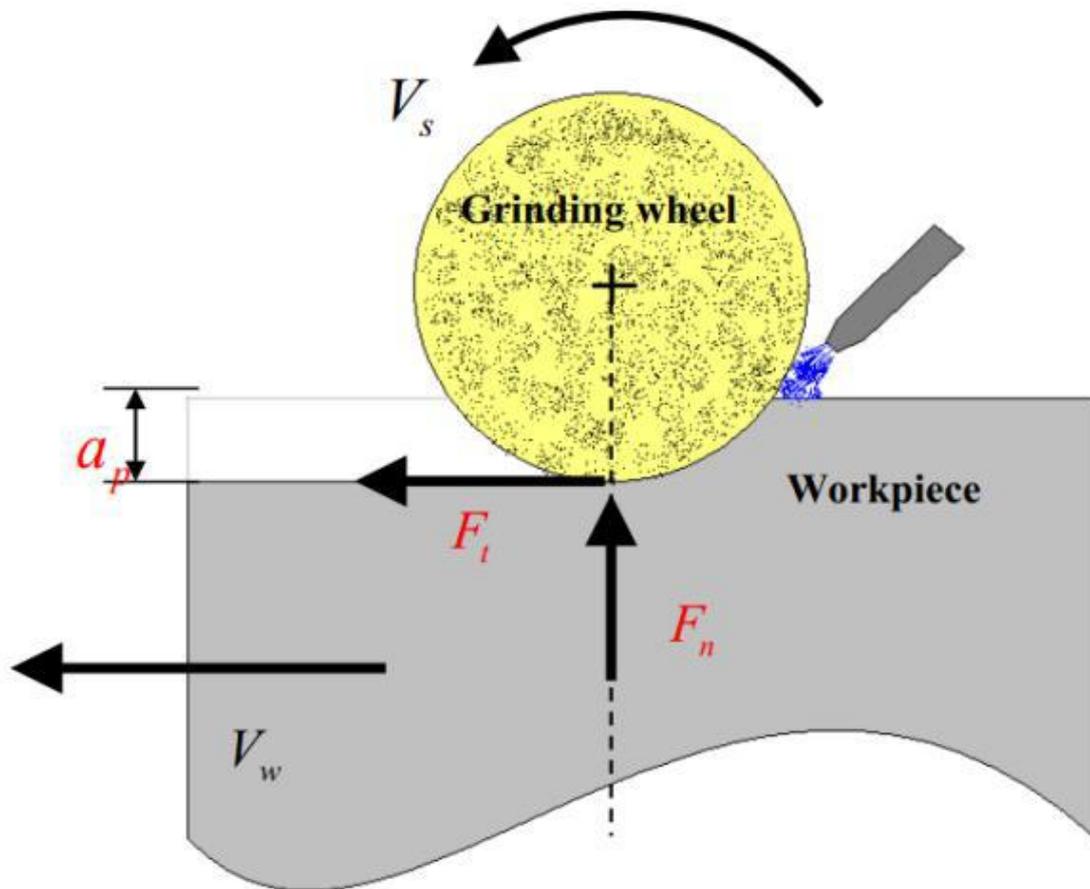
#### Chapter 1 INTRODUCTION

This section provides a general overview of the grinding process with a brief introduction on the grinding wheels, geometry of grinding process, and grinding mechanisms.

In grinding forces are generated by two mechanisms, chip formation and friction. Forces are generated by structural elements of the grinding wheel which are in physical contact with the work piece. Actually the friction related part of the total grinding force can be greater than the part related to the chip formation under certain conditions. These two types of grinding forces cannot be clearly distinguished because they always come together in the chip formation process. The cutting force determines the wheel life and wear, the accuracy and finish of the machine surface, energy consumption and other criteria of grinding process. In order to study the effect of wheel loading on various materials, some experiments were conducted. With the work piece mounted on a dynamometer, the radial force and tangential force measurement was achieved.

## 1.2 Geometry of Grinding Process

Figure 1 shows the typical geometry of the grinding process, is a detailed view of an abrasive grain traveling along the workpiece, showing the uncut chip.



