KAUNAS UNIVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING AND DESIGN

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NUMERICAL ANALYSIS OF TURNING PROCESS

Master's Degree Final Project

Supervisor
Lect. dr. Virginija Gyliene

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INDUSTRIAL ENGINEERING AND MANAGEMENT (621H77003)

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INDUSTRIAL ENGINEERING AND MANAGEMENT (621H77003)

"NUMERICAL ANALYSIS OF TURNING PROCESS"

DECLARATION OF ACADEMIC INTEGRITY

14 JUNE 2016

Kaunas

I confirm that the final project of mine, **NUTHAN HOSUR RANGASWAMY GOWDA**, on the subject "**Numerical analysis of turning process**" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources; all direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme **INDUSTRIAL ENGINEERING AND MANAGEMENT**

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

NUMERICAL ANALYSIS OF TURNING PROCESS

Approved by the Dean Order No.V25-11-7, 3 May 2016

2. Aim of the project

To investigate and study the Numerical analysis of turning using DEFORM 3D simulation.

3. Tasks of the project

Summary, Introduction,
1. Literature Review, 2. Methodology, 3. Results and discussions, 4. Conclusions,
References.

4. Specific Requirements

Conducting the final experimental project thesis according to KTU regulations and requirements.

5. This task assignment is an integral part of the final project

6. Project submission deadline:

Task Assignment received ______________________ ______________________
(*Name, Surname of the Student*) (*Signature, date*)

Supervisor ______________________ ______________________
(*Position, Name, Surname*) (*Signature, date*)

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SUMMARY

In this Master thesis research work, we introduce to resolve the numerical analysis of turning process using AISI304 stainless steel, since now a days turning is the key process in all industrial applications it is very progressive field to give new ideas. Main objects of this paper is detecting thee influence of meshing and temperature investigation in rough and finish turning. Experiment conducted using DEFORM-3D in finite element analysis. To achieve objects we have used DNMA432 tool with DDJNL tool holder with a specific parameter like cutting speed, depth and feed rate. We have mainly concentrated on different cutting speed because it effects on final cutting force and temperature. The cutting speed and cutting force appeared to have more pronounced effect on the cutting temperatures. The temperature distribution in the tool and workpiece and the effective stress and effective strain at specific time is measured. The effect of cutting speed in temperature distribution is also analysed.

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Studijų kryptis ir sritis: Gamybos inžinerija, Technologijos mokslai.

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Kaunas, 2016. 55 p.

SANTRAUKA

Kadangi šiuo metu tekinimas yra vienas iš pagrindinių apdirbimo būdų pramonėje, tai yra progresyvi sritis. Magistro baigiamajame darbe atliekama skaitinė analizė tekinimo proceso, kai pasirinkta apdirbamoji medžiaga yra AISI 304. Pagrindiniai šio magistrinio darbo tikslai yra skaitinė analizė, būtent temperatūros skaitinis teorinis temperatūros nustatymas, atliekant grubųjį ir išbaigiamąjį aptekinimą. Skaitinė analizė atlikta, naudojant DEFORM-3D baigtinių elementų paketą. Skaitinei analizei atlikti pasirinktas standartinis programiniame pakete esanti aptekinimo plokštelė DNMA432 su laikiklis DDJNL. Skaitinei analizei parinkta plokštelė pagal savo geometrinius parametrus yra tinkama tiek išbaigiamajam apdirbimui, tiek grubiam. Skaitinė analizė atlikta parenkant optimalius (rekomenduojamus) pjovimo parametrus pagal apdirbamą medžiagą ir įrankį. Darbe tiriama pjovimo greičio įtaka susidarančiai temperatūrai. Dėka skaitinio modeliavimo įvertinta temperatūra ant įrankio priekinio paviršiaus ir apdirbamojoje medžiagoje bei deformacija, įtempiai tam tikru laiko momentu.

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INTRODUCTION

Machining process, for instance, turning, milling, boring and exhausting are among others the most vital procedure for discrete part production. The examination of turning has continued going over a period, however despite everything it draws in a great compact of exploration exertion. This is an outcome of turning is not simply practically from time to time used machining operation as a part of the now a days producing industry, furthermore in light of the way that is customary single-point machining operation.

Finite element simulation is carried out utilizing commercially available DEFORM 3D software. DEFORM is an engineering simulation software is used to analyse different manufacturing process, which forms a successful Tool for research and industrial application. Utilizing cutting tool parameters, the output parameters like tool chip impedance temperature and cutting force (Tangential force) is analysed. Stainless steel (AISI 304) material for both Tool and Work piece and Tool DNMA432 without coating is using

. The fundamental goals of the research works are Numerical analysis of the turning using DEFORM 3D simulation. It will be helpful for the experts to know the machining process. Although it is an easy way to predicting the metal flow and selecting the ideal working conditions like tool and work piece temperatures stress & strain and cutting force. In like manner, the effect of cutting speed concentrated on. The current research work deals with the analysis of the following.

- Effect of cutting (Tangential) force
- Temperature distribution for both work piece and tool
- Effect of cutting speed on temperature distribution
- Effective stress and strain distribution with different cutting speed

1. LITERATURE REVIEW

1.1 Turning process

In any turning operation a single point cutting tool is parallel to the material. It can be completed physically, in a conventional kind of machine, this needs continues supervision by the person who handle this procedure, or by using a computer controlling and automating lathe. This is known as, CNC (computer numerical control), this CNC typically used with different kinds of machine tools notwithstanding the lathe.

Turning is the most essential machining handle and can create a wide variety of parts. Basically, turning is utilized to produce round and hollow shape parts by a single point cutting tool on lathe. The tool is feed in two ways that is direction parallel or opposite to the axis of revolution of the work piece, or along a predetermined way to generate difficult rotational parts. Important movement of cutting in turning is spin of work piece, and another movement of cutting is the feed. Figure 1 delineates a regular turning operation in machines. Various type of machines is accessible today from broadly useful to particular operation situated specific reason machines. When all is said in done, turning refers to a class of forms did on a machine. [1]

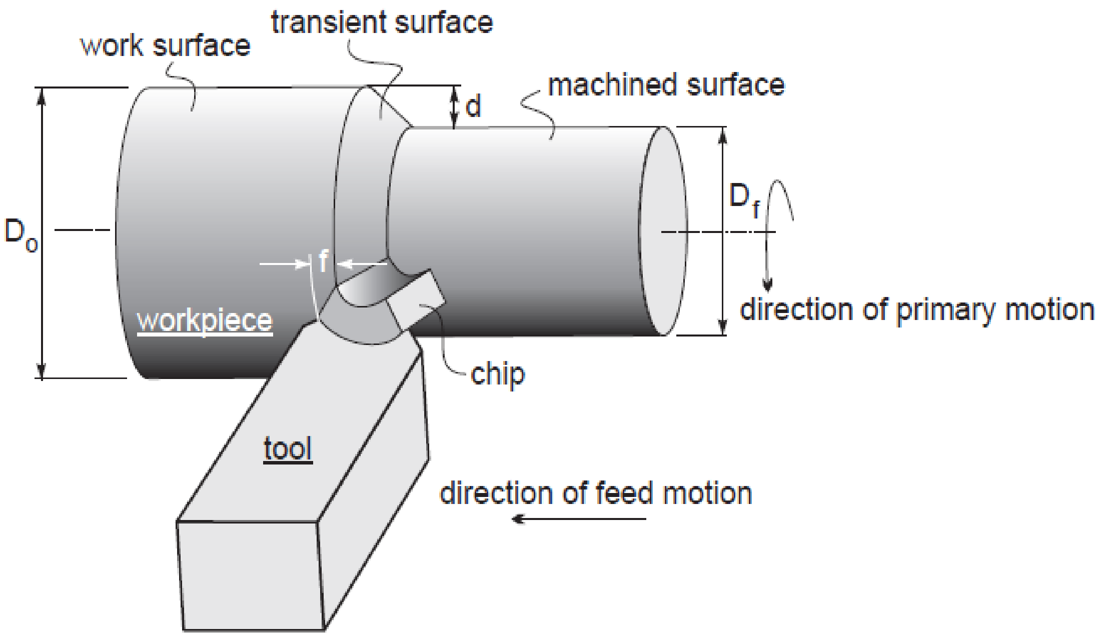


Figure 1 : General Turning operation. [1]

1.1.1 Temperature investigation in turning process

Cutting is a standout among all the essential and normal manufacturing forms in industry. Machining is not a simple process to study and show due to of the inherent trouble to know exactly what happens in the region near by the tool tip. The heat generation during machining has been studied by large number of researchers using theoretical, experimental and numerical procedure. The analyzation of the highest temperature and temperature distribution along the rake face of the cutting tool is important because of its controlled impact on tool life, on the quality of the machined part and generation costs. [2]

Factors impact for variation of cutting temperature are

- Work material: Specific energy requirement is Ductility, Thermal properties (λ, CV)
- Process parameters: cutting speed (VC), feed rate (so), Depth of cut (t)
- Cutting tool material: thermal properties, wear resistance, chemical resistance
- Tool geometry: rake angle (γ), cutting edge angle (φ), clearance angle (α), nose radius (r) [2]

If temperature is high, it will be harmful for tool and work piece. Here more heat taken by chips, anyhow, these chips will be removed. The conceivable detrimental impacts of maximum temperature at cutting edge are,

- Quick tool wear, this reduces tool life span.
- Thermal flanking and cracking of cutting edges because of thermal shocks
- Built up edge development.

The conceivable detrimental impacts of different machine jobs for different cutting temperature are,

- Dimensional in accuracy of the product because of thermal deformation and expansion compression while working and after finishing of machining.
- Damages of surface caused by oxidation, rapid corrosion, burning and so on. [2]

The turning process are classically carried out on lathe, considered to be the oldest machine tools. In common, turning utilizes simple single-point cutting tools. Here single cluster of work piece materials has a prime set of tool angles that is manufactured as the years progressed. The bits of removed waste metal from turning operations are known as chips. [3]

From the above literature description, it tells that turning procedure by assistance of finite element analysis the temperature distribution can be studied. Typical methods for modelling of machining processes is Lagrangian and Eulerian technique, by combining both it's called as arbitrary Lagrangian-Eulerian definition. We have notice here that all these methods are statistically equal. Here the actual element of Lagrangian formulation utilized as a part of this work is that the mesh is joined to the work piece. Furthermore, the finite element analysis was achieved by Johnson-cook's constitutive equation with three distinct arrangements of material constants is executed in the FE model to focus on the performance of Ti6A14V alloy through the machining process in usual and fast administrations. Requirement for advanced results and best quality for machining products has got many researchers for work on the impact of machining factors using FEM simulation using either 2D or 3D versions. [4]

In the paper proposed by Asmaa A. Kawi, Finite Element method is a successful method to present exploration for the estimation of cutting temperatures, a chance of increasing temperature method suitably characterising machining temperature as a Polynomial model 3rd, 4th and 5th degree with time. Here all alloys have a simple rising temperature by increasing feed rate, while it seems like less sharp with increasing cutting speed. One more criteria is the relation of the number of nodes have highest temperature of any working circumstances and different alloy are used parallel to the absolute number of nodes is not exactly 1%. [5]

One more paper proposed by, Mofid Mahdi, Liangchi Zhang. In this paper they concentrated on the study of the chip ending and established a 2D cutting force model from the finite element method. Variability in the cutting force was investigated sensibly with the cutting circumstances and the anisotropy of the material by the respected growth here 1. Contact model of the tools of the machining process. 2. Constitutive model of a homogenous anisotropic elastic material with respect distortion of the plane. 3. A failure model of the work material in view of the Tsai Hill foundation, a relationship with test estimations dimension that the constitutive model indications to a well-organized prediction. [6].

A paper proposed by another author namely Tugrul Ozel, Taylan Altan, shows a methodology to define instantaneously 1. At deformation amounts and temperatures, the flow stress is faced in cutting section 2. Chip tool edge friction. Data about this is essential to encourage high-speed machining by FEA centred programs. A process parameters based stress model defines like strain-rate and temperature here these two utilized together with a friction model in view of shear flow stress of the work piece at the chip-tool line. High-speed cutting experiments and procedure simulations were applied to conclude the strange parameters in flow stress and friction models. [7]

The finite difference technique was applied surprisingly by Rapier [9]. But setting up work practically speaking is a finite component procedure in machine investigational et al. [10] . The finite element method used to determine energy equation. Here finite elements used to find out first and second heat zones with addition to fractional zones. Finite element method also utilised for exploratory speed, to test limits of experiments to find out development rate of heat. By taking help of matrix or grid design, at tool chip interface we measure and velocity distribution were find out also utilized as part of input in experiment. They have been focused on different cuttings and got the temperature distribution. Later on, Stevenson et al. [11] amplified the model including the stream field differentiated temperature field between metallographic ally and model.

From the finite element technique, Muraka et al. [12] selected on effect of variables procedure example as, coolant water at the temperature distribution, feed rate, rake edge, cutting velocity etc. Here the temperature at tool chip edge was found at the end by growing rate and speed with respect to feed and speed respectively.

Ng et al. [13] make use of finite element method for the computation of cutting force and scattering of temperature. The temperature develops from the cutting tool thermal conductivity and edge development were calculated. For smaller tool conductance, portion of heat transmitted by the chip and the temperature of the tool–chip interface was higher.

Ramesh et al. [14]presented a 3D model including the edge impacts. From this they came to a conclusion that the 3D prediction for temperature profile more nearly followed the experimental trend. In their parametric study, the impact of cutting velocity and feed rate was observed to be critical while the intensity of cut had just a smaller impact.

1.2 Description numerical modelling

Modelling is a helpful for engineering strategy and study. The meaning of modelling depending upon the application, yet the basic idea remains the same. The procedure of solving of physical issues by proper rearrangements of reality in engineering, modelling is isolated into two major parts: Physical modelling and hypothetical/analytical modelling. Research centre and in with model tests are examples physical modelling. From which specialists and researchers get valuable data to create experimental or semi-observational calculations for tangible application. Theoretical modelling has four stages. The initial step is development a mathematical model for comparing physical issues with suitable assumption. This model, may take the type of an alternate or algebraic equation. In most engineering cases, these mathematical models can't be resolved systematically, require a numerical result. Further step is improvement of a proper numerical model or approximating to the mathematical model. The numerical model need more carefully calibrated and authenticated against previous information and analytical results. Error analysis of the numerical model is likewise required in this development. Last step of theoretical modelling is genuine usage of the numerical model to find the results. The final step is analysis of the mathematical results in graphics, charts, tables, or other helpful structures, to support engineering design and operation. [15]

With the expansion in computational technology, many numerical models an engineering. The programs are constructed for different engineering practices. Numerical modelling has been utilized broadly as an amount of industries for both for forward and reverse problems. Forward problems include simulation of space transport flight, ground water flow, material strength, earthquakes, and atomic and pharmaceutical formula studies. Reverse problem consists of non-destructive evaluation (NDE), tomography, source location, image processing, and configuration deformation during loading checks. Despite the fact that numerical models empower engineering to solve the problem the potential for misuse and deception continues. Brilliant amazing realistic presentation of a modern programming bundle does not as a matter of course give accurate numerical results. Central investigative studies and intensive comprehension of the physical phenomena give a reliable and strong rule for engineering modelling. The numerical results are likewise deliberately analyse against existing research centre tests information. [15]

During the most recent two decades, numerical analysis has been effectively utilized to explain the energy transport equation for cutting region. The energy equation was explained numerically utilizing strategies for finite differences, finite elements and boundary elements. The temperature distribution everywhere throughout the cutting domain has been obtained and numerically pictured. The very important discussion for both numerical and analytical works is about the implementation of the heat source regarding distribution and introduction in the cutting domain.

1.2.1 Establishment of numerical model

Modelling is basically the fundamental of engineering. A model is a proper rearrangements of reality. The skill in modelling is to identify the appropriate level of simplification, recognize critical elements from those that are unimportant in a specific application, and use engineering judgment. There is a long history of physical modelling in structural designing. Therefore, the advancement of more rigorous modelling tools has wrapped after the necessities of engineering. In this project, progressions in computational procedures, structural designing and material sciences are joined into a theoretical/mathematical numerical models in light of the analysis of physical phenomena and constitutive laws for the utilization of penetrated shafts in roadway engineering. [15]

1.2.2 Validation of numerical models

Before the numerical models is applied to solve engineering problems, it is utilized to simulate some little issues and basic cases for which the results are known or can be naturally acquired for verification. A few constants and parameters must be pre-characterized or calibrated in view of material properties and specified conditions. In this study, the strength of the numerical modelling has been checked in three diverse ways before being utilized for huge scale difficulties: 1) Energy Conservation 2) Dynamic relaxation 3) Elastic wave propagation. [15]

1.3 The deform system

DEFORM 3D is a powerful procedure simulation system grounded on the finite element method technique intended to analyse the three dimensional flow of complex metal forming procedures (Scientific forming technologies corporation 2001). Its in-Built pre-processor was utilized to make the finite element info deck for DEFORM-3D. The DEFORM-3D system comprises of three main steps:

A pre-processor for making, collecting, or changing the information essential to analyse and simulate for creating much needed database document.

A model engine for execution of the numerical computations essential to analyse the procedure and take these outcomes for databases. The simulation engine reads the database document, works on the real solution computation and then it gives this results to databases. The simulation engine works effortlessly with the Automatic Mesh Generation (AMG) system to prepare new FEM mesh on the job when it needs. When this simulation occurs it recognize the data, and counts different kinds of errors, to the message and log documents.

The data from simulation engine reads from the post-processor and it shows the outcomes in graphical way. [16]

Deform is a business FEM programming based procedure simulation system intended to analyse stream of various metal forming system. It's accessible in both Lagrangian and arbitrary Lagrangian and the Eularian modelling. Additional, the product is starting now limit of Steady-State capacity and it is required of running a transient simulation past to steady state cutting simulation. [3]

The sequence of steps followed in the analysis is appeared in Figure 2. The operation begins while making new program in DEFORM 3D. In the wake of making a project open the particular turning operation. At that point you can give the correct inputs like feed rate, speed of turning, depth of cut, environment temperature depending on the operation. Chosen one the correct tool and tool holder for turning operation from the library. Further select the material of tool and work piece from the library or make another new. After words make accurate mesh of the tool and work piece. The number of simulation steps and time additions can be given in this development. Generation of database happens after given all inputs. Here simulation is keep running with solver manager. The representation of results happens in Final Post Processing step.

