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# Grey Cast Iron Turning Process Modeling and Simulation using AdvantEdge 2D
# Edge rounding comparison for uncoated carbide inserts

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**Abstract: -- In the last decades, the modeling and simulation of machining processes became very important for researchers. AdvantEdge FEM is an explicit commercial code for designing, improving and optimizing machining processes. The solver is optimized for metal cutting processes. For grey cast iron turning coated carbide inserts without chip-breaker (like CNMA geometry) is being used. Insert micro-geometries like edge rounding radius r and edge symmetry S plays an important role in deciding insert wear criteria and tool life. An optimum edge rounding radius should be provided for the insert during edge honing process to obtain maximum insert tool life. The stresses acting on the tool and the temperature distributions inside the tool tip are crucial. The strength of the cemented carbide depends strongly on temperature, a dependency that increases with increasing temperature. In this paper finite element simulations of orthogonal turning of GG25 Cast Iron with uncoated cemented carbide inserts are performed. Cutting forces, stress and edge temperature distributions are compared in 2D orthogonal turning for different edge rounding radius (r = 10µm, 30µm, 50µm and 70µm) and using the actual testing parameters. The modeling and simulation of the turning process can be used to get more inputs the turning process and process parameters**

**Keywords: Turning Inserts, Cemented Carbides, Tool Life, AdvantEdge 2D, Insert micro-geometries**

## I. INTRODUCTION

Carbides have high hardness over a wide range of temperatures, high thermal conductivity and high Young's modulus making them effective tool materials for a range of applications [1]. A precision cutting tool insert mainly consists of mainly four elements: Substrate, Coating, Macro-geometry (Chip breaker) and Micro-geometry (Edge preparation). Variation in any of the above parameters will cause variation in tool life. For gray cast iron turning CNMA inserts without chip breaker is generally used.

Gray cast iron is an attractive material used in industrial applications due to its some advantageous properties such as good castability, corrosion resistance, machinability, low melting point, low cost, and high damping capacity. It is used widely in the manufacturing of some machine components, disc brake rotors and hydraulic valves [2]. In spite of competition from newer materials and their energetic promotion, gray cast iron is the second most widely used metallic material for engineering purposes, next to wrought steel. Gray cast iron for a given hardness level is one of the most readily machinable [3]. However there are some machining problems encountered like hard skin, hard spots which will affect the tool life of turning insert also the few alloying elements added to grey cast iron will affect its machinability. The chips were in the form of small segments instead of powder which may lead to rapid wear.

Cutting edge micro-geometries influence the tool wear behavior and therefore the tool life significantly. The cutting edge micro-geometry influences the distribution of the temperature and mechanical loads on the cutting edge and therefore the process [4]. So many research works are going on in carbide tool manufacturing companies to understand the effect of insert micro-geometry on insert performance.

## II. TURNING PROCESS MODELING AND SIMULATION

Due to the high cost involved in obtaining machining data experimentally, there are strong motivations for development of methodologies for description of different machinability phenomena using a numerical approach. The temperature in the cutting zone plays a key role in practically all aspects of machinability and in particular for tool wear [5].

Simulation of the actual metal cutting and chip formation process is very time consuming, even with modern software packages and computers. The saturation of the tool-chip interface temperature is typically reached after a few milliseconds [6]. However, further development of steady state temperature distribution in the tool interior is a more sluggish process which requires several seconds of machining, corresponding to several meters of cutting length, which is practically impossible to simulate. Instead, steady state heat transfer analysis, e.g. using finite element method, can be employed in order to estimate the steady state distributions in tool interior[7].