### Chapter 2

#### PROBLEM STATEMENT:

The surface roughness is dependent on the cutting force exerted by the grinding wheel on the workpiece so to improve the surface roughness the forces will be calculated for different workpiece material

#### OBJECTIVES:

- To analyze the effect of cutting force on various work piece material.
- To analyze the effect of speed and depth of cut on cutting force.
- To analyze cutting force of same grinding wheel on different material.
- To make the comparative analysis between the experimental and analytical result.

**METHODOLOGY:**

- Step 1: - I started the work of this project with literature survey. I gathered many research papers which are relevant to this topic. After going through these papers, I learnt about Evaluation of cutting forces in Grinding for various metals using Experimental And FEA.
- Step2: - After that the components which are required for my project will be decided.
- Step 3: - After deciding the components, the 3 D Model and drafting will be done with the help of CATIA software.
- Step 4: - The components will be manufactured and then assembled together.
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- Step 5: - The Experimental Testing will be carried out.
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- Step 6: - The Analysis will be carried out with the help of ANSYS software.
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- Step 7: - The comparative analysis will be done between experimental observations and analysis and the result and conclusion will be drawn.
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**Chapter 3****Experimental Setup and Tooling**

Grinding experiments were carried out on a 5-axis high-speed, high-power horizontal machining center Makino A88ε having the following characteristics: 50 kW spindle, 3 linear and 2 rotary axes, maximum spindle speed of 18,000 rpm, maximum feed rate of 50 m/min, minimum feed setting unit of 1μm, and HSK 100A spindle adapter.

Figure 8: Experimental Set up.

- 1 - Grinding wheel
- 2 - Workpiece
- 3 - Chuck
- 4 - Dynamometer
- 5 - Power sensor
- 6 - Coolant nozzle
- 7 - Wash nozzle
- 8 - Machine spindle
- 9 - Drive motor

10 - Power source11 - Data acquisition system (Charge amplifier and

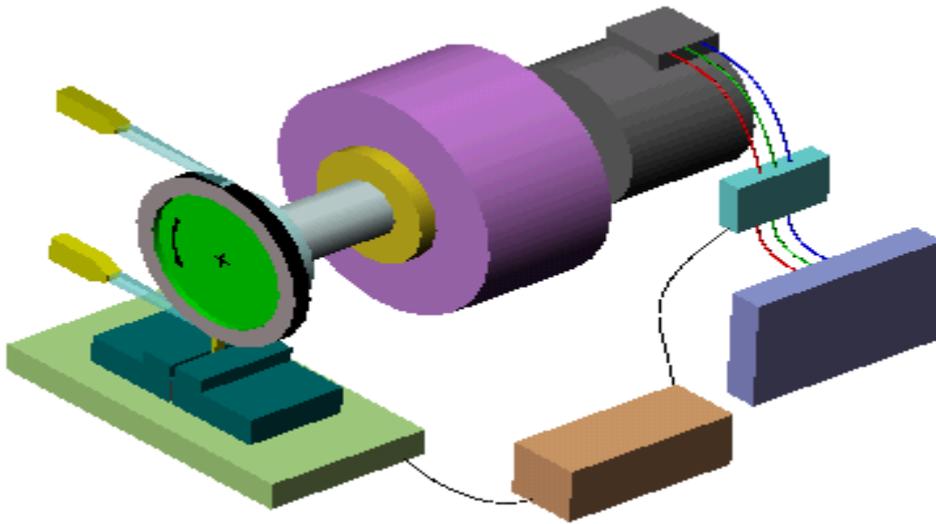


Figure 9: Measurement of force by using dynamometer.