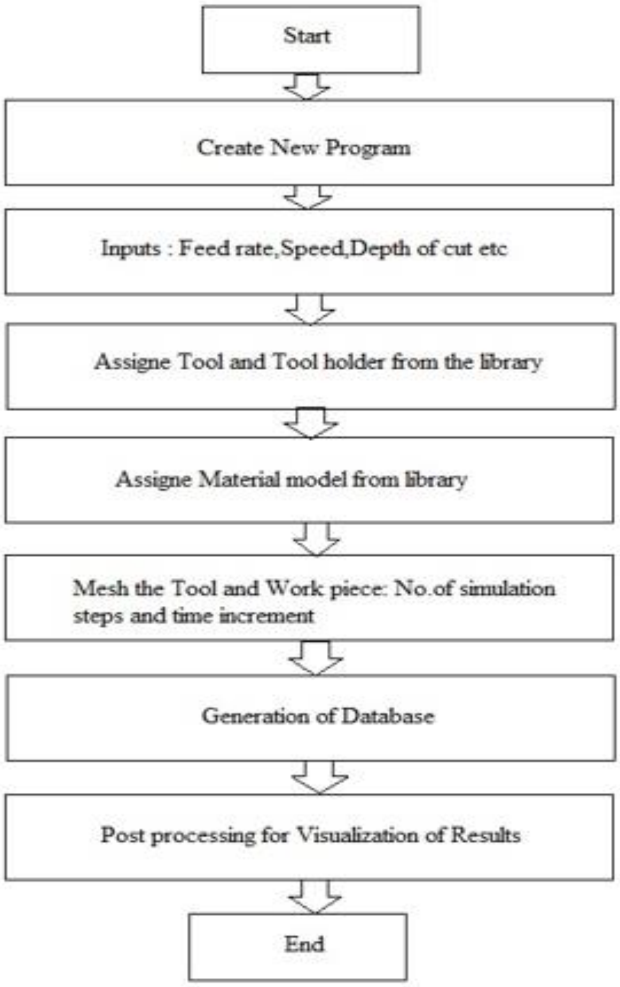


Figure 2 : General procedure for DEFORM 3D analysis

1.4 Tool geometry

The metal cutting tool isolates chips from with a specified end goal to remove metal to the given size and shape. Here various metal removal tools, which performs the specific work, in machine processing. Here the placement and shape of tool with respect to the work piece, importantly affect metal cutting. The most vital geometric components, in respect to chip development, are the area of the cutting edge and the positioning of the rake face with respect to work piece and way of cut. References used to assign the surfaces, edges and radius of single point instruments, is demonstrated as follows. [16]

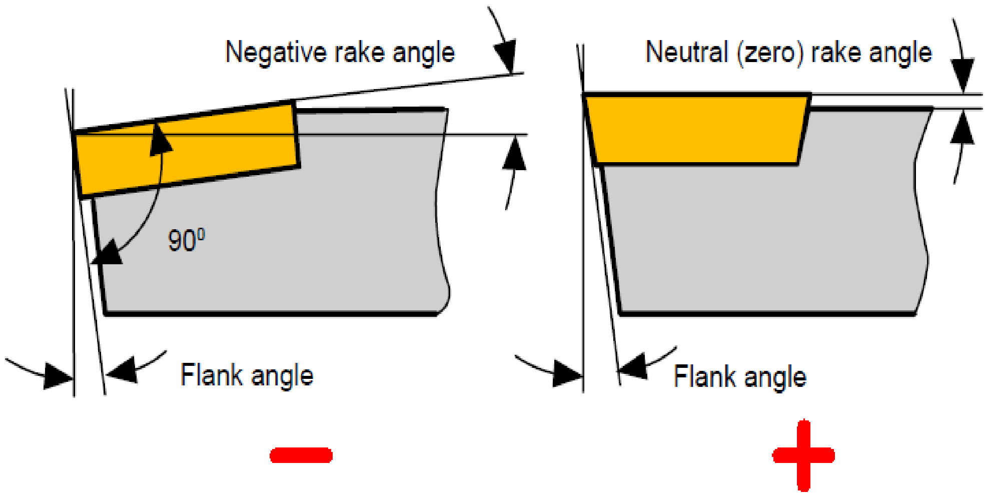


Figure 3 : Negative and Positive geometry of tool [17]

The Rake Angle: Rake edge is a parameter utilized as a part of different cutting and machining forms, portraying the point of the cutting face with respective to the work. There are two rake points, in particular the back rake edge and side rake edge, both of which guide chip stream. There are three sorts of rake edges: positive, negative, and zero. It impacts on cutting tool strength and cutting pressure. Figure 3 represents the Negative and Positive geometry of tool. Side Rake Angles: It defines by the tool maker, it will fluctuate according to the tool makers, insert and tool holder type. Side and End Relief Angles- It eliminates the tool breakage and helps to increase the span of tool. When relief angle is huge, production of chip may produce or may break. If relief angle is miniature, then workpiece undergoes rubbing process and it leads to the excessive temperature. [16]

1.5 Insert shape and nose radius

Insert shape: It's one of the important parameters in machining. We can get various size and shape inserts such as square, round, triangle and diamond with different thickness. Depending on operation, every insert which have declared has merits and demerits. Feature of insert: positive and negative rake, with/without holes, with/without chip breaker grooves, with various edge preparations, radii, size and tolerance. Selection of insert depends on the work piece material, on how much material to be machined, capacity of tool and economics.

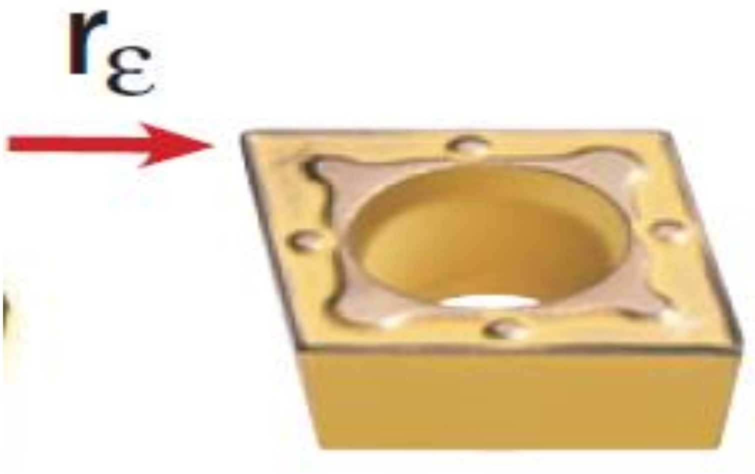


Figure 4 : Insert with nose radius (rε) [17]

Nose radius: Its main purpose is to strengthen tip of the tool. Results of cutting process depends on nose radius. Tools are available in various nose radius. Greater the nose radius tool tip will be stronger and good surface finishing. [16]

1.6 Tool and work piece material properties

The accuracy of finite element prediction of turning operation depends extraordinarily on the accuracy of the values of material properties. A careful study of material properties of the cutting tool and the workpiece are offered. Here AISI 304 stainless steel is picked as cutting tool and workpiece material. AISI 304 cutting tool perform well during machining of hardened stainless steels in view of their high hot hardness, low solubility in iron, and great fracture toughness. Preferred corrosion resistance over. Different characteristics like more toughness, framing, spinning. Less carbide precipitation is takes place in the temperature effected zone while welding process, and helplessness to inter granular corrosion [20]. They offer the likelihood of more prominent process flexibility, reduced machining time, lower energy utilization, recycling possibilities, and the optional utilization of a coolant. The Physical and mechanical properties, the chemical composition of the material and Work piece material group shown in below tables1, 2 and 3.

Table 1: Physical and Mechanical properties of AISI304 stainless steel material. [21]

Physical properties

DESCRIPTION	**VALUE**	**NOTES**
Density	8 gr/cm3	
Hardness	29HRC	
Hardness(annealed)	82 HRB	1100^0 C, cool rapidly

Mechanical properties

DESCRIPTION	**VALUE**	**NOTES**
Elastic Modulus	197 GPa	
Elongation % (break point)	70%	At 50 mm
Shear Modulus	86 GPa	

Table 2: Composition of AISI304 stainless steel material [21]

Composition % per weight

Element	C	Cr	Ni	Fe	Mn	P	S	Si
%	Ma0.08	18-20	8-10.5	66.34-74	Max 2	Max 0.045	Max 0.03	Max 1

Table 3: AISI304 workpiece material into material group. [22]

Seco mat group No	**For power calculation $K_{C1.1}$ m_c**	**AISI**	**W-stoff**	**DIN**	**BS**	**AFNOR**	**SS**	**U.N.E. / I.H.A.**	**JIS**
8	1750 0,20	04	1.4301	X5CrNi 18 10	304 S 10	Z5 CN 18-09	2333	F.3504	SUS 304

1.7 Analysis of cutting forces (Tangential force)

Cutting force impacts cutting process. Information about the normal cutting force parts is huge for the accompanying reasons: the forces happening in the metal cutting procedure give information about the power requirement of the machine, choosing the right cutting process and the ideal technological parameters results in significant saving of power during machining. For improvements in the field of versatile control of the cutting process, information of the cutting force is of major importance in characterizing as far as possible binding the scope of enhancement. Of the factors affecting the cutting force,

The following are vital: cutting strategy (constant or varying cross-sectional area of cut), cutting conditions (Surface cutting speed, feed rate and cutting depth), the material of workpiece (chemical composition, heat treatment), and the cutting tool (tool material, cutting angle geometry, chip breaker, coating, tool wear), and cutting fluid. [23]

The studies primary objective keeping in mind the end goal to know the cutting force, stress and temperatures required in the process. Different techniques were proposed which are a few of the study taking into account essentials of mechanical cutting process and others in light of test rearranged investigative methodologies of orthogonal cutting were initially considered by Merchant [Merchant, 1995], who presented the idea of shear plane angle. [3]

1.7.1 Merchant’s model

Merchant's analysis changes on the two-dimensional procedure geometry as appeared in Figure 5 [Shaw, 1984]. Here an orthogonal cutting considered with cutting Velocity V, and uncut chip thickness t_u, chip thickness t_c, shear angle Ø, rake angle α, and width of cut. Parallel to the ordinary and cutting edge width of cut w is measured to cutting velocity. [3]

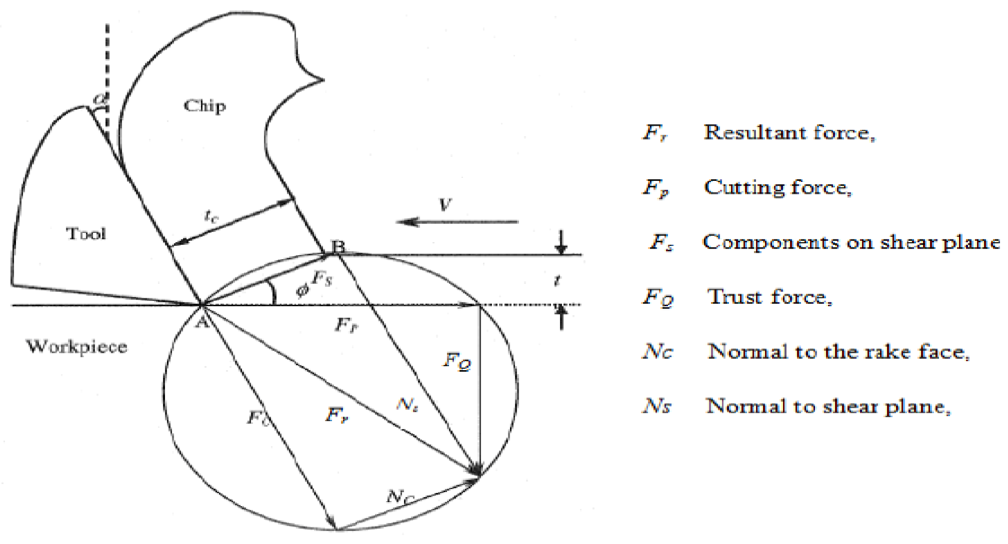


Figure 5 : Merchant analysis circle [3]

Most importantly here cutting tool stays still while material moves along cutting speed. Here a chip along these lines accepted and shaped to go like rigid body balance situated with the help of force over interface of shear plane and chip tool. For flank or tool edge forces doesn't go along. For rake power, shear plane we denote Fr on direction of cutting by experiment person idea. Fs and NS are normal to shear plane on shear plane component. Fp is cutting power and Fq trust force direct and normal to surface of work piece respectively is flow stream and Nc that is normal force is typical for rake force. [3]

1.7.2 Influence of meshing

A continuous region is divided separate region called elements in FE analysis. This system is called discretization or meshing. Initial planned FE mesh can't hold its original shape and it is distorted because of extreme plastic deformation during metal cutting or metal framing process. The deformation causes convergence rate and numerical errors. To handle with this issue new FE mesh must be produced in method for changing the size and distribution of the mesh. This is called adaptive mesh process. One of adaptive mesh procedure is re-meshing technique and it include the generation of a totally new FE mesh out of the current existing distorted mesh. Second one is called refinement technique which depends on increasing the local mesh density by decreasing the local element size. [24] The mesh generated workpiece shown in figure 6.

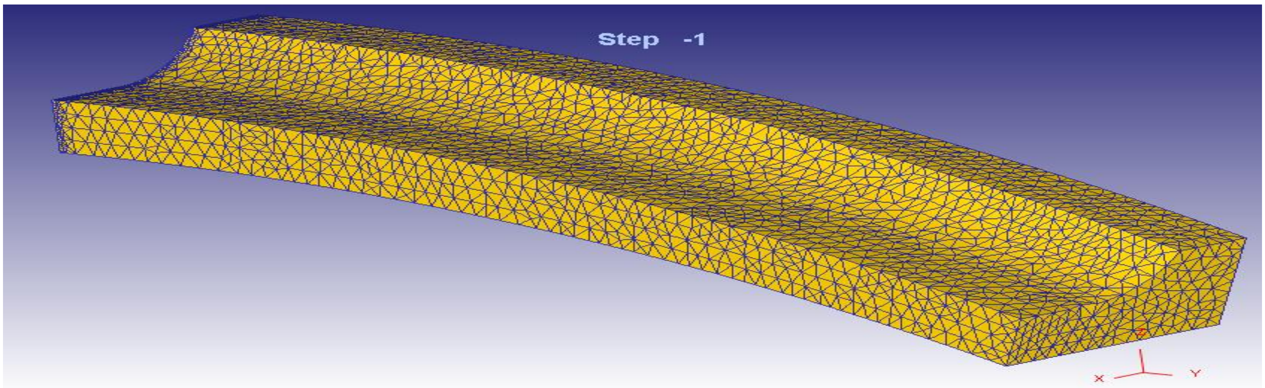


Figure 6 : Mesh generated work piece.

FEM utilizes Lagrangian or Eulerian meshing criteria. The Lagrangian mesh is reformulated at nearly all time in steps, in order to manage the material deformation. If a simulation crashes, for any reason, new simulation can begin where the one stopped. Tool and work piece meshing are very important for an accurate process simulation. A better mesh gives a better accuracy. If the number of element increase, time additionally increases. Meshing the work piece is much more essential. In general work pieces are modelled as plastic objects, they can be effectively deformed and cut by tools. At the point when the mesh deforms, it must be frequently regenerated. The generation of tool mesh and meshed tool is shown in Figure 7. During the simulation, the mesh helps recreation the deformed material. The new mesh is produced based on user defined parameters to keep fine elements where they are required for resolution. [25]

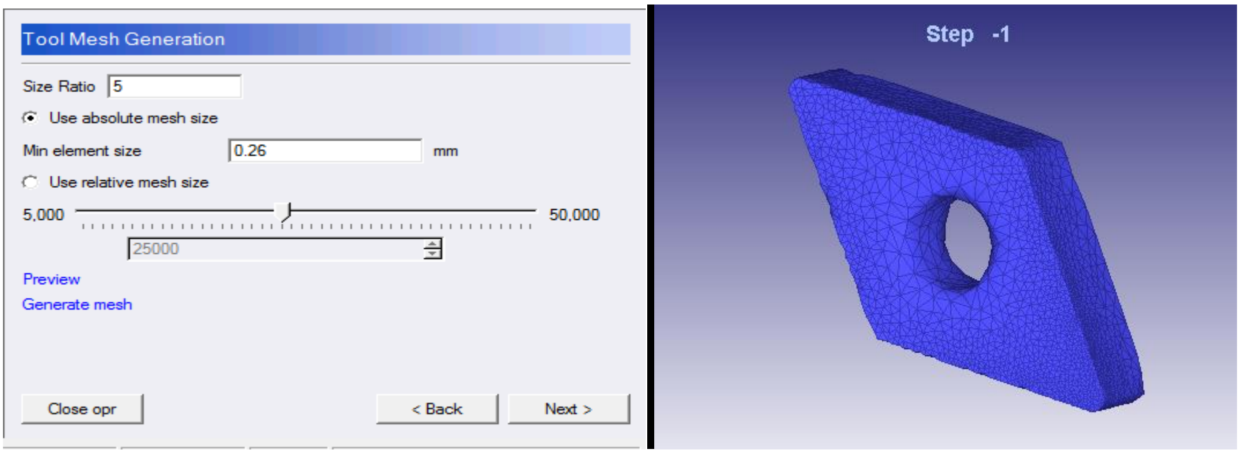


Figure 7 : Generation of tool mesh and meshed tool

Here we have taken same surface speed 75 m/min with 5 different work piece meshing elements and plotted a graph with obtained results as shown in below figure 8. Here X axis is number of finite elements and Y axis represents load in newton's F(y). In load prediction graphs we get different values. That is shown in table4. The percentage of difference between 20000-30000 is around 8%, 35000-45000 is around 12 %, 30000-45000 is around 14 % and between 45000-50000 its only 6.6 % so we chose that values 45000 FE work piece meshing for further operations with different surface speed (v). Because it won't affect the overall result due small difference in it. Table 4 shows that the value of different work piece meshing with respect to load in 0.00130 second time.

Table 4: Number of finite elements with respect to tangential force F(y) in N

Number of Finite Elements in work piece	F(y) N at 0.00130 sec
20000	221
30000	205
35000	202
45000	180
50000	192

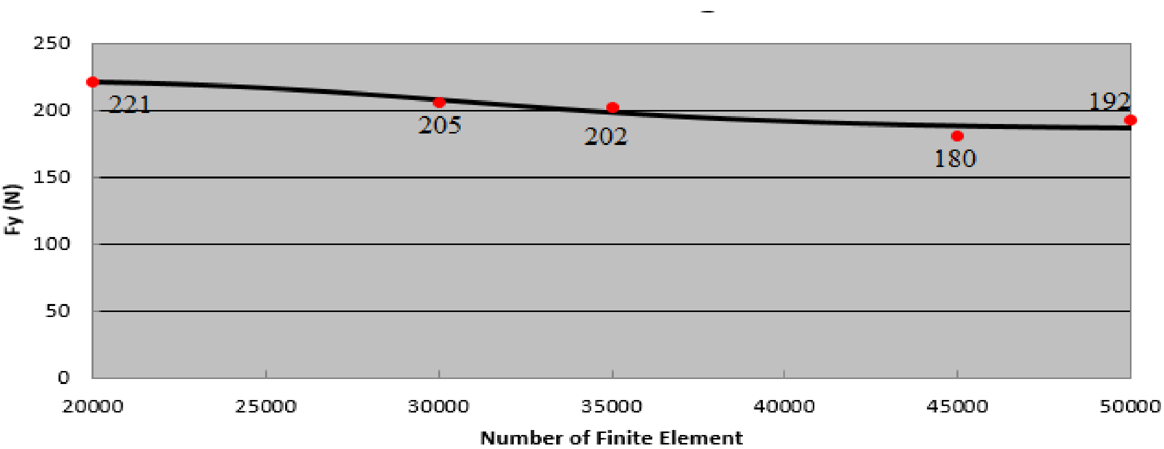


Figure 8 : Number of finite elements with respect to tangential force F(y) in N

2. METHODOLOGY

2.1 Evaluation of temperature in turning process

In any machining process heat generation affect the process. May be it will increase tool wear by affecting decrease in tool life.[26]. Also it suggests the heat softening of cutting tool. While doing cutting process some of failures and wear phenomena at cutting tool are generated by temperature and also it changes cutting tool properties. Like, hardness. It is better to evaluate temperature generated while cutting process to achieve final result and to reduce wear and some of other negative features. Below Figure 9 shows the different heat regions in turning like, tip tool interface, tool work interface zone and shear zone.