***The AdvantEdge simulation tool consists of mainly below three modules[8],***

1. Pre-processor module: The Simulation Setup. Interface allows users to setup the entire simulation, defining tool geometries, material conditions and machining parameters. It contains a user friendly interface, an extensive standard tools library, an extensive material library. It offers the possibility of creating new tool and workpiece geometries within the program and also to import complex geometries form other CAD files, possibility of introducing new materials
2. Simulation module: The AdvantEdge Engine performs all the hidden calculations. Simulations can run in: Demonstration mode (decreases the simulation time but is less accurate) or Standard mode (requires longer simulation time but is more accurate)
3. Post-processor module: Tecplot displays and assists in analyzing the simulation results.Among the displayed results there can be enumerated: chip formation, chip and tool temperature, cutting forces, steady state variables such as: strain, stress, strain von Misses, etc.

Among the three commercial finite element codes: FORGE 2D, DEFORM2D and AdvantEdge. AdvantEdge was found to be most suitable for modeling and simulation of turning operation [5]. Many studies were being carried out for modeling of steady state temperature distributions in coated cemented carbide tools used for steel turning. The cutting forces and edge temperature distributions in 2D orthogonal turning were being studied [7]. In this work an attempt is made to predict cutting forces, stress and edge temperature distributions for inserts with different edge rounding values.

## III.EXPERIMENTAL

Finite element simulations of orthogonal turning of GG25 Cast Iron with uncoated cemented carbide inserts are performed.Cutting forces, stress and edge temperature distributions are compared in 2D orthogonal turning for different edge rounding radius (r=10μm, 30μm, 50μm and 70μm).

### *Turning Process Parameters*

Continuous turning of grey cast iron (GG25) with hardness of 200BHN is done QUICK TURN NEXUS 200-II CNC Turning machine. The experiment wear data were taken for calculating the unknown coefficients in wear model used for actual cutting process simulation.

***TABLE1: TURNING PROCESS PARAMETERS***

| **Cutting Velocity (Vc)** | **Feed (f)** | **Depth of cut (doc)** | **Lead Angle** | **Turning Process** | **Insert Geometry** |
|---|---|---|---|---|---|
| 75 m/min | 0.3 mm | 2 mm | -5° | With Coolant | CNMA120408 |

### *Turning Process Modeling*

Standard grey cast iron workpiece Japan(JIS)-Cast iron-FC250 is selected from AdvantEdge material library which is having composition (in wt%) as 3.15%C, 2%Si, 0.75%Mn, 0.08%P, 0.15%Si and hardness of 200BHN.

Carbide-Grade-K (standard) tool with different edge rounding radius 0.01mm, 0.03mm, 0.05mm and 0.07mm were selected for different trails. Rake angle -5° and relief angle 5° were used. Tool meshing is done with maximum tool element size of 0.1mm and minimum tool element size of 0.015mm.

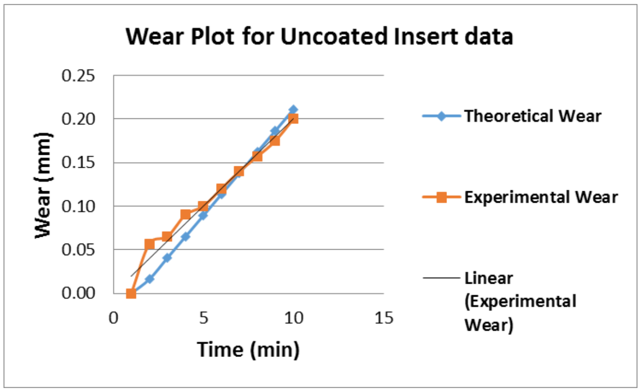
### *Wear Model*

Usui's tool wear model is used. The model variable K=2E-5 (1/Pa), and α =4881.9 calculated from actual wear data of turning process were used. In Usui's Tool Wear Model, the wear rate is given by below equation.

$$\dot{w} = K.exp\left(\frac{-\alpha}{T+273.15}\right).p.v \tag{1}$$

Where
K, α = Unknown coefficients that is specific for every combination of tool and work piece material
p = Pressure (N/mm2)
v = Cutting Velocity (mm/min)
T = Temperature (°C)

K and Alpha can be found by Curve fitting method in excel solver, using Experimental and Theoretical plots