**Experimental Results(high Chromium Steel)**

Sr No	Speed	Feed	Depth of cut	FT	FR	R
1	4500	0.0667	0.03	62	29	68.44
2	4500	0.0667	0.06	65	38	75.30
3	4500	0.0667	0.09	36	25	43.82
4	4500	0.0833	0.03	38	25	45.48
5	4500	0.0833	0.06	65	34	73.35
6	4500	0.0833	0.09	62	43	75.45
7	4500	0.1	0.03	65	40	76.32
8	4500	0.1	0.06	41	46	61.61
9	4500	0.1	0.09	74	38	83.18
10	6000	0.0667	0.03	71	51	87.41
11	6000	0.0667	0.06	158	143	213
12	6000	0.0667	0.09	67	132	148.03
13	6000	0.0833	0.03	35	33	48.10
14	6000	0.0833	0.06	51	130	139.64
15	6000	0.0833	0.09	99	92	135.14
16	6000	0.1	0.03	129	79	151.26
17	6000	0.1	0.06	111	56	124.32
18	6000	0.1	0.09	95	116	149.93

17	6000	0.1	0.06	111	56	124.32
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**Experimental Result (Stainless steel)**

Sr No	Speed	Feed	Depth of cut	FT	FR	R
1	4500	0.0667	0.03	59	28	68.44
2	4500	0.0667	0.06	106	37	75.30
3	4500	0.0667	0.09	51	45	43.82
4	4500	0.0833	0.03	50	27	5.48
5	4500	0.0833	0.06	78	30	73.35
6	4500	0.0833	0.09	79	42	75.45
7	4500	0.1	0.03	41	19	76.32
8	4500	0.1	0.06	72	21	61.61
9	4500	0.1	0.09	64	35	83.18
10	6000	0.0667	0.03	34	12	87.41
11	6000	0.0667	0.06	85	46	213
12	6000	0.0667	0.09	82	78	148.03
13	6000	0.0833	0.03	79	63	101.04
14	6000	0.0833	0.06	85	43	95.25
15	6000	0.0833	0.09	117	88	146.40
16	6000	0.1	0.03	81	12	81.88
17	6000	0.1	0.06	87	103	134.83
18	6000	0.1	0.09	58	55	79.93

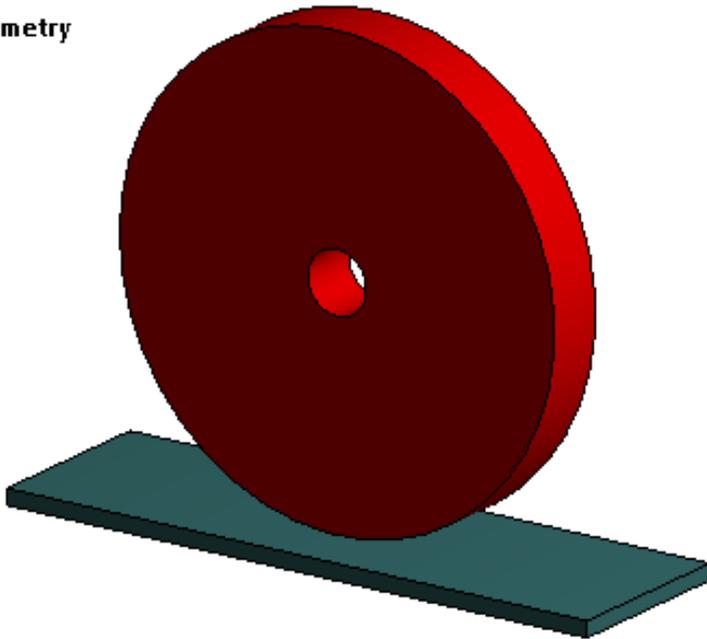
**Experimental Result (Mild steel)**

Sr No	Speed	Feed	Depth of cut	FT	FR	R
1	4500	0.0667	0.03	59	28	68.44
2	4500	0.0667	0.06	106	37	75.30
3	4500	0.0667	0.09	51	45	43.82
4	4500	0.0833	0.03	50	27	5.48
5	4500	0.0833	0.06	78	30	73.35
6	4500	0.0833	0.09	79	42	75.45
7	4500	0.1	0.03	41	19	76.32
8	4500	0.1	0.06	72	21	61.61
9	4500	0.1	0.09	64	35	83.18
10	6000	0.0667	0.03	34	12	87.41
11	6000	0.0667	0.06	85	46	213
12	6000	0.0667	0.09	82	78	148.03
13	6000	0.0833	0.03	79	63	101.04
14	6000	0.0833	0.06	85	43	95.25
15	6000	0.0833	0.09	117	88	146.40
16	6000	0.1	0.03	81	12	81.88
17	6000	0.1	0.06	87	103	134.83
18	6000	0.1	0.09	58	55	79.93