Primary shear zone: By this shear energy only plastic deformation happens, also, temperature increase because of heat. In this process some areas of heat abstracted by chip by its movement through tool. Since a constant sort chip, by increase in cutting speed it will decrease in chip thickness also less amount of shear energy to chip alteration so the chip temperature less from this deformation. Around 80-85% of the temperature produced in shear zone.

The chip-tool interface zone: Here secondary plastic deformation happens as of friction between the heated chip and tool. Hence it reasons to additional increment in temperature of chip. This chip-tool interface contributes 15-20% of heat generated

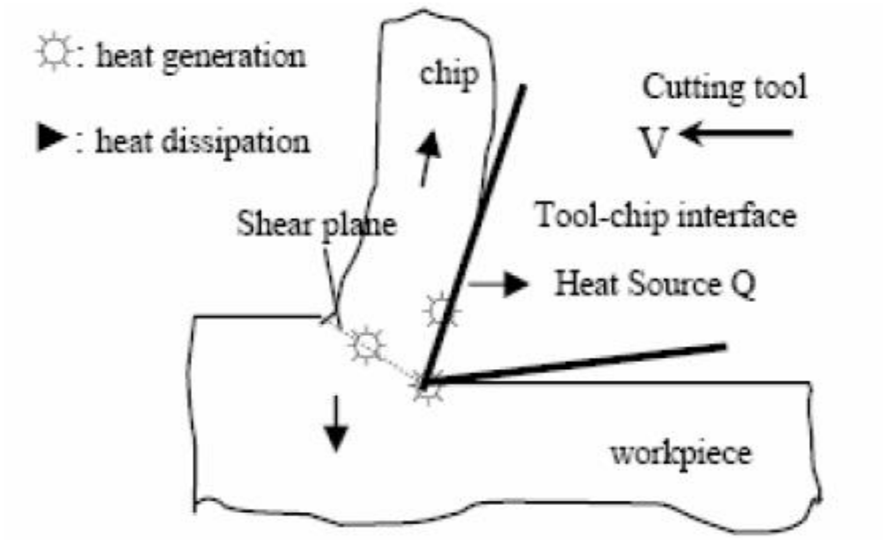


Figure 9 : Heat generation zone during machining [27]

The tool- work piece interface zone: At flanks where frictional rubbing happens. This range contributes 1-3% of heat generated. Measure of warmth that streams into the device cause high temperature in locale of hardware tip which thusly diminish the hardness of the apparatus material and in convincing case may even consequence of softening. The wear rate of hardware in this way augments, bringing about a decrease in profitable presence of the device. It is logically crucial to see how Machining temperature is affected by the procedure variable included which is instrument geometry, bolster and cutting rate. [27]

2.2 Finish turning

At the point when selecting feed for finishing operations, surface finish, tolerance and chip breaking requirements should be considered. Surface finish is resolute by the combination of feed rate and insert nose radius, and additionally the work piece stability, clamping and the common state of the machine. Chip breaking is determined by the selection of insert geometry. [20]

Basically (ideally) we have to generate new program in DEFORM 3D software. In DEFORM 3D machining, dependent upon the machining type we can create a program in its Turning operation. When a new program is created, the date gets stored in a database. After creating a new program, the program is opened to give the required inputs for the process to start. To finish the process, the feed rate (f), surface speed (v) and depth of cut are the most important parameters. The maximum feed rate depends on machine power, stability, workpiece material, insert shape and size, setting angle and so on. The feed rate should always be considerably smaller than the nose radius. Too small feed rate can result in poor chip breaking and tool life. The feed rate ranges from 0.1 to 0.4 mm/rev. A feed rate of 0.1 mm/rev is chosen. In order to have a good finish least amount of feed is given. Cutting speed choice depends on three factors, workpiece material, insert grade and feed rate. For stainless steel material of feed rate 0.1 mm/rev, here we choose three different surface speed (v) 75, 100 and 125m/min. Very high surface speed can result in tool wear, bad surface and other problems. Finally, the Cutting depth depends on machine power, stability, workpiece material, insert shape and size grade, setting angle and so on. The maximum cutting depth should not be smaller than the nose radius. We give 0.5 mm cutting depth which is suitable for finishing. The three various surface speed process setup shown in table 5 and figure 10.

Table 5: Cutting process parameters for Finish Turning

CUTTING PROCESS PARAMETER	**VALUES**
Surface feed (v) in m/min	75, 100, 125,150
Depth of cut (d) in mm	0.5
Feed rate(f) in mm/rev	0.1

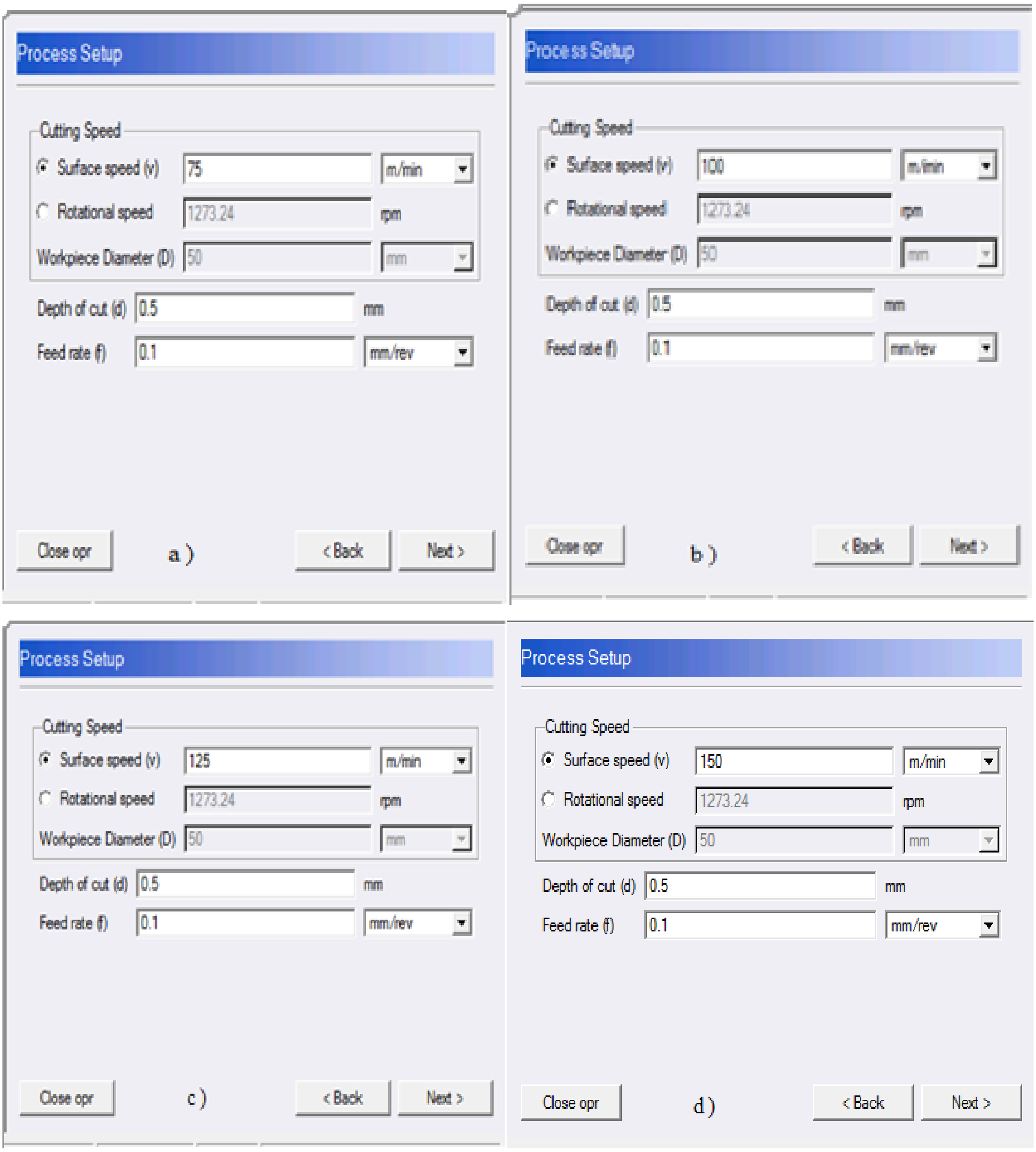


Figure 10 : Process set up with a) 75, b) 100, c) 125 and d) 150 m/min surface speed

Once all the process setup parameters are given, we have to give the process condition. 20 C environment temperature is selected here, which is usually the room temperature of the work station. The friction parameters among the tool and the chip are impacted by elements, for example, cutting speed, feed rate, rake angle, and so on. Predominantly because of the high normal pressure at the surface, shear friction factor is 0.6 and heat transfer co-efficient is 45 N/sec/mm/C.

Tool and tool holder selection is very vital in this machining. Tool and tool holder varies from one operation to another. If we choose inappropriate tool and tool holder we can end up with very bad results like Tool wear, breaking of tool, bad machining and so on. So in this operation we choose DNMA432 Without coating (WC) tool and DDJNL tool holder from the library. This combination is suitable for both rough and finish turning. Stainless steel can be easily machined using this combination of tool and tool holder. This allows machining at high speed and variety of feed. Tool DNMA432 WC material dimension is shown below in the Figure 11. Here the Inscribed circle of DNMA432 tool is 12.7 mm, nose radius of the tool R is 0.8 mm, thickness of the tool is 4.76 mm and the diameter of the hole in the tool is 5.15 mm. This is suitable for both rough and finish turning.

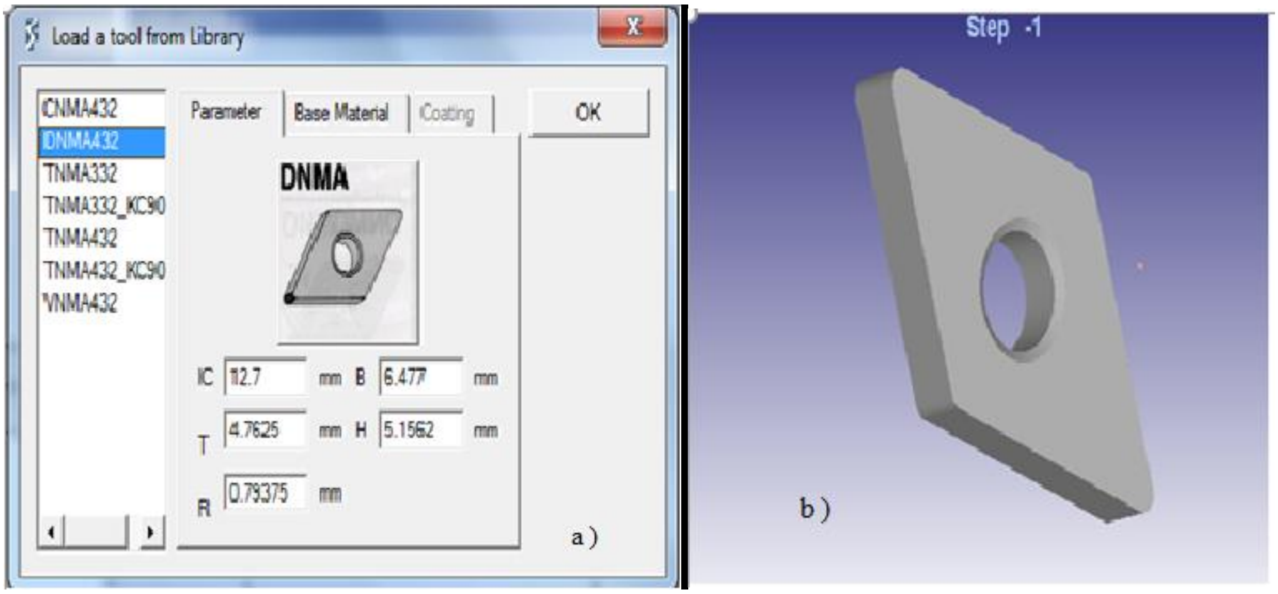


Figure 11 : a) and b) Dimension and graphical view of the DNMA432 cutting tool

In this DNMA432 stainless steel cutting tool, the three most important angles are the rake angles, end angles and side cutting angles. The back rake angle disturbs to the ability of the tool to shear the work piece and create a chip. May be it can positive or negative? Positive rake angle decreases the cutting force resulting in lesser deflection of workpiece. On right and left hand turning tools cutting operation takes place within the tool. Because of this side rake angle is also important and deep cut can be made. Here we take -5-degree back rake angle and side rake angle. The side cutting angle (SCEA) is -3 degree.

After selection of proper tool and tool holder, further step is meshing of tool. This is important process. The meshing of tool depends on the final results. Meshing consists of number of finite elements, which can be given by absolute mesh size and size ratio. Number of finite elements and nodes can be obtained depending on the polygons and points. Here we use 0.26 mm of absolute mesh size with 6 size ratio to generate nearly 20000 elements. Tool setup is finished, the generated tool mesh can create a boundary condition which contains temperature, heat exchange with environment.

For workpiece setup here we choose plastic type workpiece, deformation takes place and also we can get clear result about temperature, static load and so on. The temperature of the workpiece is approximately room temperature around 20C. In selection of work piece shape, desired shape of the workpiece used in the operation can be given. The desired shape is created by system. Here we choose curved model of workpiece which is 50 mm diameter and 20-degree arc angle. Workpiece geometry is created by system. The created work piece geometry is shown in Figure 12.

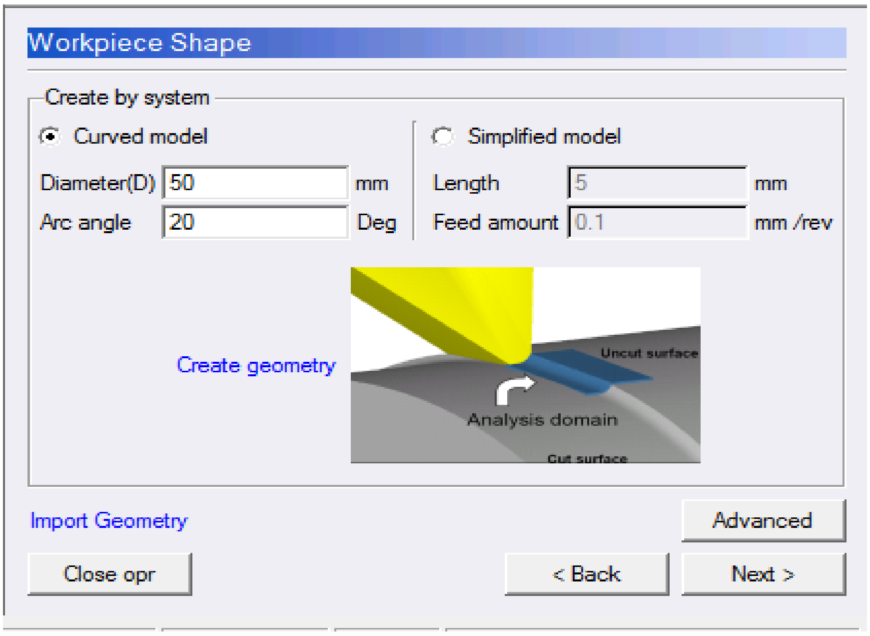


Figure 12 : Selection of Work piece shape

For workpiece mesh generation here we are giving size ratio of 5 and 30 % of feed. Here we use absolute mesh size. That can create a meshing elements of nearly 45000. The meshing elements of workpiece is more than the tool meshing. Because of that we can get clear results on tool wear, work piece temperature, stress and strain. And generation of work piece meshing process is shown in Figure 13.

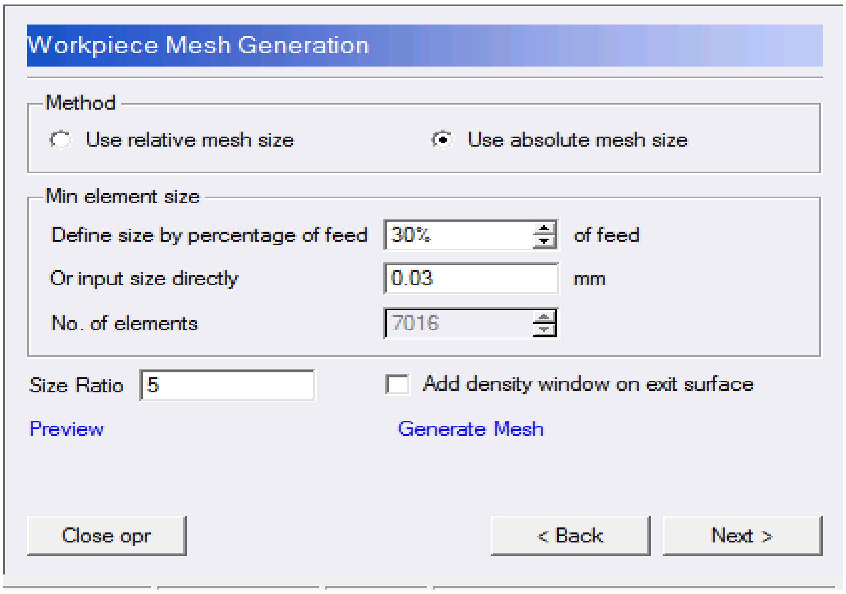


Figure 13 : Work piece mesh generation

We can see boundary condition of the work piece after generation of workpiece mesh. That shows the clear picture of deformation velocity, heat exchange with environment. We can see the boundary condition of workpiece. In workpiece material set up, we can create new material depending up on need. Here we import work piece material from the library. In library we can get various category of material. In our case we select stainless steel as a work piece material. In stainless steel, AISI 304(machining -AMTC) is used for our operation. That is shown in the Figure 14. The process set up is completed here.

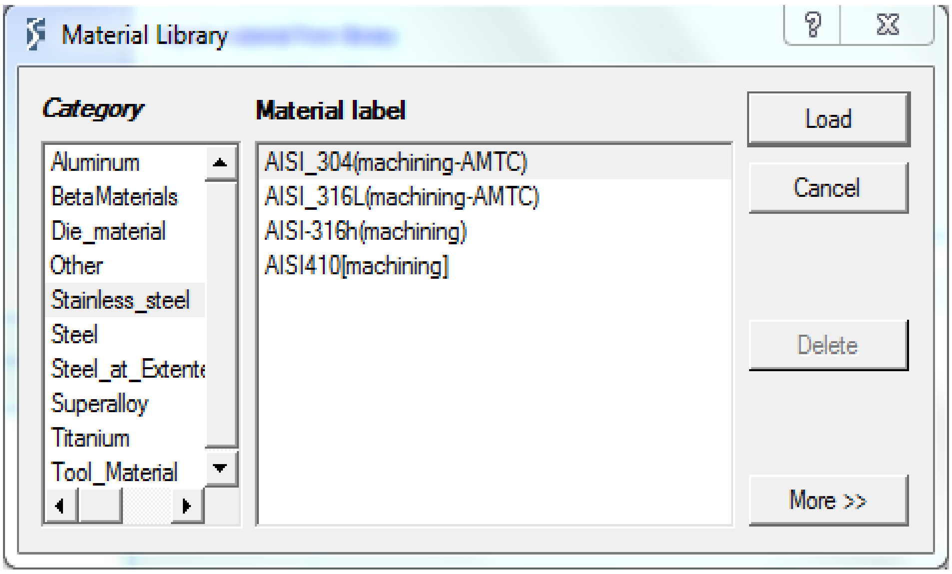


Figure 14 : Selection of Work piece material.

