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3D FINITE ELEMENT SIMULATION OF MILLING

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ABSTRACT:

The objective of the current research is the modelling and simulation of milling predictive temperature in the cutting area by employing the finite element technique. Milling is one of the preferred and intricate traditional treatment procedures and is impacted by several output criteria. Temperature is one of the moist crucial benchmark as it impacts the tool life. So s to envisage the incidence of thermal processing milling was employed by utilising the Third Wave AdvatEdge software package. The software package SolidWorks was utilised to develop the 3D prototype of the workpiece and end mill. The inferences drawn from the simulations and investigational work when contrasted were validated to be correct.

Key words: finite element evaluation, milling, temperature, Third Wave AdvatEdge

1. INTRODUCTION

Milling is one of the crucial traditional machining procedures employed in the sector. Additionally, it is pne of more intricate processing of metals by cutting, as the milling cutter, in addition to the multi-cutter tool, puts forth a more intricate function in contrast to turning and drilling procedure, not only due to the huge number of cutting edges, but also on account of the difference of intersection of the chips while a tooth is being processed. This procedure is impacted by several resultant criteria and one of the most significant criteria is the temperature as it impacts the life and body of the tool. Cutting tools are costly and their duration is gauged in minutes and is thus envisaging temperature and tool wear during the machining procedure is extremely significant to comprehend and maximise the procedure criteria. Furthermore, it is presumed that post the turning milling procedure is a preferred technique to eliminate the material. Face

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milling with milling heads and end milling isthe preferred technique. The end milling is one of the characteristically interruptible procedures. In the procedure, as the cutting tool duplicates the cutting material and air cutting, the temperature of the cutting tool duplicates heat up and cooling down process. Cutting temperature is a crucial criterion as alternating heating and cooling of cutting tools impacts the tool wear and quality of the surface. To ascertain cutting temperature or temperature domains in end milling, one can employ varied techniques. On account of the intricacy of the milling processing the chief issues in gauging the cutting temperature when the milling is on can be attributed to the following: the tool rotates and teeth tool get involved with the workpiece in and out of it; the area covered with heat shifts across the workpiece; chips may impede the measurement [1, 2]. In the past many years several investigational techniques have been created to gauge the milling temperature. Thermocouples are preferred and employed to gauge temperature as they are simple to use, encompassing several temperature ranges and are comparatively inexpensive; despite there being a chance of mistakes during the installation and while understanding the readings. Techniques depending on the radiation allow the possibility of gauging the temperature without any link with the object whose temperature is being gauged. These techniques comprise of gauging the point temperature by employing infrared pyrometer and gauging point temperature of the temperature fields, or a specific domain by employing an infrared thermal imaging camera. It was proved that the technique of gauging temperature by employing infrared thermal imaging camera seemed to be the most suitable technique in context of recording the temperature. The high quality thermographic machine provides the best acceptable degree of preciseness of approximations, though this technique may provide incorrect approximations due to the modifications in the emission coefficient and the likelihood that the chips with the position covers the area whose temperature is to be gauged. The investigational technique for analysing treatment procedure is costly and takes a lot of time particularly when it encompasses a variety of tool geometry, material and processing criteria. The substitute techniques have been created due to these issues including mathematical simulations that employ mathematical techniques. It was seen that the numerical finite element methods were most beneficial and preferred to be

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employed by many. The suitable choosing of FEM software is extremely crucial to ascertain the range and quality of evaluation that would be executed. For the simulation processing, the researcher employed the third Wave Advantage Edge software package.

2. EXPERIMENTAL SETUP FOR END MILLING

The experiments were undertaken on a vertical CNC machine centre in cutting conditions that were dry. The researcher used a workpiece of size 50 × 20 × 10 millimeters of AISI 4340 steel with the material Attributes as provided in Table 1.

Density	785 (kg/m^3)
Melting point	1450 (^0C)
Young's modulus	208 (GPa)
Poission ratio	0,3
Specific heat	477 (J/kg^oC)
Thermal conductivity	44,5 (W/m^oC)

Table 1. AISI 4340 steel material properties

The tests employed an uncoated tungsten carbide end mill prototype whose diameter was 10 mm, length was 72 mm, whose depth of cut was 22 mm, and had 4 number of flutes. The researcher painted the pieces black on account of the emissivity. The machining function is undertaken for the cutting settings as indicated in Table 2.