## Chapter 4

**Computer-aided design (CAD)** is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for Computer-aided engineering (CAE) and Finite element analysis (FEA)

### Geometry



## Chapter 5

### ANALYSIS:

The **finite element method (FEM)**, is a numerical method for solving problems of engineering and mathematical physics. Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential.

Properties of Outline Row 3: ABRASIVE MATERIAL			
	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	2130	kg m <sup>-3</sup> ▼
4	Isotropic Elasticity		
5	Derive from	Young's Modulu... ▼	
6	Young's Modulus	42.5	MPa ▼
7	Poisson's Ratio	0.3	
8	Bulk Modulus	35.417	MPa
9	Shear Modulus	16.346	MPa

Material Properties of Abrasive material

**MESH**

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient multiphysics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation.

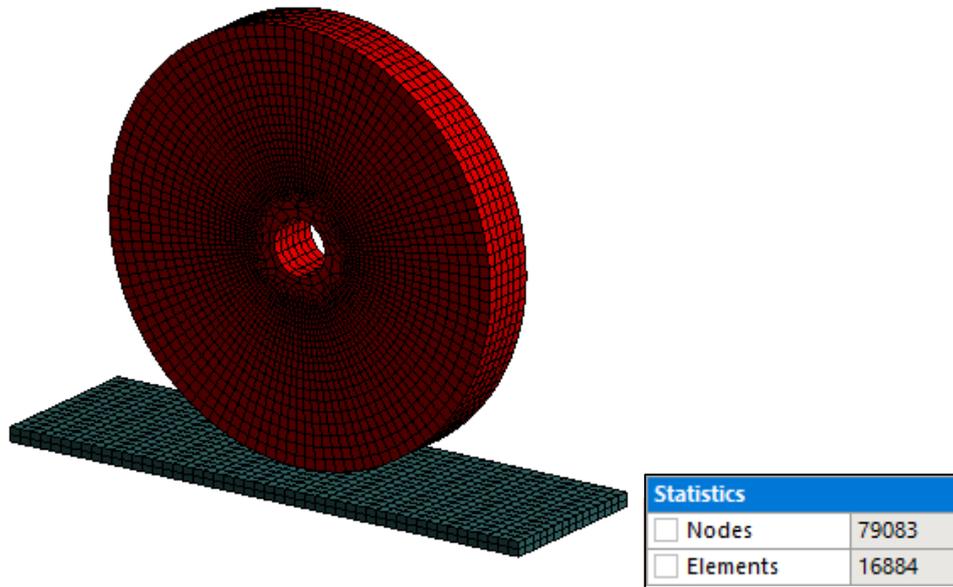


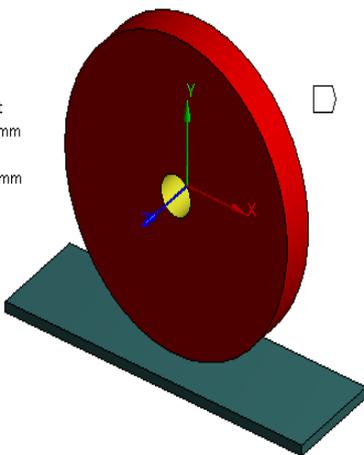
Fig. 7 Meshing of Steel Plate Grinding

**Boundary Condition**

A boundary condition for the model is the setting of a known value for a displacement or an associated load. For a particular node you can set either the load or the displacement but not both.