Finally, the process set up is completed when we control the simulation set up. In this step we give 1500 has simulation steps. It can be easily varied up to 100000. Here the arc angle of cut is 25 degrees. Tool wear calculation with Usui models are also calculated. That is shown in Figure 15.

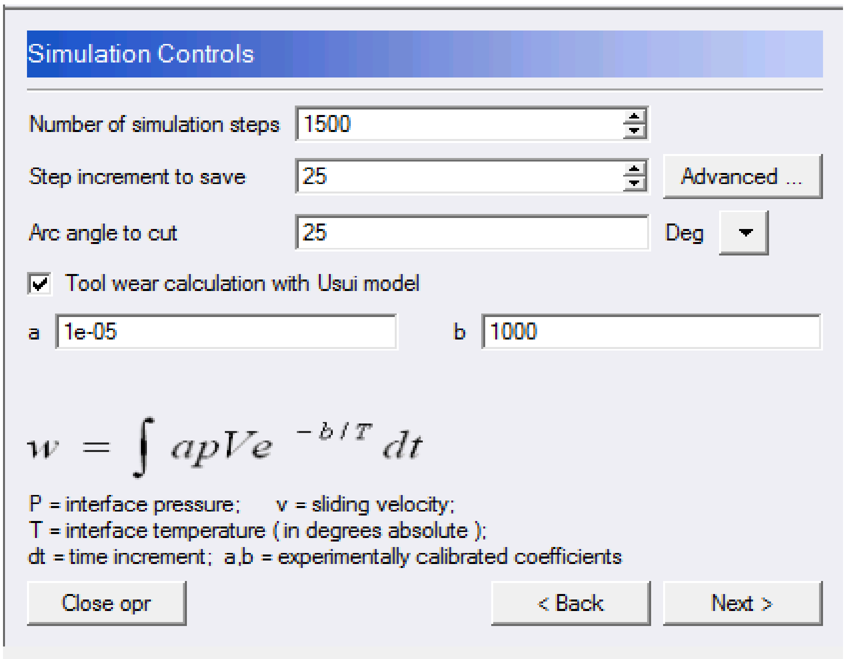


Figure 15 : Simulation control process

Data base generation is the last step in pre-processor of DEFORM 3D operation. Here primarily the process condition is checked if everything is fine, then we can generate data. This data stored in database. If any correction is needed in the process condition, we have to change it before generating the data base. After correction, the data is checked and generated.

2.3 Rough turning

The same process is set up and data used in finish turning is also used in Rough turning except at some points. For Rough turning, the feed rate (f), surface speed (v) and depth of cut are more vital in the operation. In rough turning maximum feed rate depends on machine power, stability, workpiece material, insert shape and size, setting angle and so on. A too small feed rate can result in poor chip breaking and tool life. The feed rate range from 0.2 to 0.7 mm/rev. Here we choose 0.2 mm/rev feed rate. Cutting speed choice depends on three factors, workpiece material, insert grade and feed rate. For AISI 303 stainless steel material of feed rate 0.2 mm/rev, here we choose three different surface speed (v) 50, 75 and 100 m/min. Very high surface speed can develop tool wear and other problems.

Finally, the Cutting depth depends on machine power, stability, and workpiece material and so on. Here we give 2 mm cutting depth which is suitable for rough turning. That is shown in Table6.

Table 6: Cutting process parameters for Rough Turning

CUTTING PROCESS PARAMETERS	**VALUES**
Surface feed (v) in m/min	50, 75, 100, 125
Depth of cut (d) in mm	2
Feed rate(f) in mm/rev	0.2

Process set up and tool set up is similar to finish turning. But in the work piece set up, the shape of the work piece is changed, because here we give 2mm cutting depth. That is shown in the Figure 16.

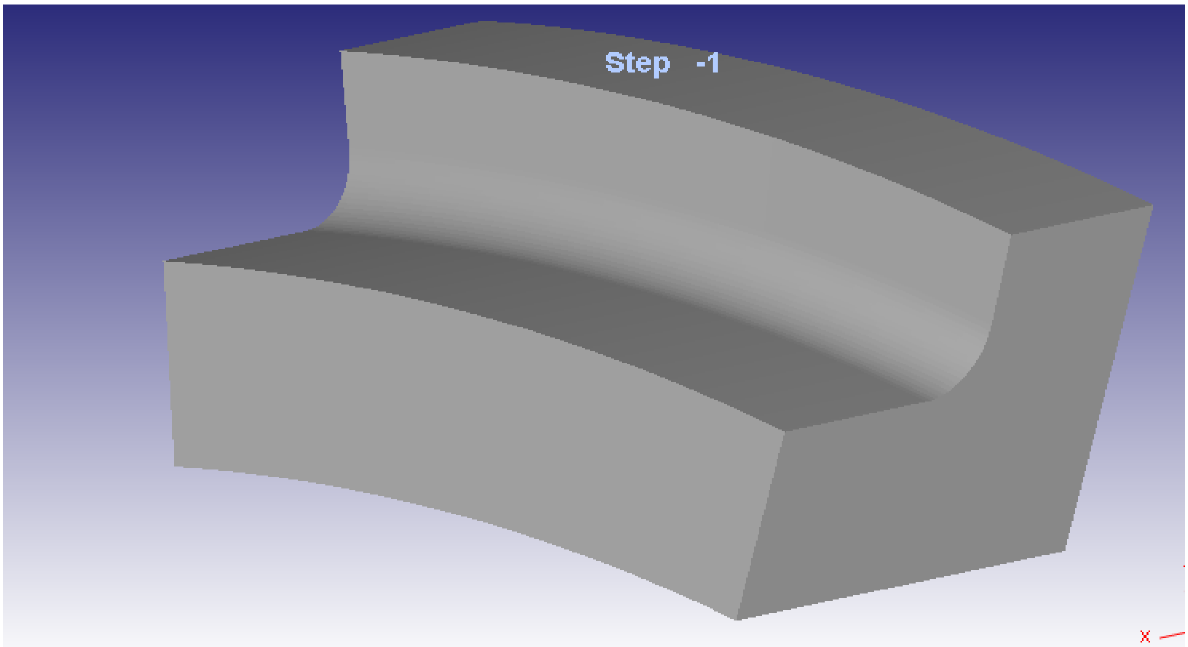


Figure 16 : Shape of the work piece for Rough turning with 2 mm cutting depth

Simulation setup and database generation is same as finish turning. After all this process, pre-processing is finished and simulation process starts. A simulation process for performing the numerical calculations required to analyse the process and writing the outputs to the database file. Here we select the machine like 32-bit or 64-bit operating system in computers. Then we run the simulation process with solver manager. Simulation process takes some time to simulate the operation, which depends on the pre-processor data. Here we can stop simulation at any time or in case of any sudden interruption in simulation, the process automatically stops. After stopping we have to correct and continue the simulation process. In this stage we can know the running jobs and queued jobs in the process monitor. We can also observe the graphical simulation. Including graphical simulation, we can also see the detail summary, message and log of the operation simulation step.

The final step in the operation is post-processing. After completion of pre-processor and simulation process, postprocessor occurs, that is shown in Figure 17.

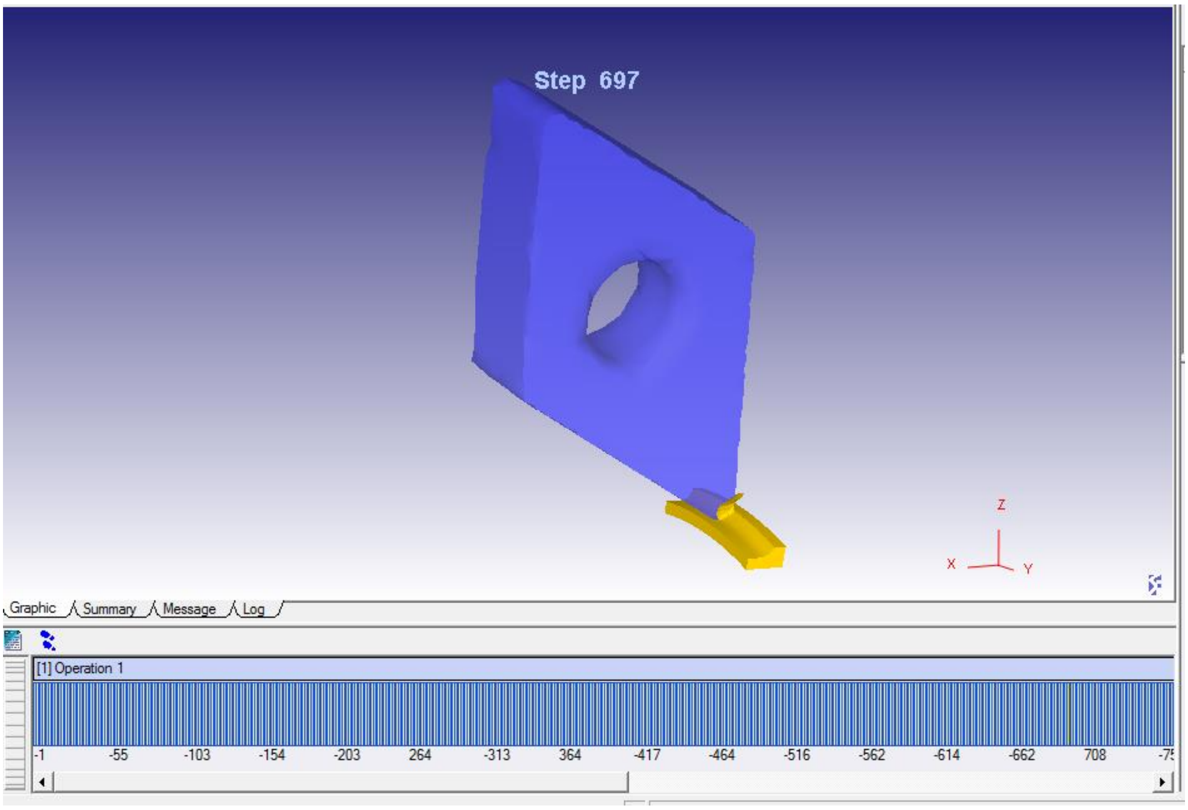


Figure 17 : Graphical view of simulated results

Here we can get the visualization of final results with clear quality. The results like effective stress and strain, effective stress and strain rate, total velocity, total pressure and temperature and so many results can be seen numerically or graphically. Also we can get results on graphs, step list, flow chart, and animation setup and so on.

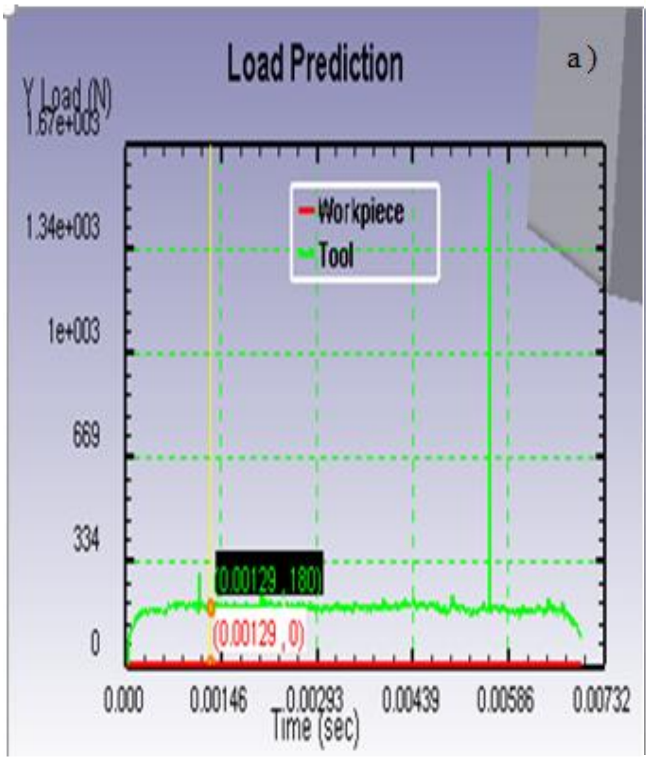
3. RESULTS AND DISCUSSION

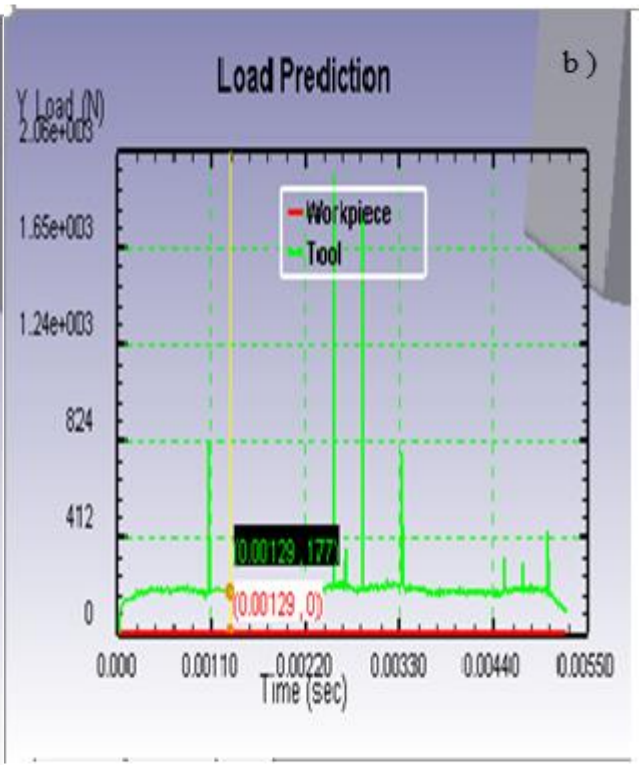
3.1 Effect of cutting (Tangential) force

Cutting force is an essential parameter in cutting process that affects cutting temperature, tool life, machining accuracy, and so on. For finish turning various cutting speed were simulated with feed rate 0.1 mm/rev and depth of cut 0.5 mm, as shown in table 7we can get different cutting force Y load in N and its shown in figure 18.

Table 7: Cutting speed with respect to cutting load for Finish turning with 0.5 mm cutting depth.

CUTTING SPEED IN m/min	CUTTING LOAD in N at 0.00129 sec
75	180
100	177
125	193
150	201





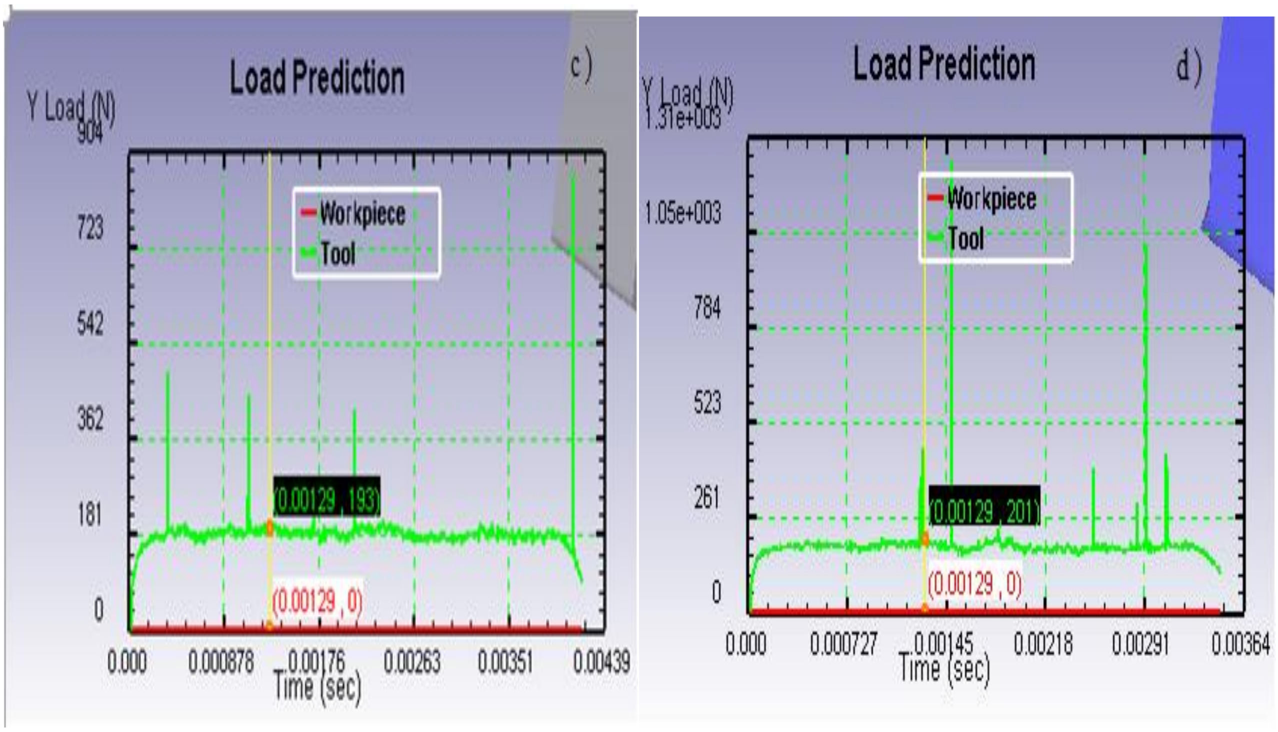


Figure 18 : Tangential force with a) 75, b) 100, c) 125 and d) 150 m/min cutting speed with 0.5 mm cutting depth

For Rough turning various cutting speed were simulated with feed rate 0.1 mm/rev and depth of cut 0.5 mm, as shown in table 8 we can get different cutting force Y load in N and its shown in figure 19.