*Graph 1: Wear plot for uncoated insert machining data*

*TABLEII : Uncoated insert wear data*

| Time (min) | Theoretical Wear Rate | Theoretical Wear | Experimental Wear | Error Square |
|---|---|---|---|---|
| 0 | 0.0000 | 0.0000 | 0.000 | 0.000 |
| 2 | 0.0081 | 0.0162 | 0.057 | 0.002 |
| 5 | 0.0081 | 0.0405 | 0.065 | 0.001 |
| 8 | 0.0081 | 0.0649 | 0.090 | 0.001 |
| 11 | 0.0081 | 0.0892 | 0.100 | 0.000 |
| 14 | 0.0081 | 0.1135 | 0.120 | 0.000 |
| 17 | 0.0081 | 0.1379 | 0.140 | 0.000 |
| 20 | 0.0081 | 0.1622 | 0.157 | 0.000 |
| 23 | 0.0081 | 0.1865 | 0.175 | 0.000 |
| 26 | 0.0081 | 0.2108 | 0.200 | 0.000 |
| Sum of Error square= | | | | 0.003 |
| **Root Sum Square (rss)=** | | | | **0.058** |

*TABLEIII: Original and final K and Alpha Values from curve fitting*

| Name | Original Value | Final Value |
|---|---|---|
| K | 1.99E-05 | 2.05E-05 |
| α | 5284.87 | 4055.86 |

## IV.RESULTS AND DISCUSSIONS

Cutting force for sharp tool (r=10µm) will be lesser compared to tool with higher edge roundings (r=30µm/50µm/70µm)
Peak temperatures are almost same in all case but temperature distribution will be different

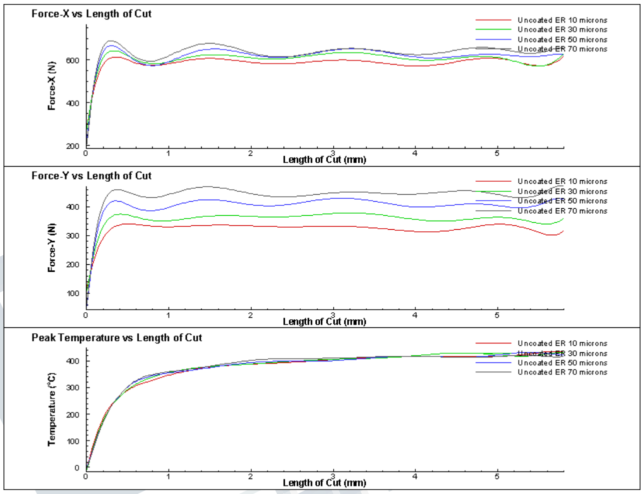


*Fig 1: Cutting force (Fx and Fy) and peak temperature comparison*

*TABLE IV: Peak temperature data*

| Simulation LOC (mm) | Peak Temp (degree C) | | | |
|---|---|---|---|---|
| | Uncoated ER 10 microns | Uncoated ER 30 microns | Uncoated ER 50 microns | Uncoated ER 70 microns |
| 0.5 | 289.5 | 292.6 | 302.1 | 303.8 |
| 1.0 | 346.6 | 356.9 | 355.4 | 360.1 |
| 1.5 | 376.5 | 379.1 | 375.3 | 380.4 |
| 2.0 | 388.4 | 389.2 | 394.5 | 402.3 |
| 2.5 | 395.5 | 399.1 | 399.1 | 409.9 |
| 3.0 | 405.7 | 406.5 | 401.7 | 410.6 |
| 3.5 | 414.6 | 410.8 | 412.7 | 415.9 |
| 4.0 | 418.0 | 420.3 | 418.6 | 418.6 |
| 4.5 | 417.0 | 430.4 | 414.5 | 414.0 |
| 5.0 | 417.4 | 423.5 | 423.0 | 416.8 |
| 5.5 | 431.4 | 422.5 | 432.2 | 419.4 |