**B: STEEL GRINDING**  
Remote Displacement  
Time: 1. s

Remote Displacement  
Components: 0, 0, 0. mm  
Rotation: 0, 0, Free \*  
Location: 100, 75, 0. mm



**C: ALUMINIUM**  
Rotational Velocity  
Time: 1. s

Rotational Velocity:  
Components: 0, 0, 4500. RPM  
Location: 0, 0, 0. mm

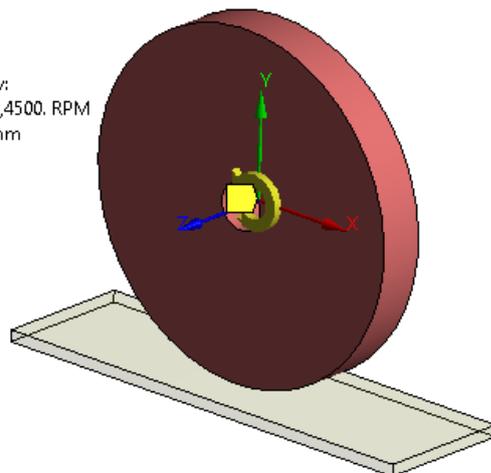


Fig. 10 Boundary Condition on Steel Plate Grinding Fig. 11 Boundary Condition on Aluminium Plate Grinding

Fig. 12 Boundary Condition on Cast Iron Plate Grinding

## Total Deformation

The total deformation & directional deformation are general terms in finite element methods irrespective of software being used.

Directional deformation can be put as the displacement of the system in a particular axis or user defined direction.

Total deformation is the vector sum all directional displacements of the systems.