Table 8: Cutting speed with respect to cutting load for Rough turning with 2mm cutting depth

CUTTING SPEED IN m/min	CUTTING LOAD in N at 0.00129 sec
50	1.3e+03
75	1.39e+03
100	1.37e+03
125	1.41e+03

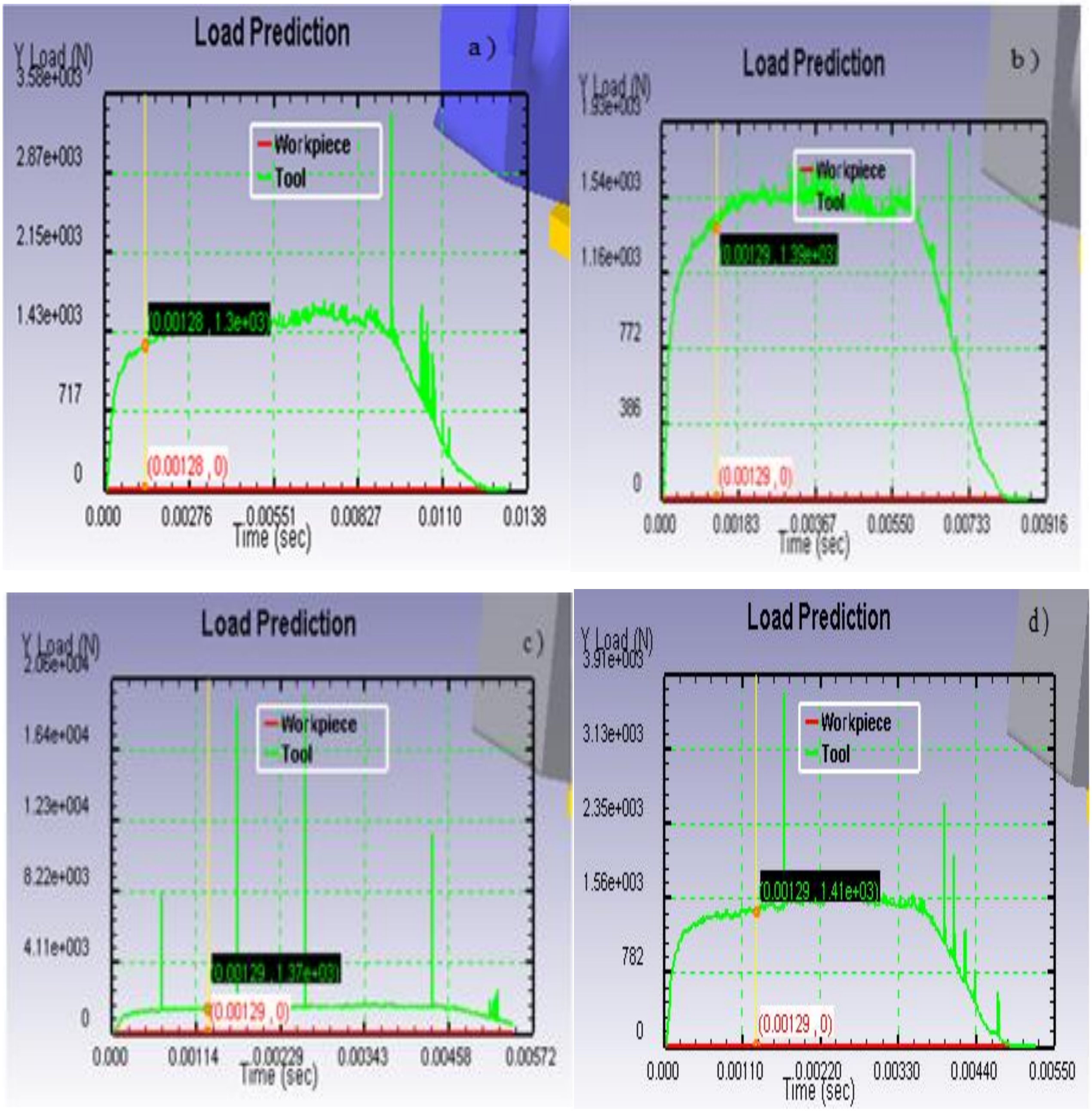


Figure 19 : Tangential force with a) 50, b) 75, c)100 and d) 125 m/min cutting speed with 2mm cutting depth.

Results of Finish turning and rough turning cutting force are appeared, we can find the variation in finish turning and rough turning. Finish turning required cutting force are moderately small compare to rough turning. With the increase in cutting depth. This represents rough turning require more load compare to finish turning.

3.2 Temperature distribution

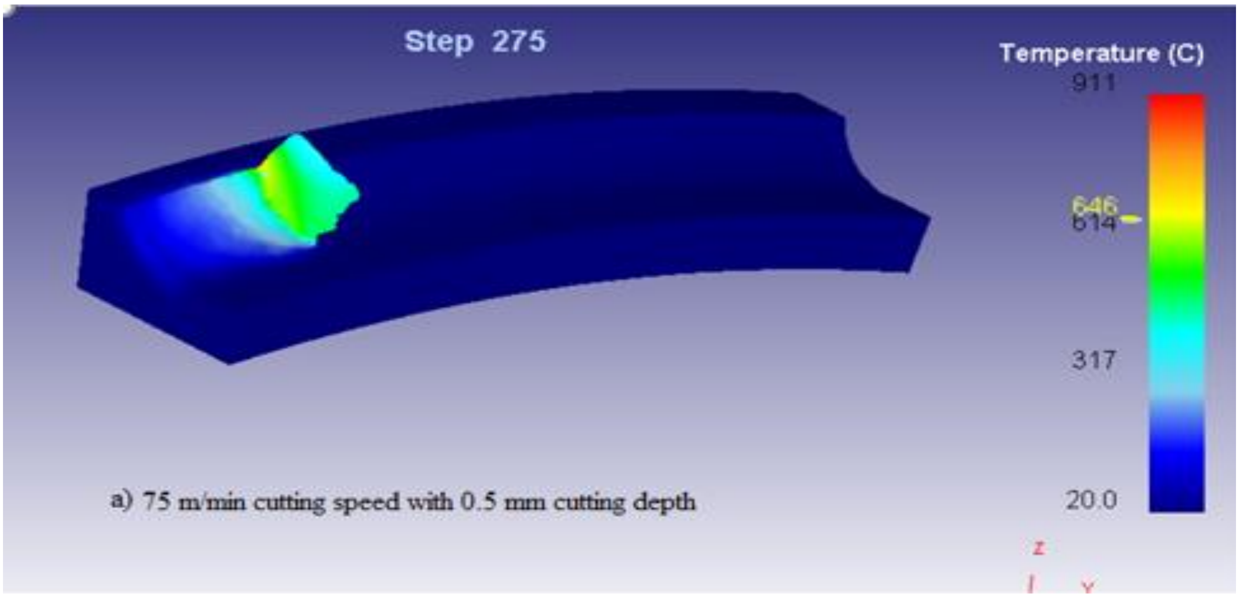
Temperature is generated by friction in tool and workpiece interference. The extreme of the temperature is more in Primary shear zone. That decreasing in temperature happens in secondary shear zone. That secondary shear zone makes unfavourable chip breaking. At the point when high temperature in secondary shear zone reaches crystallization temperature leading to annealing of chip. This generated chip carries a lot of heat produced in operation. This temperature tends to rise normal working temperature. For Finish and Rough turning good range of tool–chip interface temperature exists. Temperature Distribution across the Work Piece and Tool Face.

3.2.1 Temperature Distribution through the Work piece

It should be noticed, as in Figure 20 for finish turning. The maximum temperature value through the work piece progresses with the tool movement different cutting speed in 0.00129 sec time, when the tool progress on the work piece the contact area has a maximum temperature for Finish turning the value of contact temperature for machining AISI304 stainless steel of various cutting speed is shown in below Table 9.

Table 9: Temperature of the workpiece in different cutting speed in finish turning with 0.5 mm cutting depth

CUTTING SPEED m/min	TEMPERATURE °C at 0.00129 sec
75	646
100	675
125	726
150	754



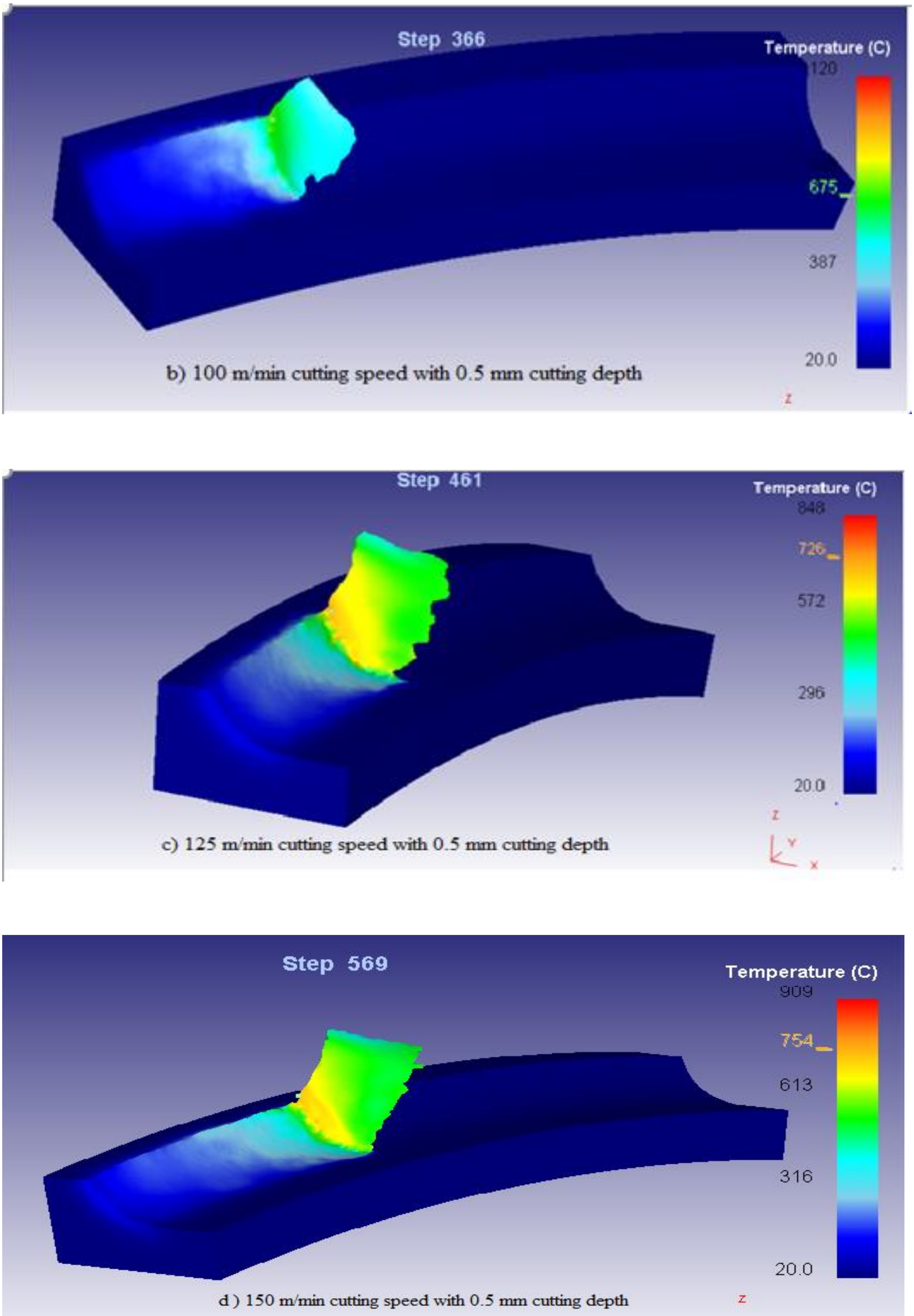
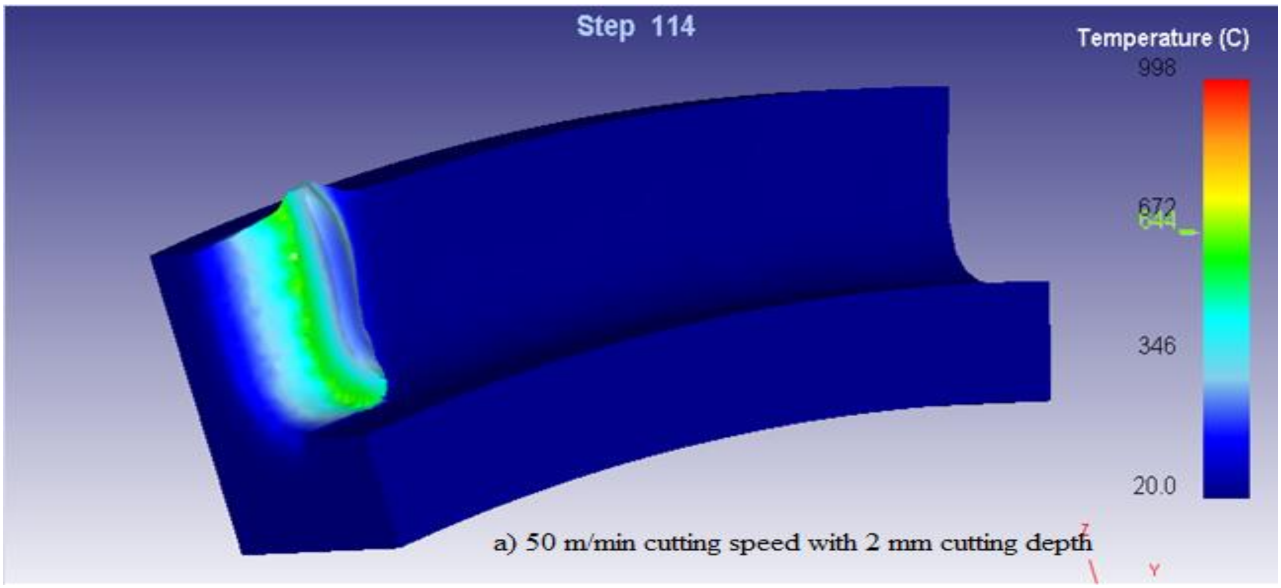


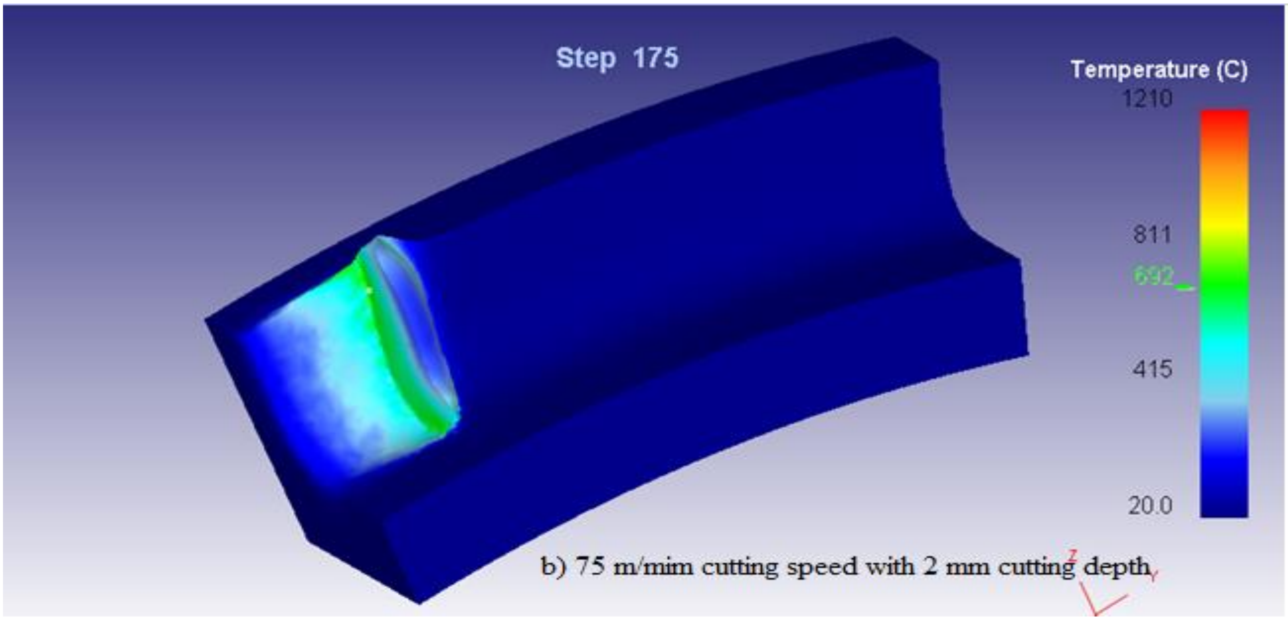
Figure 20 : Temperature distribution in workpiece with 75,100, 125 and 150 m/min cutting speed with 0.5 mm cutting depth

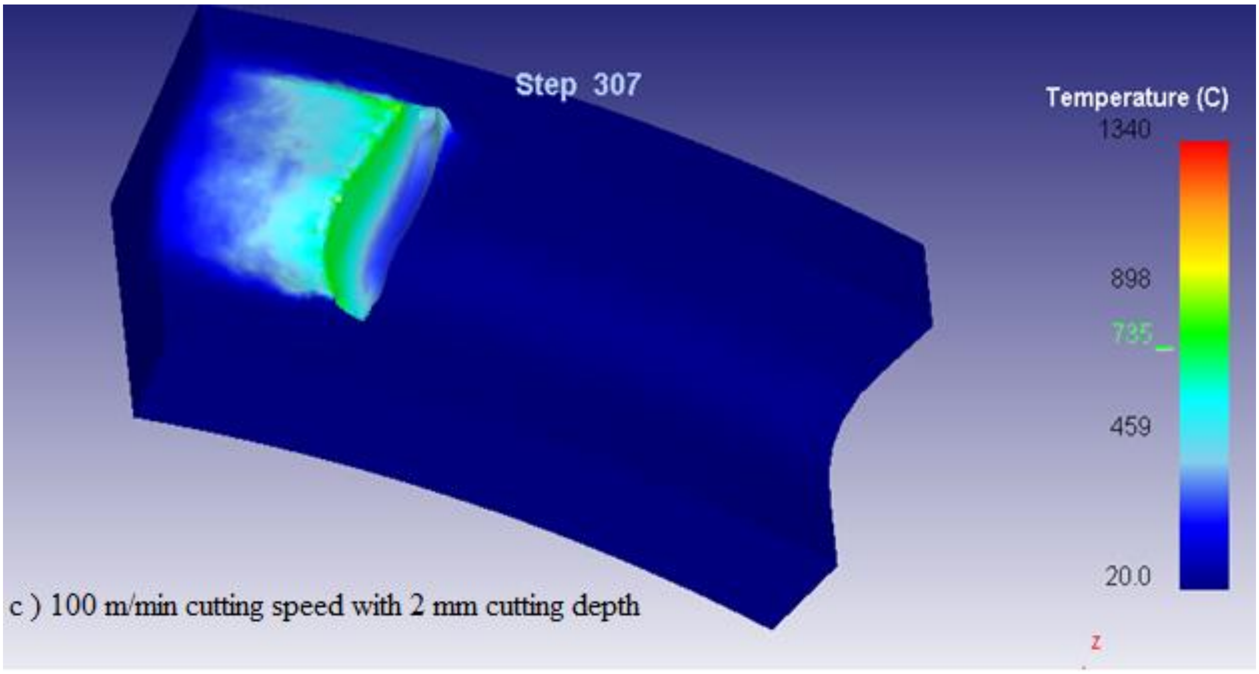
For Rough turning the value of contact temperature for machining AISI304 stainless steel of various cutting speed is shown in below Table10 and figure 21.