Cutting conditions	
Spindle speed, n	2200 (rev/min)
Feed per tooth, f	0,040 (mm/tooth)
Axial depth of cut, a_p	1 (mm)
Radial depth of cut, a_e	2 (mm)

Table 2. Selected machining parameters in experiment

The experiment's structure was indicated in Figure 1. The data attainment of temperature was conducted employing a FLIR InfraCAM Wester infrared camera, with a preciseness of 0.1°C. The setting-up of the infrared camera was at 300 mm from the heat source.

Fig. 1. Monitoring the temperature using infrared camera

Figure 2 indicates temperature that was chronicled at the end of work piece.

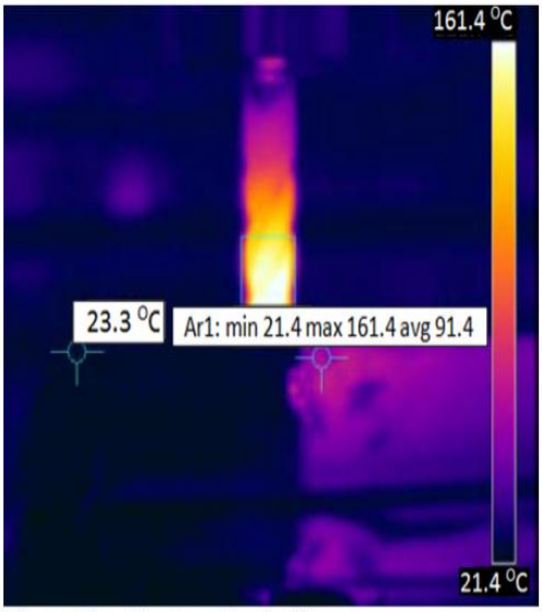

Fig. 2. Infrared imagery of end-mill process

3. FEM TOOL FOR CUTTING PROCESS

In the investigative domain of cutting procedures, the finite element technique is considered to be a beneficial method to analyse the cutting procedure of materials [3]. Finite Element Method (FEM) allows the approximation of the cutting forces, tool wear, and temperatures of the cutting procedures so that the cutting procedure can be planned. The suitable option of finite element software is extremely crucially in ascertaining the variety and quality of the evaluation that will be undertaken [4]. Third Wave AdvantEdge is one of the most crucial software package employed for simulation of metal cutting. Third Wave AdvantEdge is a distinct program developed for machining simulations. It is created depending on the dynamic specific Lagrangian formulation. The prototype is developed by choosing the kind of machining function (for instance turning, broaching, sawing or milling) and describing the essential criteria [5]. AdvantEdge includes a user friendly interface and provides the likelihood of developing novel tool and workpiece geometries in the program and also to import intricate geometries from other CAD files. It also permits users to have a widespread material library and permits detailing new materials; it employs flexible meshing to enhance the preciseness of solution. In AvantEdge simulations can be conducted in the demonstration mode, reduces the simulation time; however this is less preciseand the standard mode- which needs more simulation time but is more precise [6]. AvatEdge uses the Tecplot software to show and help in evaluating simulation outcomes [7]. Amongst the displayed outcomes there can be chip formation, chip and tool temperature, cutting forces, steady state variables such as: strain, stress, strain von Misses, etc [6].

4. FEA SIMULATION OF END MILLING

As per the experiments discussed in the earlier segment, a 10 mm diameter end mill has been planned with SolidWorks. Post

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that, another easy end mill prototype is developed with the intention to provide a coarser mesh and relying on the same it lowers the duration of the simulation. In both instances, it merely considers the cutting part of the mill engaged in machining. The end mill prototypes were sent to the STL files and imported into AvantEdge. The Figure 3 indicates the final mills prototype imported in AvantEdge.