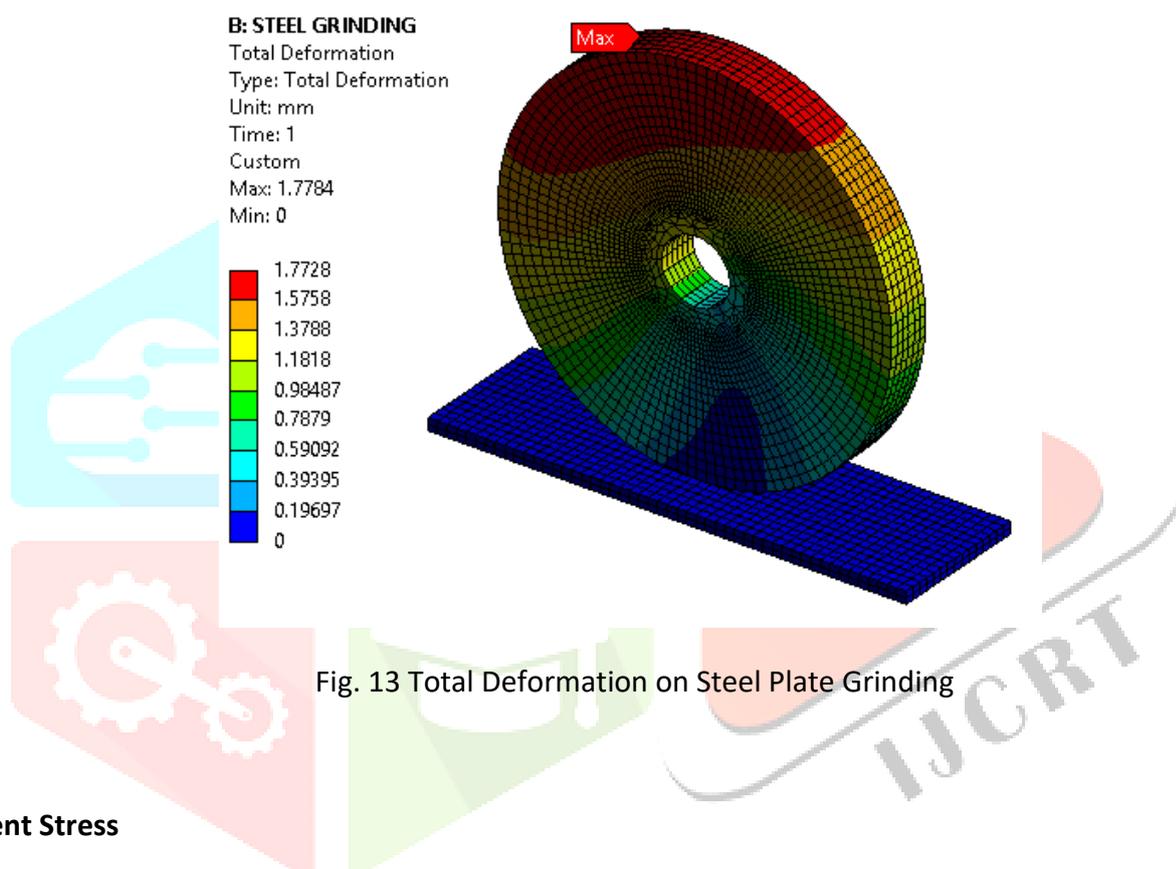


Fig. 13 Total Deformation on Steel Plate Grinding

## Equivalent Stress

Equivalent stress is related to the principal stresses by the equation:

$$\sigma_e = \left[ \frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2} \right]^{1/2}$$

Equivalent stress (also called *von Mises stress*) is often used in design work because it allows any arbitrary three-dimensional stress state to be represented as a single positive stress value. Equivalent stress is part of the maximum equivalent stress failure theory used to predict yielding in a ductile material.

The von Mises or equivalent strain  $\epsilon_e$  is computed as:

$$\epsilon_e = \frac{1}{1+\nu'} \left( \frac{1}{2} \left[ (\epsilon_1 - \epsilon_2)^2 + (\epsilon_2 - \epsilon_3)^2 + (\epsilon_3 - \epsilon_1)^2 \right] \right)^{\frac{1}{2}}$$

Where:

$\nu'$  = effective Poisson's ratio

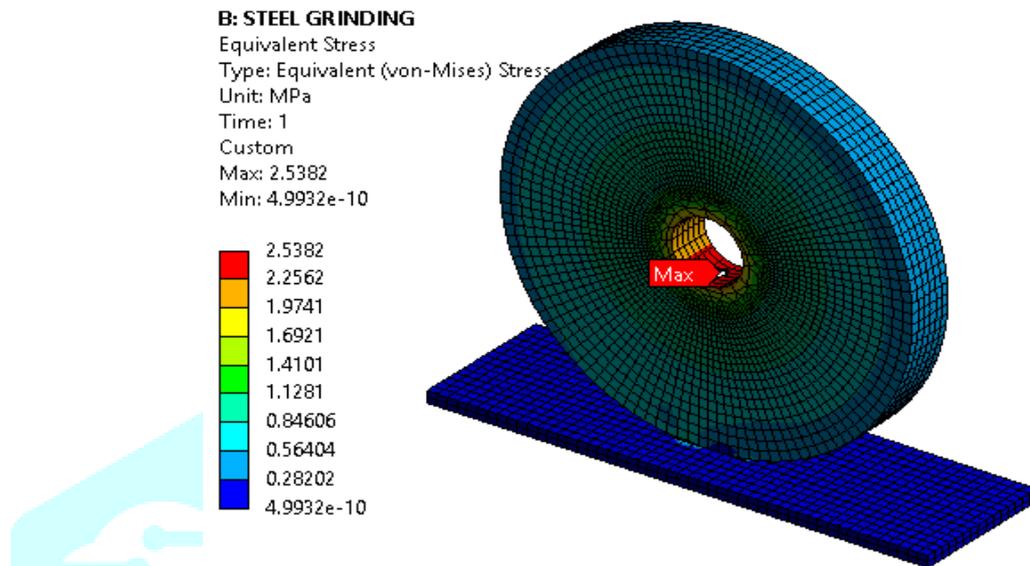


Fig. 15 Equivalent Stress on Steel Plate Grinding

Force Reaction:

**B: STEEL GRINDING**  
 Force Reaction

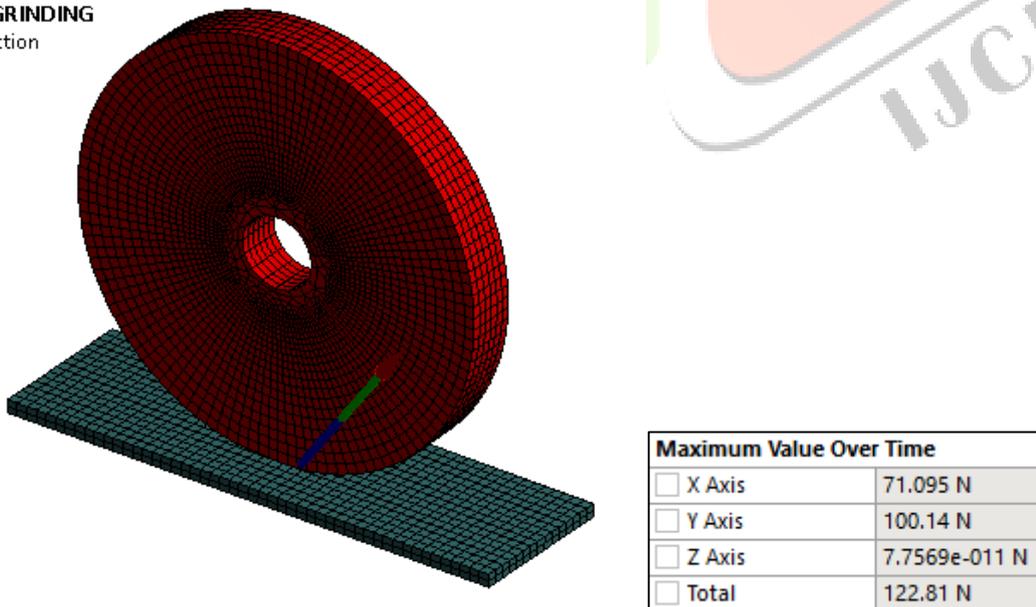


Fig. 18 Force Reaction on Steel Plate Grinding

Maximum Value Over Time	
X Axis	14.043 N
Y Axis	19.78 N
Z Axis	1.5358e-011 N
Total	24.258 N

Fig. 19 Force Reaction on Aluminium Plate Grinding

Maximum Value Over Time	
X Axis	126.39 N
Y Axis	178.03 N
Z Axis	1.3779e-010 N
Total	218.33 N

Fig. 20 Force Reaction on Cast Iron Plate Grinding

## Chapter 6

### SIMULATION RESULT

#### SIMULATION RESULT ON CAST IRON(Speed 6000rpm,feed 0.06,Depth of cut 0.9)

SR.NO.	Characteristics	Cast Iron Plate
1	Reaction (N)	218.33
2	Total Deformation(mm)	3.1616
3	Equivalent Stress (MPa)	4.5123

#### SIMULATION RESULT ON Steel Plate (Speed 6000rpm,feed 0.06,Depth of cut 0.9)

SR.NO.	Characteristics	Steel Plate
1	Reaction (N)	122.81
2	Total Deformation(mm)	1.7784
3	Equivalent Stress (MPa)	2.5382

#### SIMULATION RESULT ON CAST IRON (Speed 6000rpm,feed 0.06,Depth of cut 0.9)

SR.NO.	Characteristics	Aluminium plate
1	Reaction (N)	24.258
2	Total Deformation(mm)	0.3513
3	Equivalent Stress (MPa)	0.5013

From the Analysis Results it is clear that the Reaction Force Acting on the Cast Iron Plate is more 218.33N which is greater than the Steel plate and Aluminium Plate.

## Chapter 7

### Potential Applications and Future Work

The entire grinding process model can be effective in predicting the technical output measures of the process and explaining the mechanism in grinding process. This leads to a qualitative justification of power draw shift, which assists the grinding cycle optimization as well as proactive process parameter design. The grinding wheel model itself can be used to optimize and design the wheel composition as well as its fabrication parameters, which could minimize the „trial and error“ in current wheel design procedure and be able to proactive design wheels tailored to specific applications.

The FEM simulation visualizes the micro-machining processes and assists the factorial analysis for grain geometry as well as process parameter analysis. Therefore, more single grain micro-machining simulations should be carried out for various grain geometry factors to achieve a comprehensive understanding on micro-material removal in grinding processes. The grain geometry may cover other regular shapes from the tetrahedron, elongated column, to the geometry from measurement.

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