Table 10: Temperature of the workpiece in different cutting speed in rough turning with 2mm cutting depth

CUTTING SPEED m/min	TEMPERATURE °C at 0.00129 sec
50	644
75	692
100	735
125	823







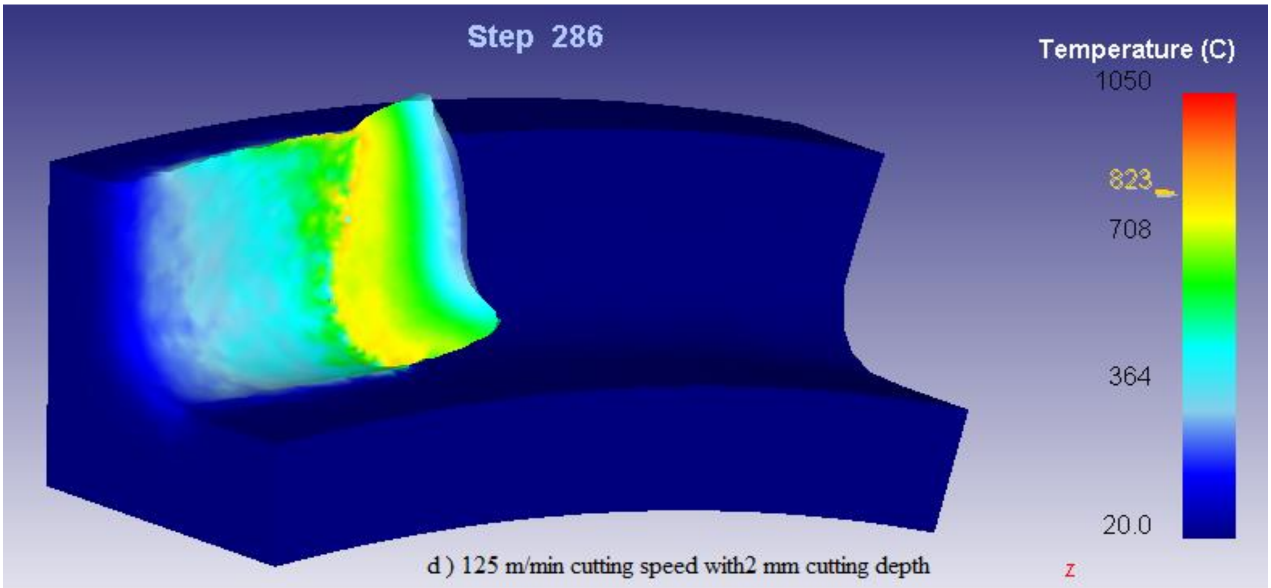


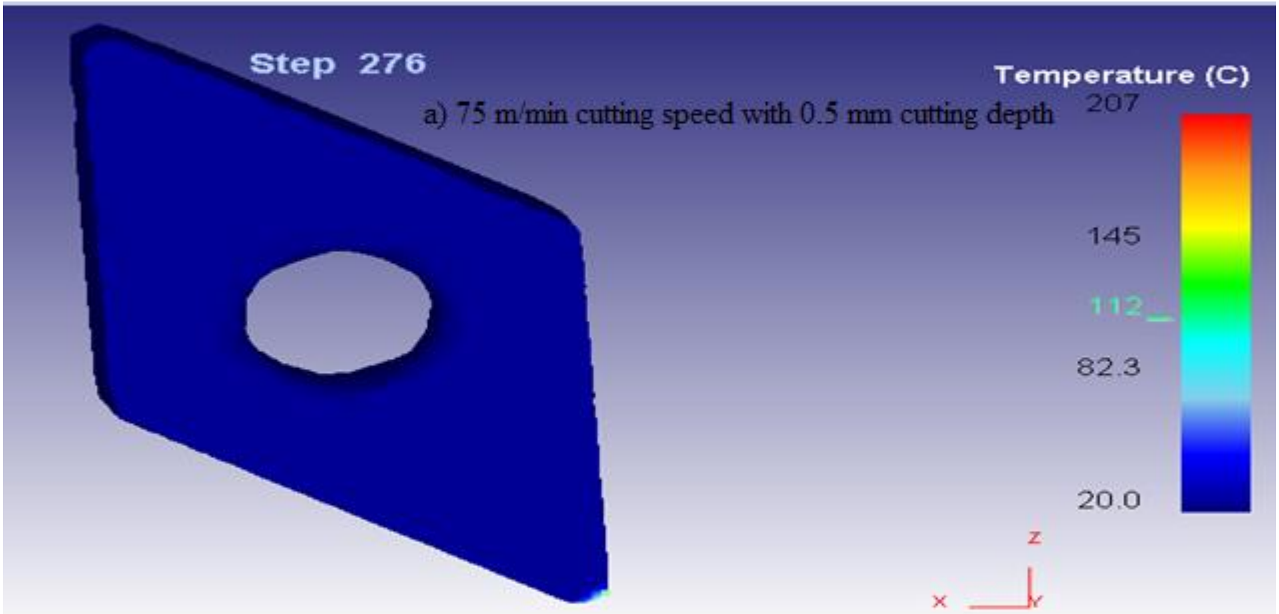
Figure 21 : Temperature distribution in workpiece with 50, 75, 100 and 125 m/min cutting speed with 2 mm cutting depth

3.2.2 Temperature distribution through the tool face

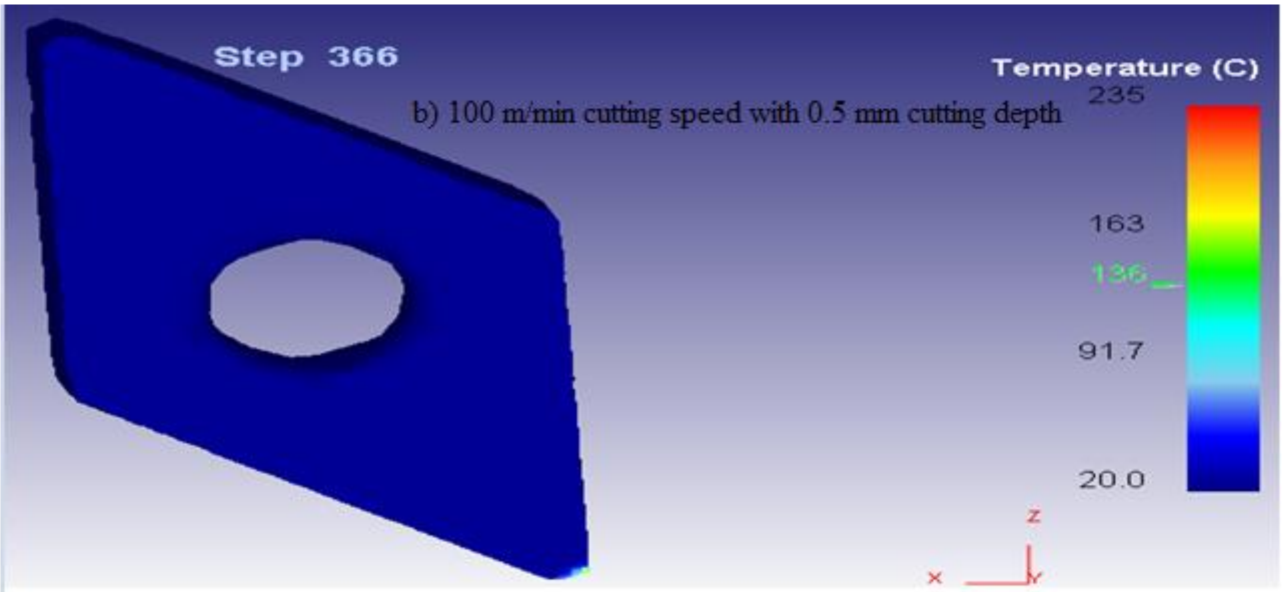
The temperature distribution in various nodes on the tool was shown in Figure 22. The greatest node temperature is obtained exactly in the centre contact between the tool and workpiece. The highest temperature of the tool surface was situated at a separation close-by the tool tip, this was because of high heat generation in the contact area amongst tool and work piece. As the node is far of the cutting edge, it has temperature lower than the closest node. Table11 and Table12 demonstrates that the temperature of the tool faces in various cutting speed in complete the process of finish turning.

Table 11: Temperature of the tool face in different cutting speed in Finish turning with 0.5 mm cutting depth

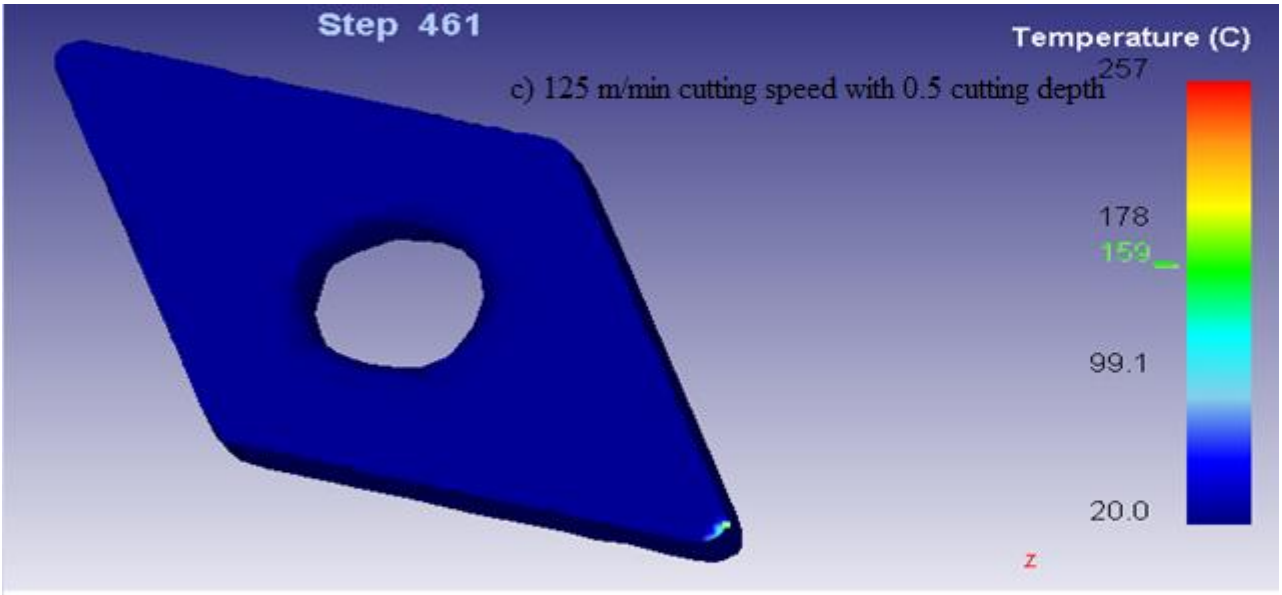
CUTTING SPEED m/min	TEMPERATURE °C at 0.00129 sec
75	112
100	136
125	159
150	185



a) 75 m/min cutting speed with 0.5 mm cutting depth



b) 100 m/min cutting speed with 0.5 mm cutting depth



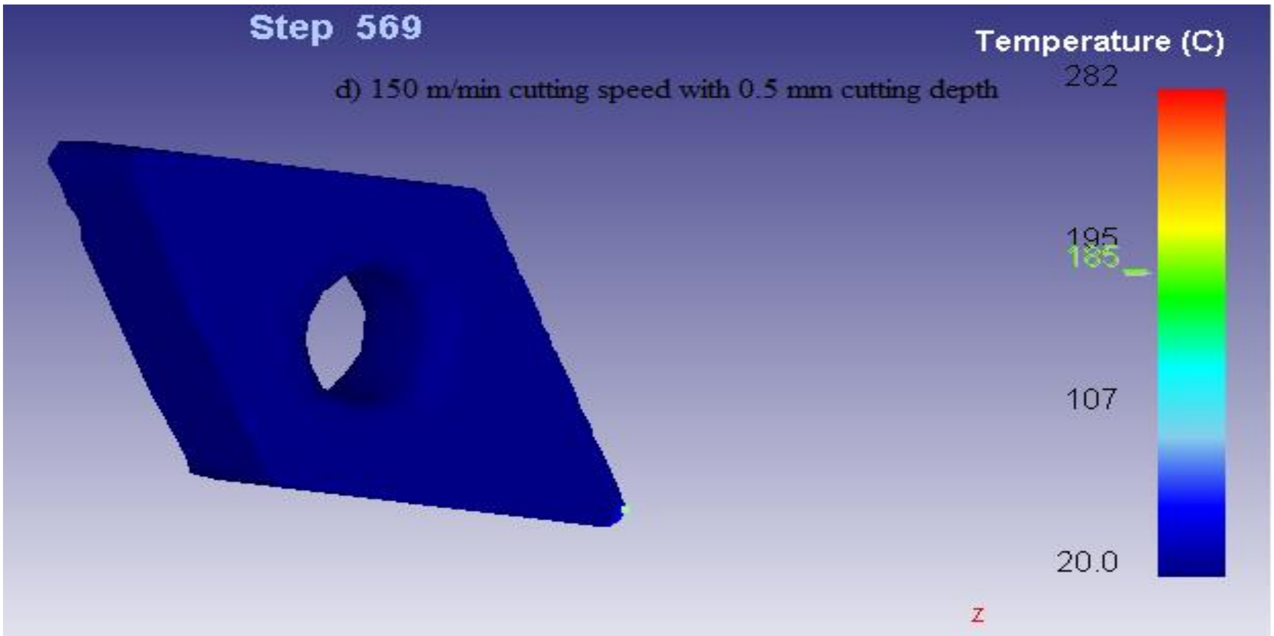
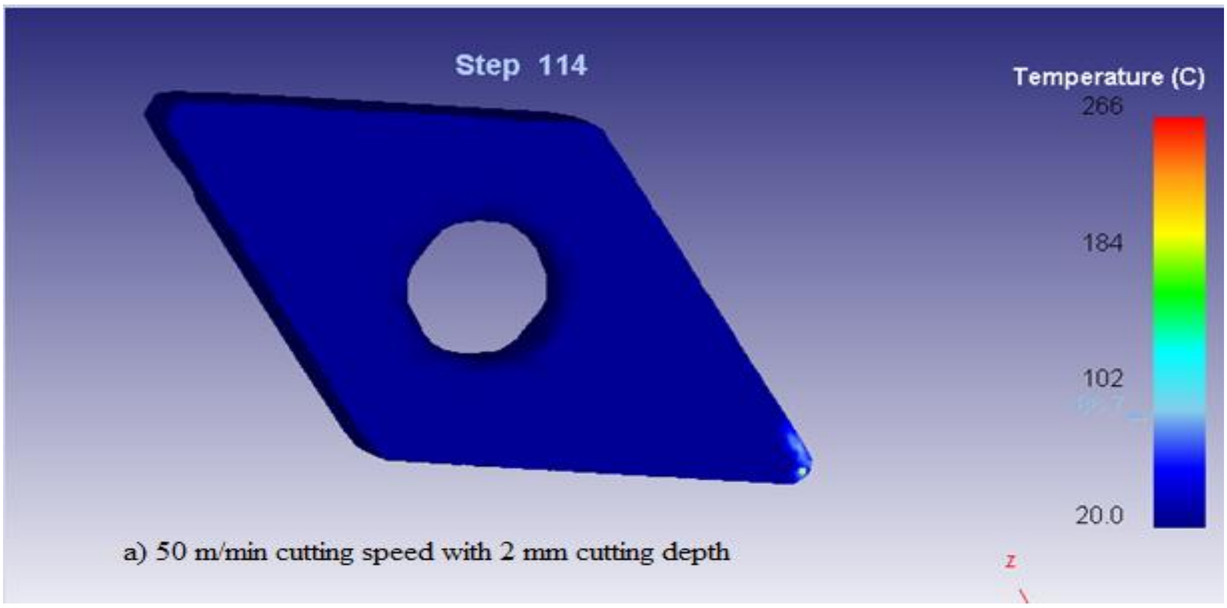


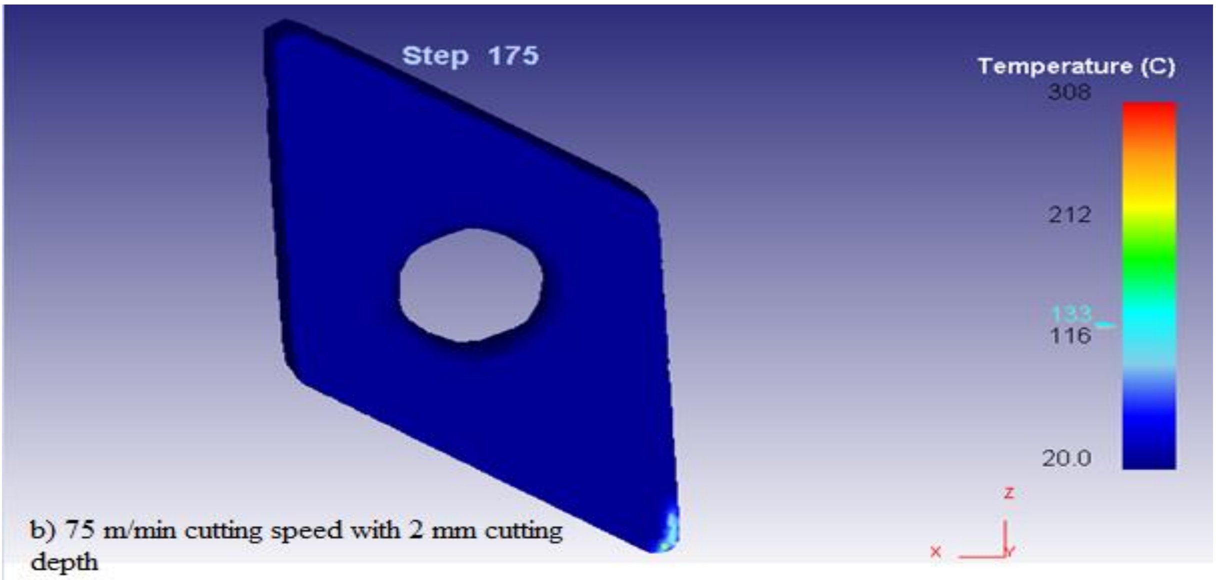
Figure 22 : Temperature distribution in tool face with 75,100, 125 and 150 m/min cutting speed with 0.5 mm cutting depth

Table 12: Temperature of the tool face in different cutting speed in Finish turning with 2 mm cutting depth