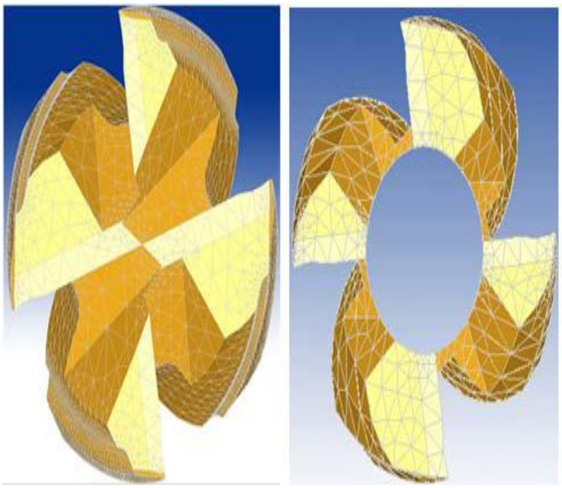

Fig. 3. End mills imported in AdvantEdge

The workpiece material AISI 4340 steel and tool material Carbide-General were chosen from the library of 3D materials. The workpiece model was lowered in context to the workpiece from the experiment on account of superior mesh generation. Figure 4 indicates the prototype of the intricate end mill and the workpiece in AvantEdge prior to beginning the simulation.

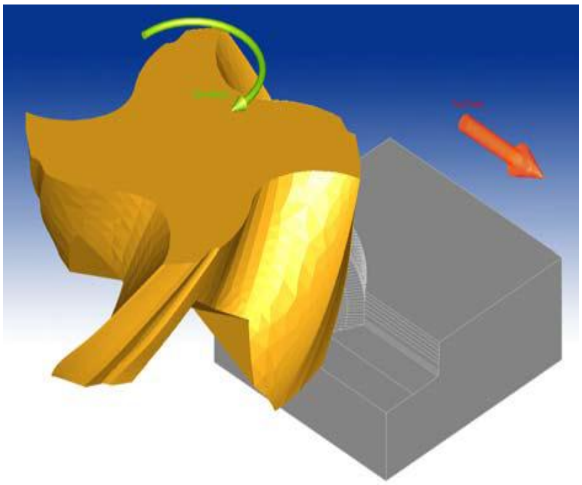

Fig. 4. End mill and workpiece in AdvantEdge

In AdvantEdge users have the choice to modify the workpiece meshing criteria; on the other hand these alterations may impact performance and preciseness. The meshing criteria chosen within the Workpiece Meshing tab of the 3D Simulation Options window are crucial for successful 3D simulations. Minimum element edge length and radius of controlled area values are gauged in a different manner relying on the procedure. In milling, these values are gauged employing maximum chip load depending on the feed per tooth and the radial depth of the cut. For all of these procedures, these meshing values are re-gauged every time the procedure criteria for these simulations are altered [6]. If a simulation crashes for any cause, a novel simulation can commence where the earlier one crashed.

4.1 Simulation results

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The researcher conducted two simulations in demonstration mode without modifications in Workpiece Meshing. The initial simulation employed simplified end mill. The next simulation employed the intricate end mill so as to gain a more precise simulation outcome. Cutting settings employed in the simulation were equivalent to the processing criteria in the experiment. The calculation time taken was roughly around 3 days for the simplified end mill simulation and 7 days for the intricate end mill simulation. A HP xw8600 workstation with 2 x CPU of 4 physical cores each was used for the simulation which indicated a sum of 8 physical cores and 16 GB RAM. Figure 5 and 6 indicate the FEM prototype of milling function and the temperature distribution for cutting Settings from Table 2

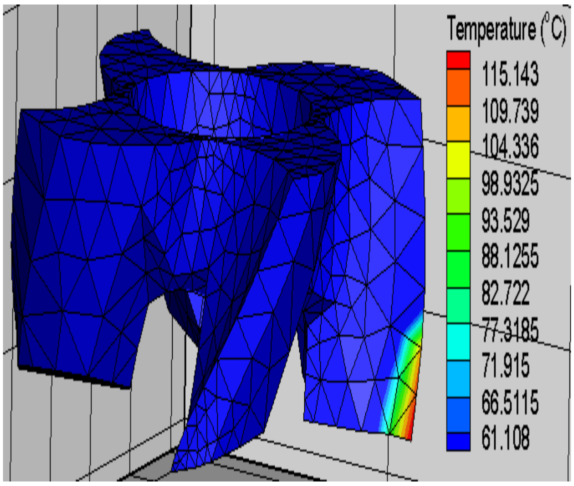

Fig. 5. Temperature distribution during simulation 1

The Contour tab of the AdvantEdge Quick Analysis window is employed to choose the contour displays in Tecplot. The varied colours on the tool signify varied degrees of temperature.