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*TABLE V : Cutting force (Fx) Data*

| Simulation LOC (mm) | Cutting force Fx (in N) | | | |
|---|---|---|---|---|
| | **Uncoated ER 10 microns** | **Uncoated ER 30 microns** | **Uncoated ER 50 microns** | **Uncoated ER 70 microns** |
| 0.5 | 598.6 | 619.1 | 621.2 | 639.8 |
| 1.0 | 581.3 | 589.9 | 591.0 | 617.7 |
| 1.5 | 606.5 | 623.6 | 649.8 | 675.6 |
| 2.0 | 588.1 | 609.0 | 624.5 | 633.0 |
| 2.5 | 583.1 | 608.7 | 614.9 | 616.6 |
| 3.0 | 598.0 | 631.9 | 645.4 | 648.0 |
| 3.5 | 589.1 | 625.6 | 643.8 | 645.4 |
| 4.0 | 571.3 | 599.9 | 613.1 | 624.0 |
| 4.5 | 590.5 | 607.2 | 614.8 | 645.3 |
| 5.0 | 605.9 | 610.6 | 624.5 | 652.0 |
| 5.5 | 571.9 | 570.1 | 616.4 | 633.3 |

*TABLE VI : Cutting force (Fy) data*

| Simulation LOC (mm) | Cutting force Fx (in N) | | | |
|---|---|---|---|---|
| | **Uncoated ER 10 microns** | **Uncoated ER 30 microns** | **Uncoated ER 50 microns** | **Uncoated ER 70 microns** |
| 0.5 | 340.0 | 371.2 | 407.3 | 450.9 |
| 1.0 | 330.4 | 351.8 | 397.8 | 442.5 |
| 1.5 | 336.0 | 367.6 | 424.9 | 468.7 |
| 2.0 | 333.6 | 366.9 | 407.1 | 445.1 |
| 2.5 | 330.3 | 366.4 | 409.4 | 434.7 |
| 3.0 | 332.4 | 376.6 | 428.8 | 448.2 |
| 3.5 | 326.6 | 374.0 | 418.8 | 448.2 |
| 4.0 | 314.3 | 355.8 | 399.6 | 444.1 |
| 4.5 | 320.7 | 352.5 | 407.1 | 454.7 |
| 5.0 | 339.2 | 363.5 | 403.8 | 442.3 |
| 5.5 | 310.3 | 342.2 | 407.2 | 442.7 |

### Temperature, Stress and Pressure distribution comparison

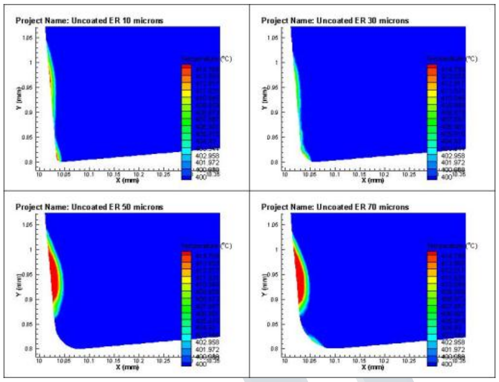
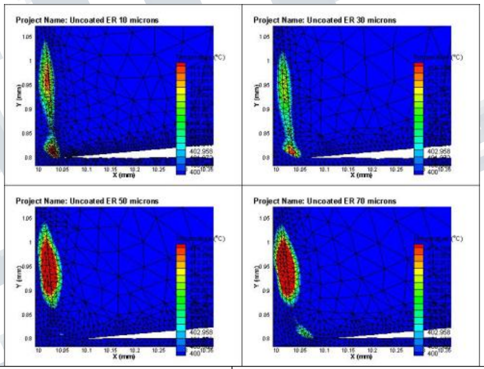