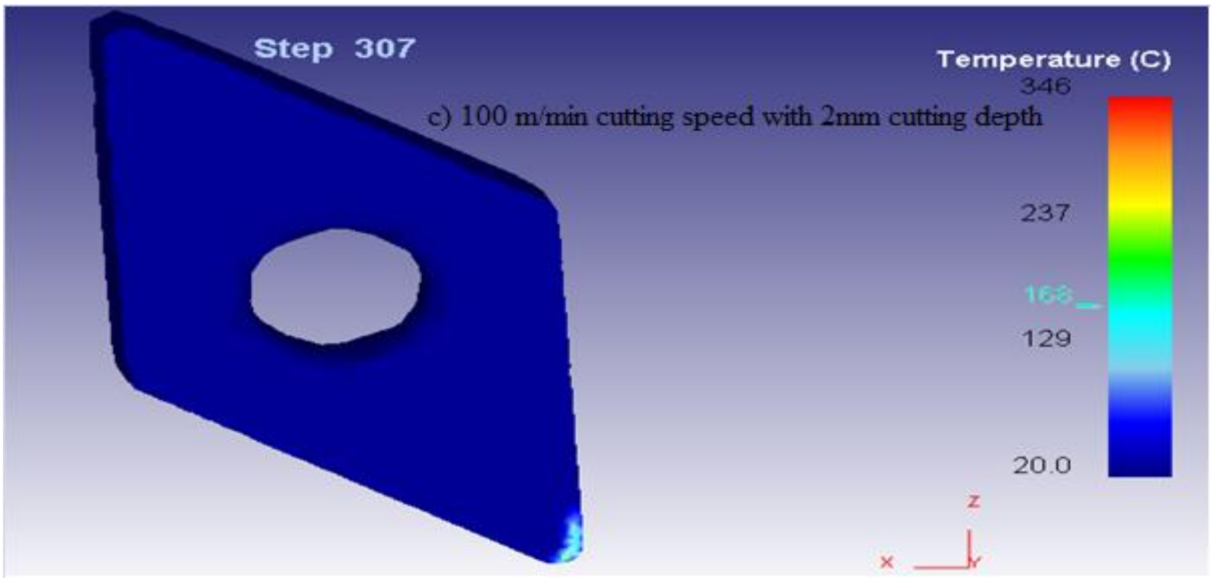
CUTTING SPEED m/min	**TEMPERATURE°C at 0.00129 sec**
50	86.7
75	133
100	168
125	199



a) 50 m/min cutting speed with 2 mm cutting depth



b) 75 m/min cutting speed with 2 mm cutting depth



c) 100 m/min cutting speed with 2mm cutting depth

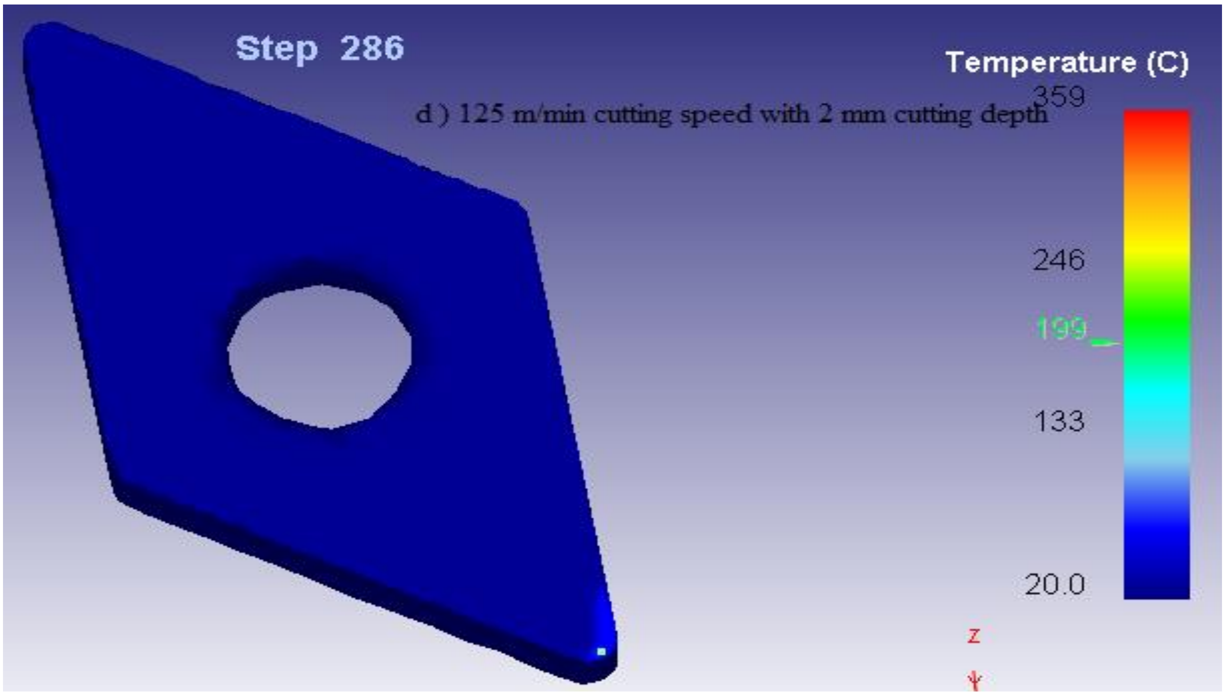


Figure 23 : Temperature distribution in workpiece with 50,75, 100 and 125 m/min cutting speed with 2 mm cutting depth

3.2.3 Effect of cutting speed on temperature distribution

Finish turning was performed at various cutting speed with feed rate at f=0.1 mm/rev and 0.5 mm cutting depth, it showed from that figure. The speed of 75 m/min, the maximum temperature is 646°C, at the rate of 100 m/min most extreme temperature is 675°C, while at the rate of 125 m/rev maximum temperature is 726°C and at the rate 150 m/min temperature is 745°C at 0.00129 sec of time. Rough turning was performed at various cutting speed with feed rate at f=0.2 mm/rev and 2 mm cutting depth. it demonstrated from that figure 25. The cutting speed of 50 m/min, the maximum temperature is 644°C, at the speed of 75 m/min most extreme temperature is 692°C, while at the rate of 100 m/rev maximum temperature is 735°C and at the rate 125 m/min maximum temperature is 823°C at 0.00129 sec of time that is shown if the below figure 24. In the cutting process when high cutting speed was utilized greatest stress are acquired, and these stress are more concentrated in the tool tip which may reason for plastic deformation of tool edge. High temperatures are generated in the contact region as a result of plastic deformation of workpiece and friction along the tool-chip interface; this induces an increase in temperature in the cutting zone. Which demonstrated that the tool work piece interface temperature is firmly associated with the cutting speed.

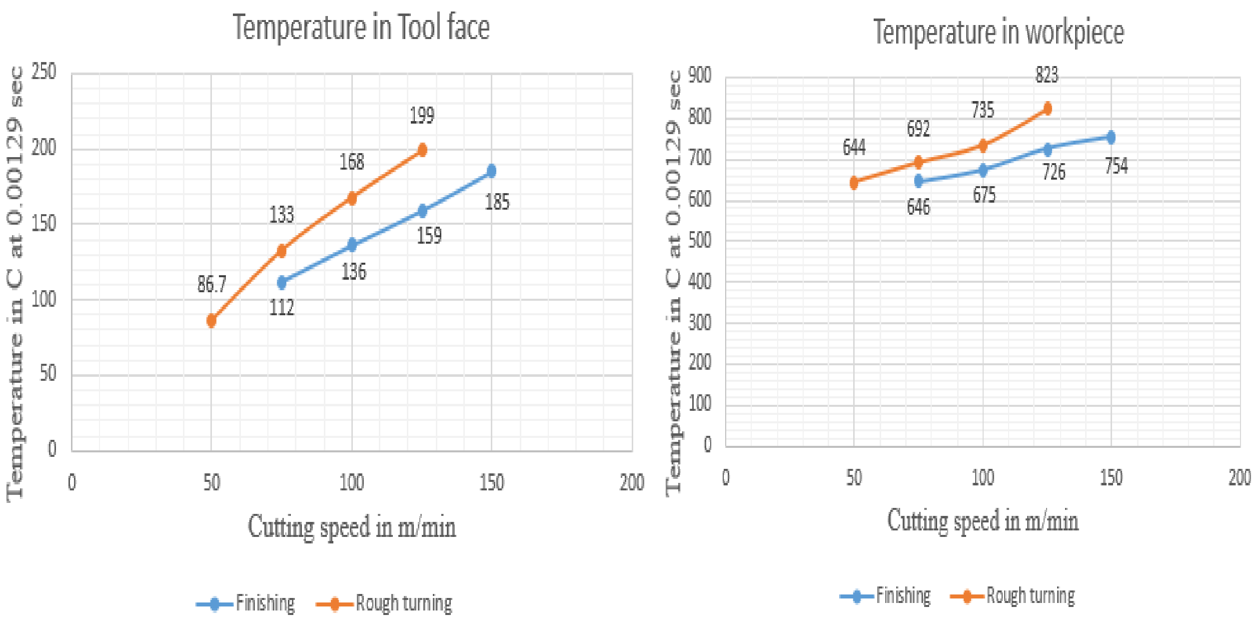
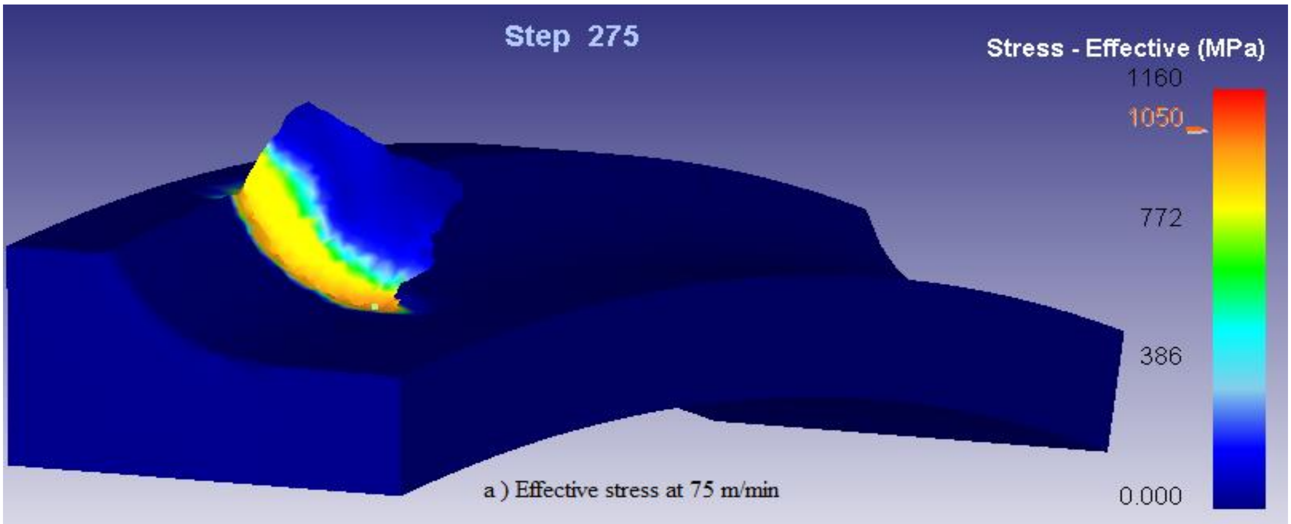


Figure 24 : Temperature distribution in Tool face and Work piece

3.3 Effective stress and strain distribution with different cutting speed

3.3.1 Effective stress distribution

At the point when turning operation is completed with AISI 304 steel as work piece and cutting material tool the effective stress and strain values are noted for various cutting speed increasing from 50 to 150 m/min in both finishing and rough turning. The simulated estimations of effective stress for Finishing and rough turning are appeared in figures 25 and 26 individually. In this FEM simulation cutting tool is keep running on work piece Depth of cut – 0.5 and 2 mm and Feed - 0.1 and 0.2 mm/rev respectively for finishing and rough turning on all cutting speed. While observing the figures higher effective stress happened around the shear zone.



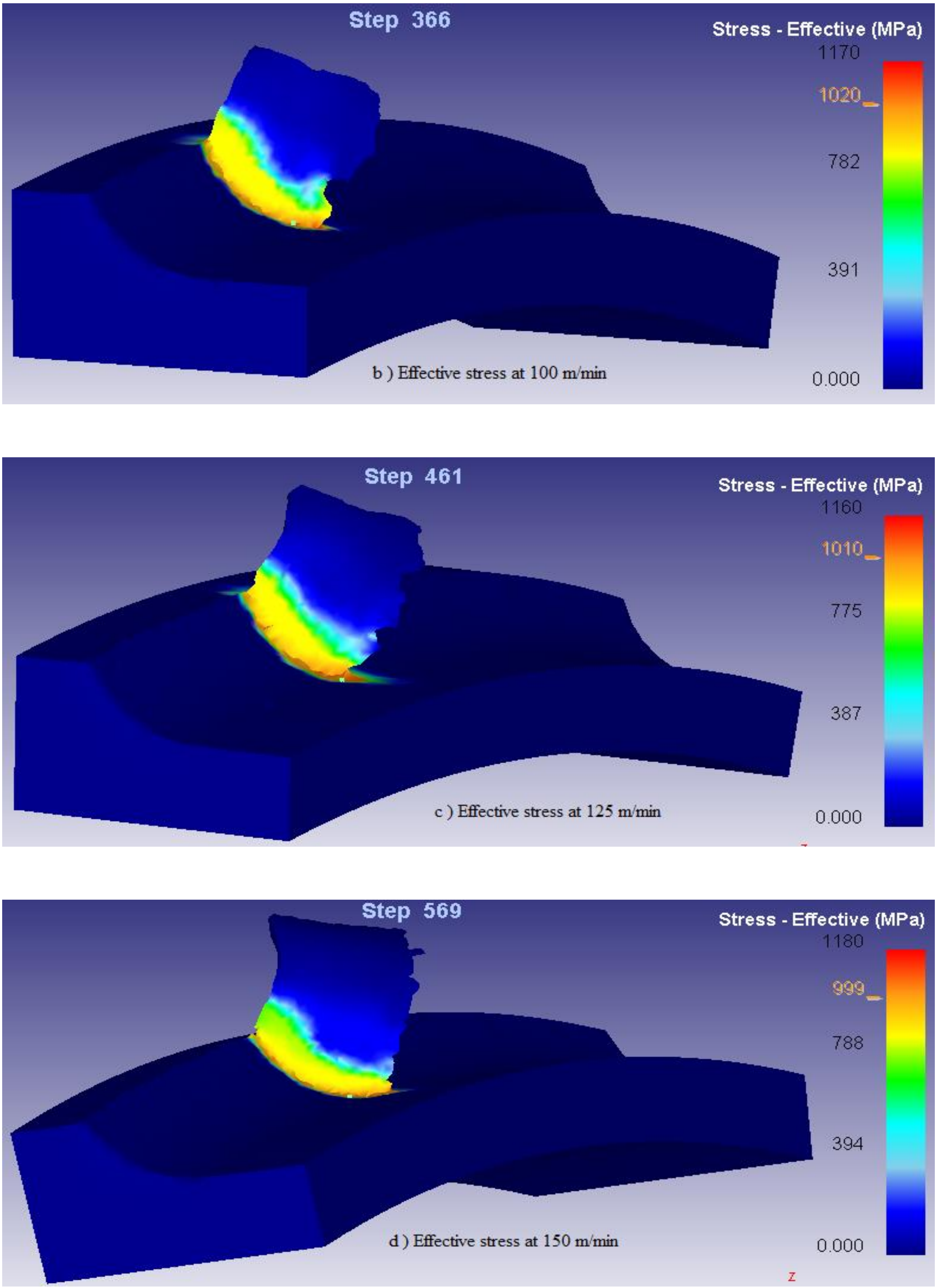
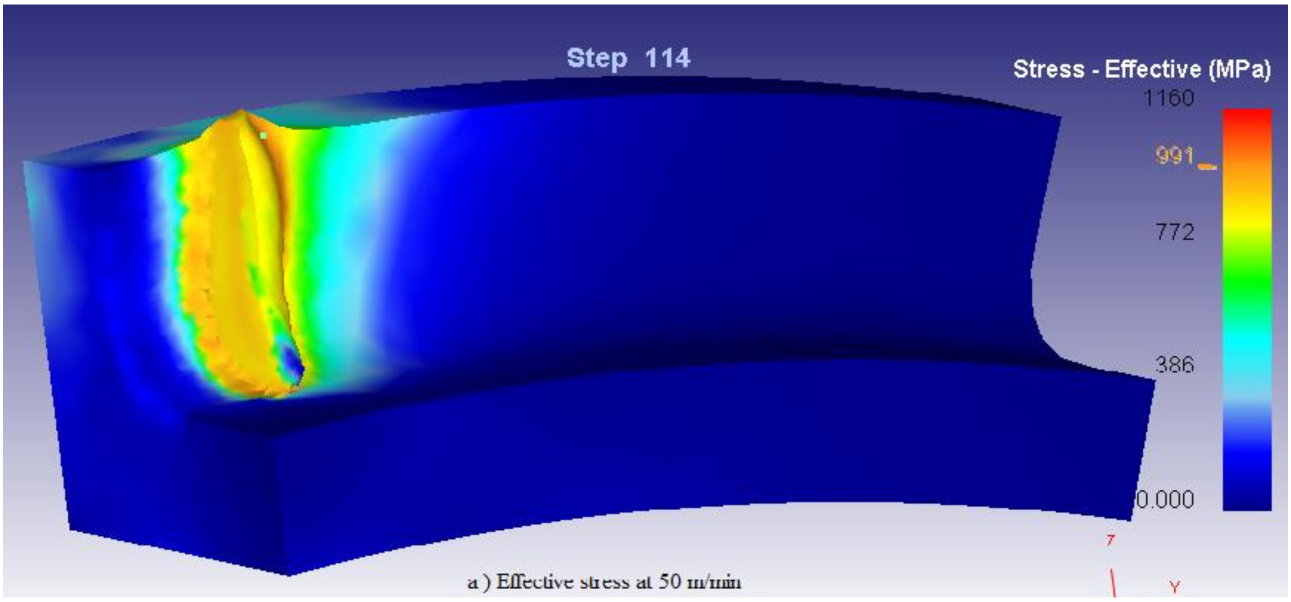
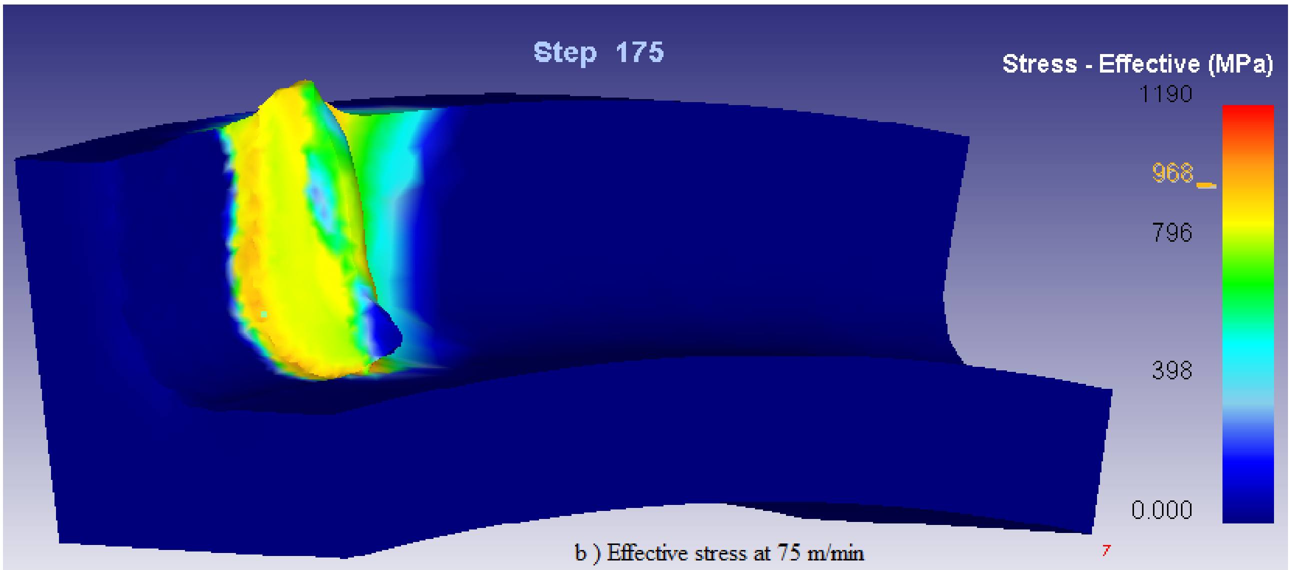