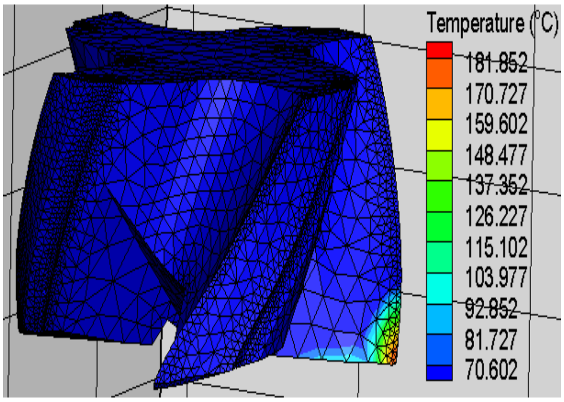

Fig. 6. Temperature distribution during simulation 2

Employing Tecplot software makes the varied phases during simulation evident. It is likely to notice the chip development during a tooth path. Figure 7 and 8 put forth the temperature contours on end mill, work piece and chips. A contour level is a value at which one draws the contour lines, or for banded contour flooding, the border amongst varied colours of flooding [8].

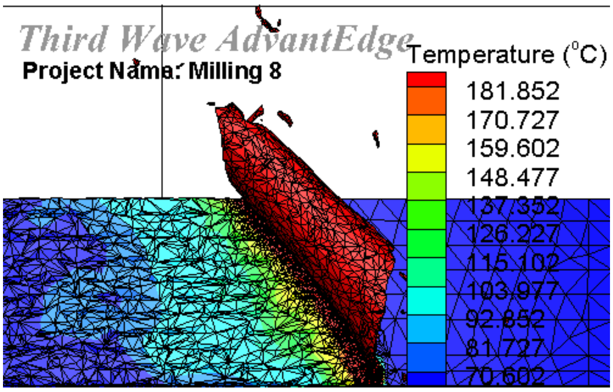

Fig. 6. Temperature contours on chips obtained through simulation results

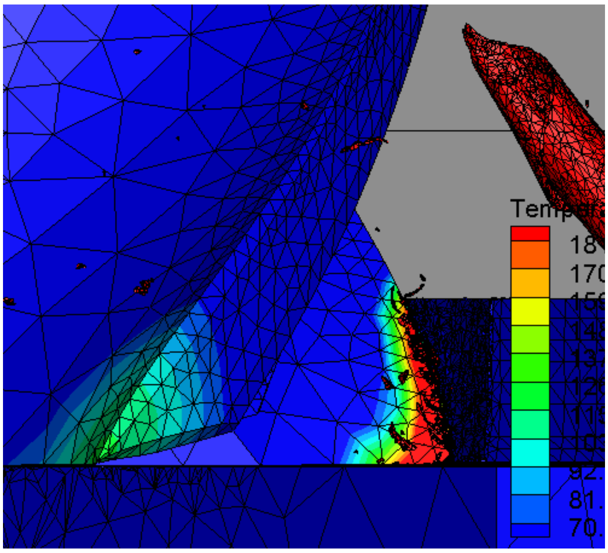

Fig. 7. Temperature contours on end mill and chips got via the simulation outcomes

4.2 Simulations vs. experiment

Table 3 indicates the difference of temperature distribution between the FEA simulations and the investigational work .By contrasting the experiment and the simulations indicated that the flaw for the first simulation stood at -28.68% and the same for the second simulation was 12.64%.

5. CONCLUSION

Simulation of milling in AdvantEdge permits assessing temperature in the cutting zone and allows getting of dependable data for the proof of the experiment. The mistake amongst the investigative work and simulation by FEA was in the range of ±30%. Precise planning of the end mill geometry needs to be employed to enhance the numerical approximation of cutting temperature despite it having a crucial influence on enhancing the length of the simulation. The outcomes of the work can be employed for maximizing the criteria function of AISI 4340 steel.