*Fig 2: Peak temperature distribution for inserts with different edge rounding*



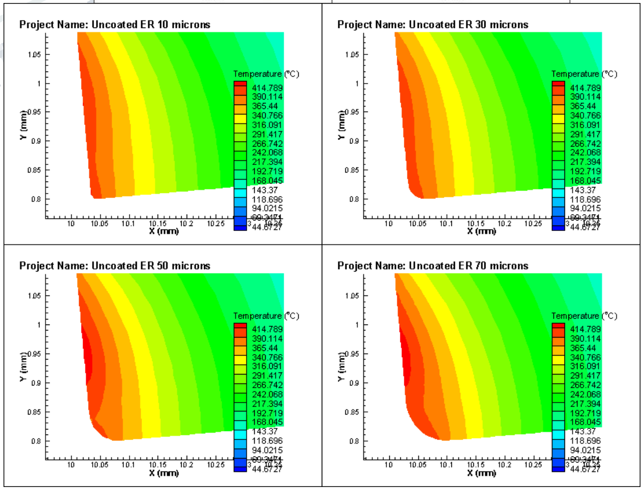


*Fig 3: Temperature distribution for inserts with different edge rounding*

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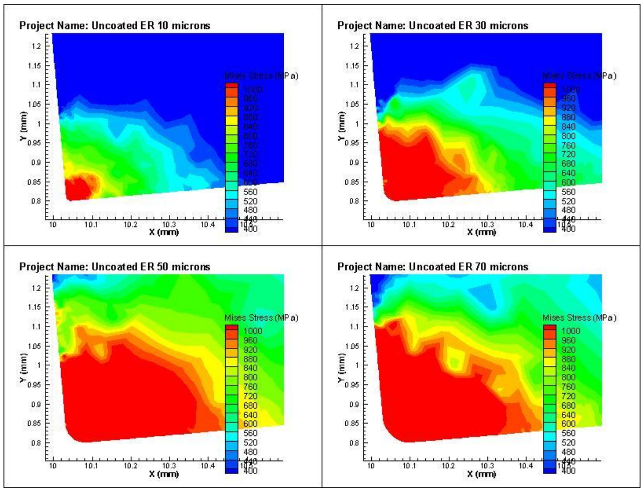

*Fig 4: Mises stress distribution for inserts with different edge rounding*

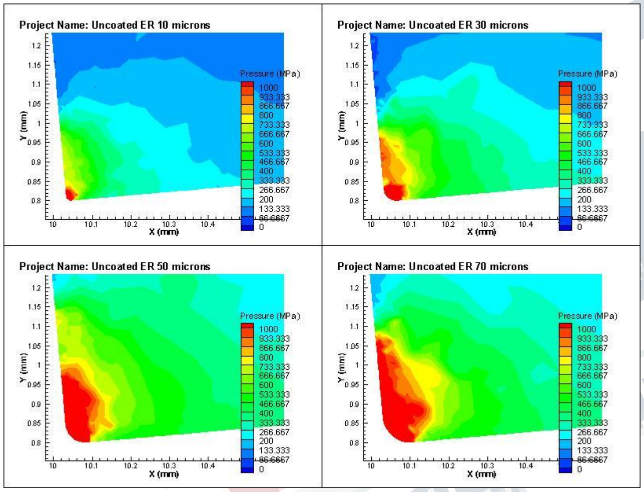

*Fig 5: Pressure distribution for inserts with different edge rounding*

## CONCLUSIONS

For better understanding of the machining process, turning process modeling and simulation is done using Third wave Advantage software and the temperature, stress, cutting force distribution on the turning insert were obtained using actual turning process parameters and few observations were made. Cutting force (Fx and Fy) increase with edge rounding value. Temperature, Pressure and Stress distribution changes with edge rounding. For sharp tool (r = 10µm), peak temperature will be concentrated at the tool tip. This will lead to breakage of sharp tip. In tool with higher edge rounding (r = 50µm and 70µm) peak temperature will be concentrated on the rake face at some distance away from the cutting edge. This will lead rapid crater wear growth at rake face. Among these four different edge rounding (r = 10µm, 30µm, 50µm and 70µm), r = 30µm seems to be good in terms of maximum temperature and pressure distribution pattern. The modeling and simulation of the turning process canbe used to get more inputs the turning process and process parameters. It helps in understanding the wear and parameters affecting the wear.

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