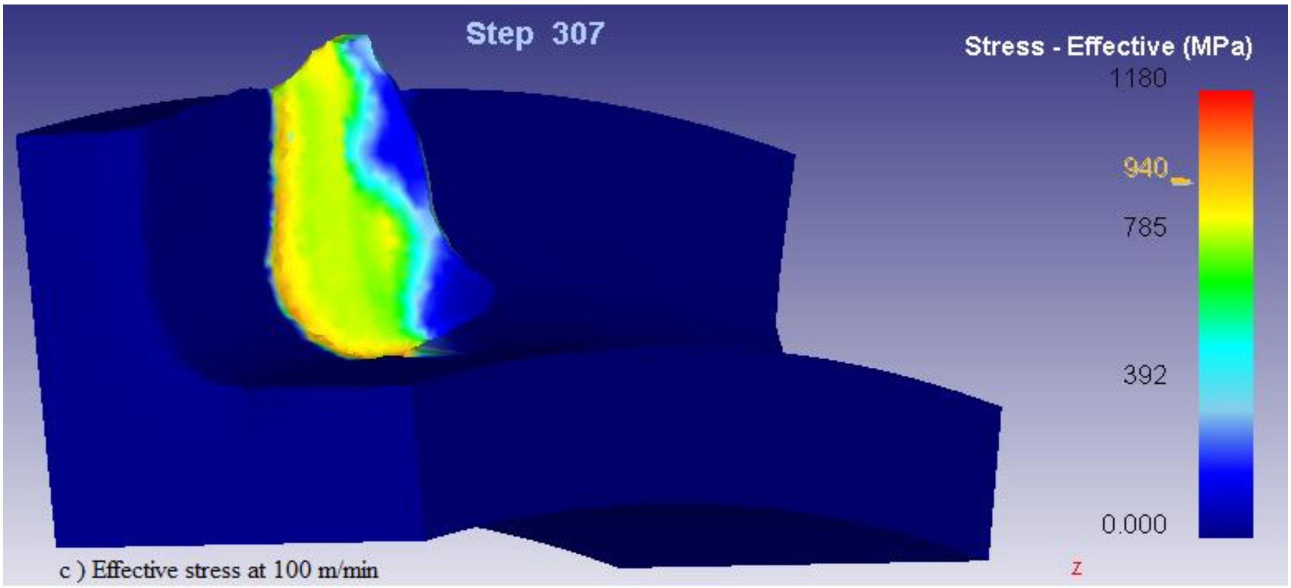
Figure 25 : Effective stress at 0.5 mm cutting depth with various cutting speed (Finishing)



a) Effective stress at 50 m/min



b) Effective stress at 75 m/min



c) Effective stress at 100 m/min

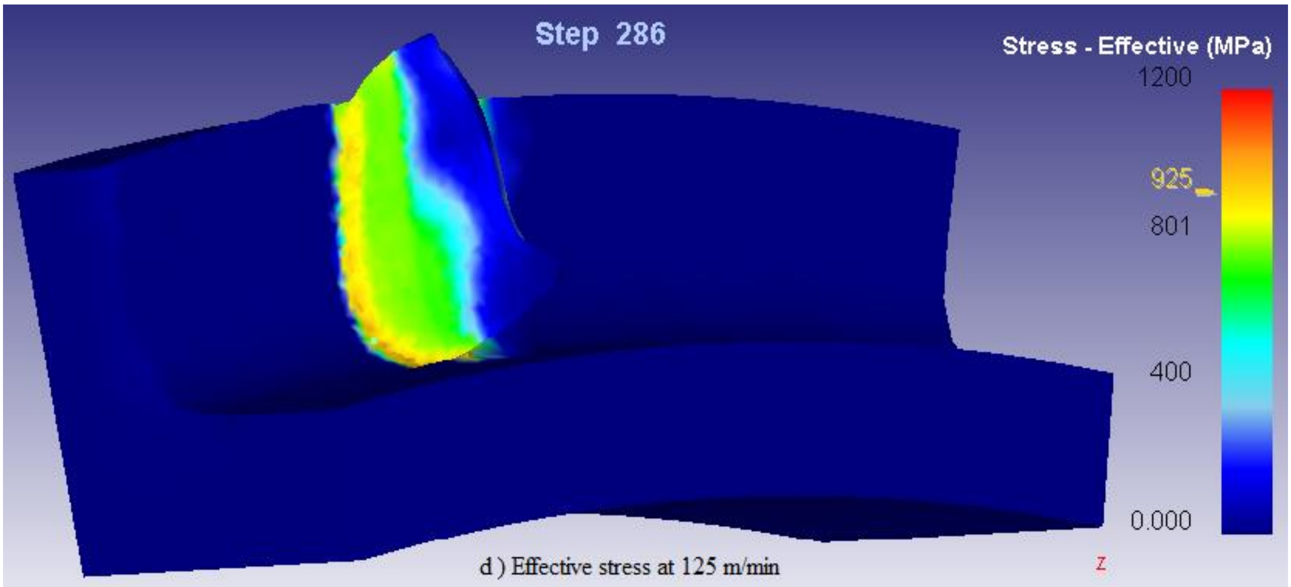
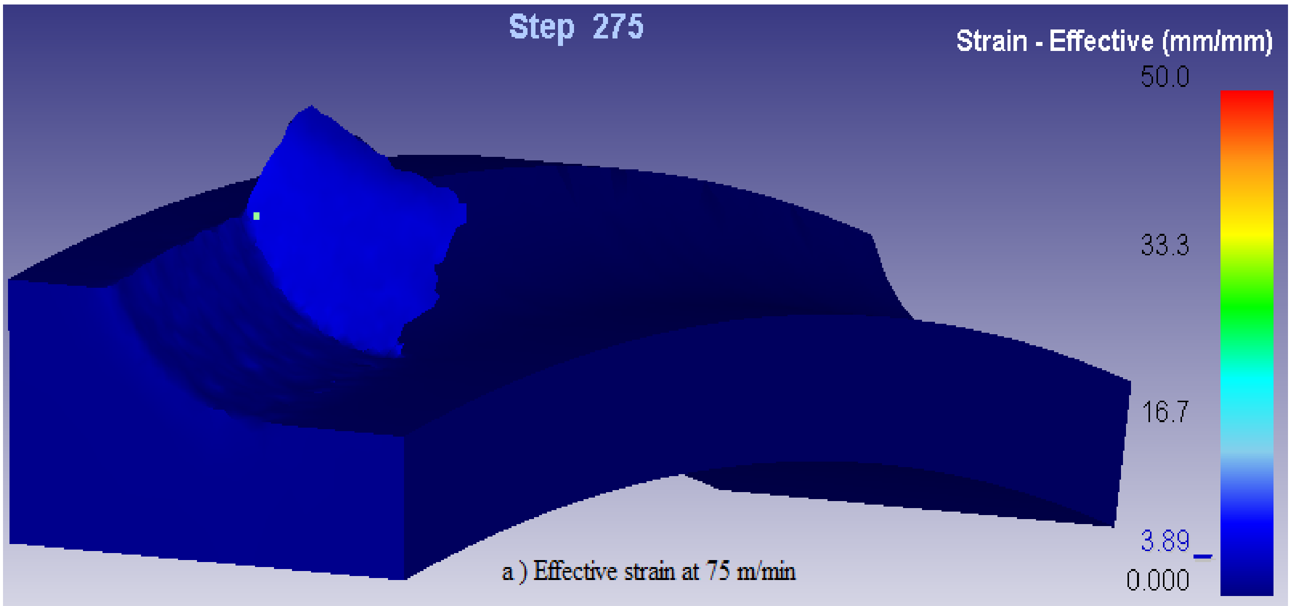


Figure 26 : Effective stress at 2 mm cutting depth with various cutting speed (Rough turning)

3.3.2 Effective strain distribution

It can be seen that the effective strain is observed to be most extreme at the secondary shear zone. Here an area of largely plastic strain exists. The secondary shear zone is likewise visible around the rake face in this distribution. The Maximum effective strain happens on the rake face simply over the cutting edge and the residual strain at the subsurface of the machined work piece, these reducing along the surface. That's shown in below figures27 and 28 respectively for finishing and rough turning.



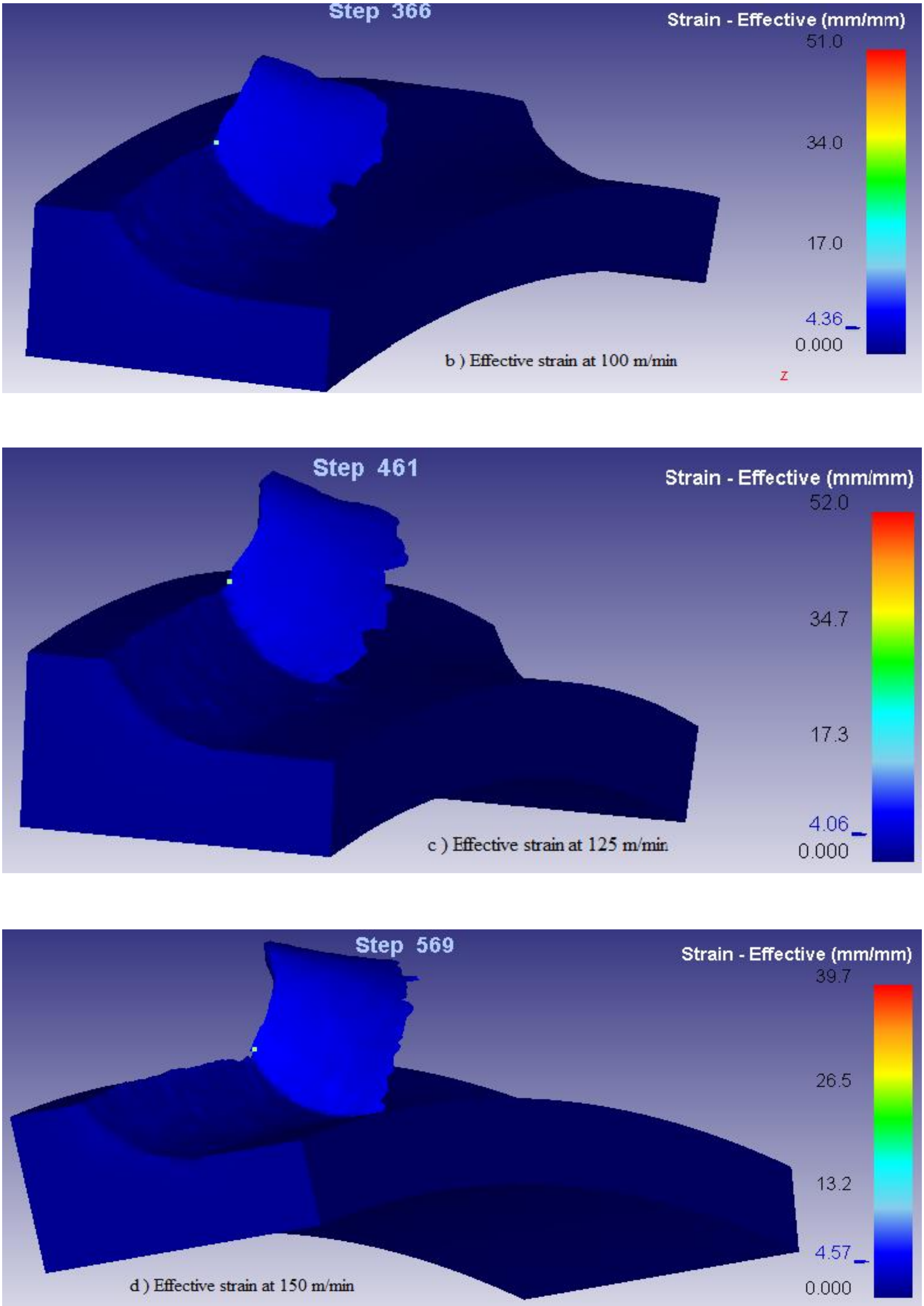
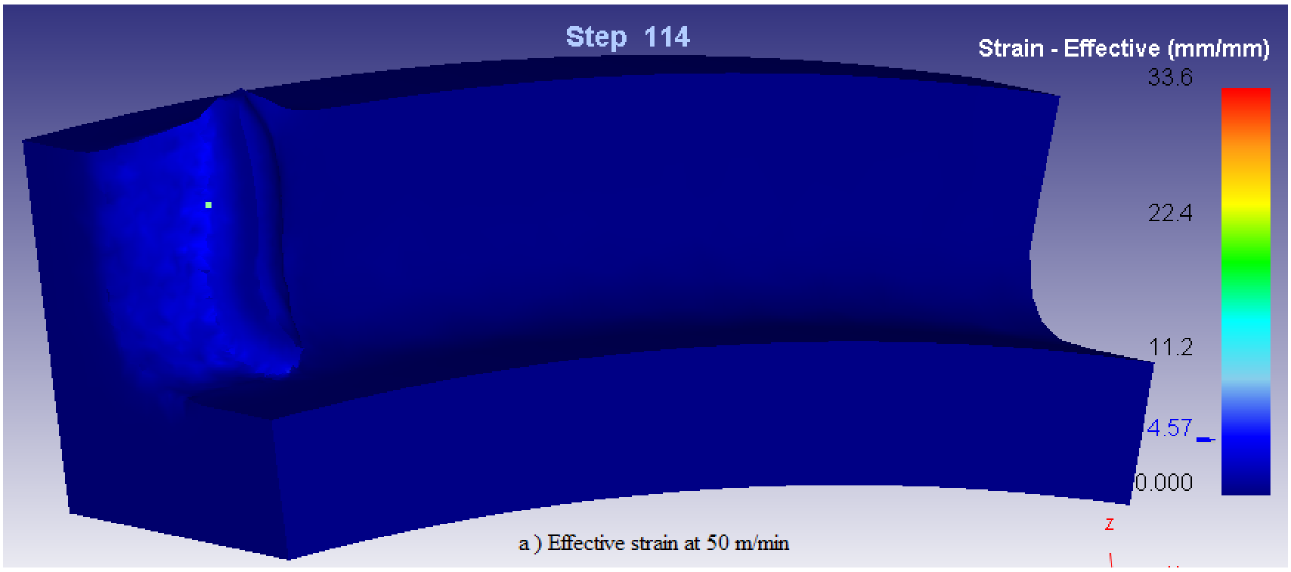
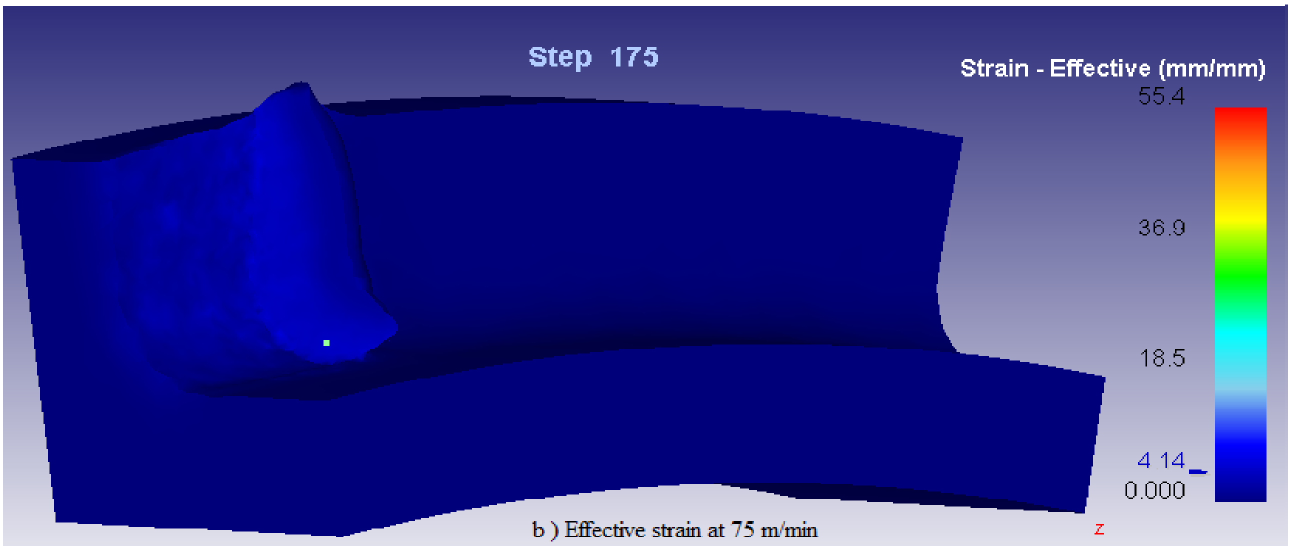


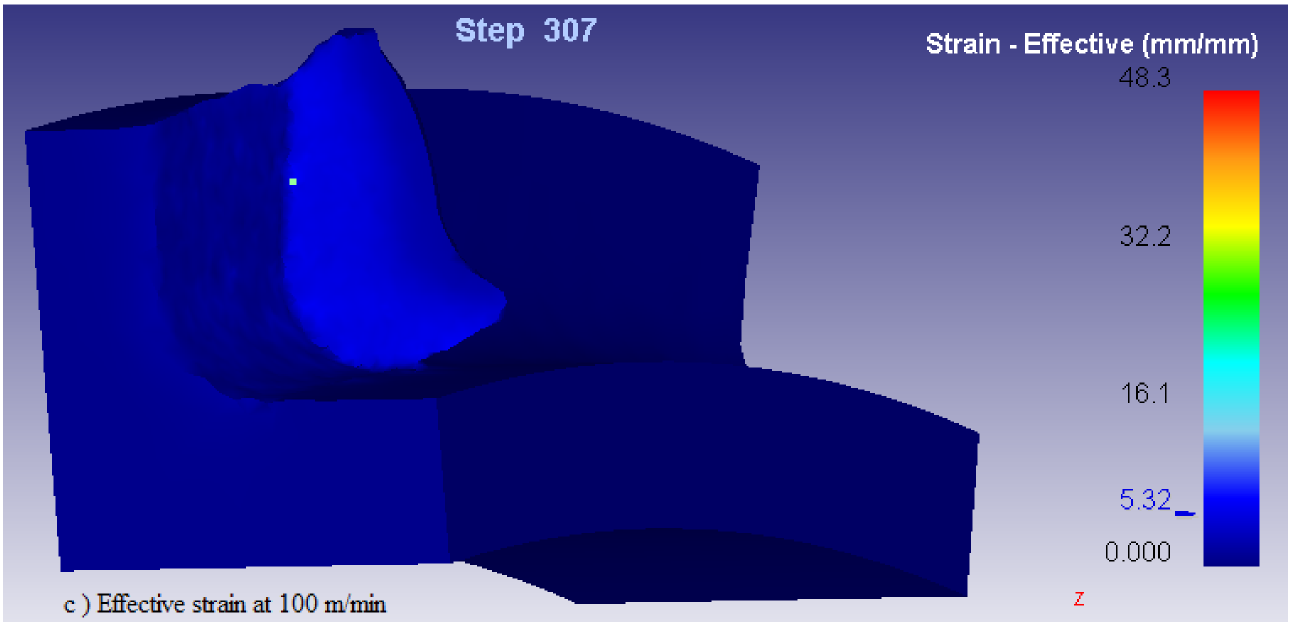
Figure 27 : Effective strain at 0.5 mm cutting depth with various cutting speed (Finishing)



a) Effective strain at 50 m/min



b) Effective strain at 75 m/min



c) Effective strain at 100 m/min

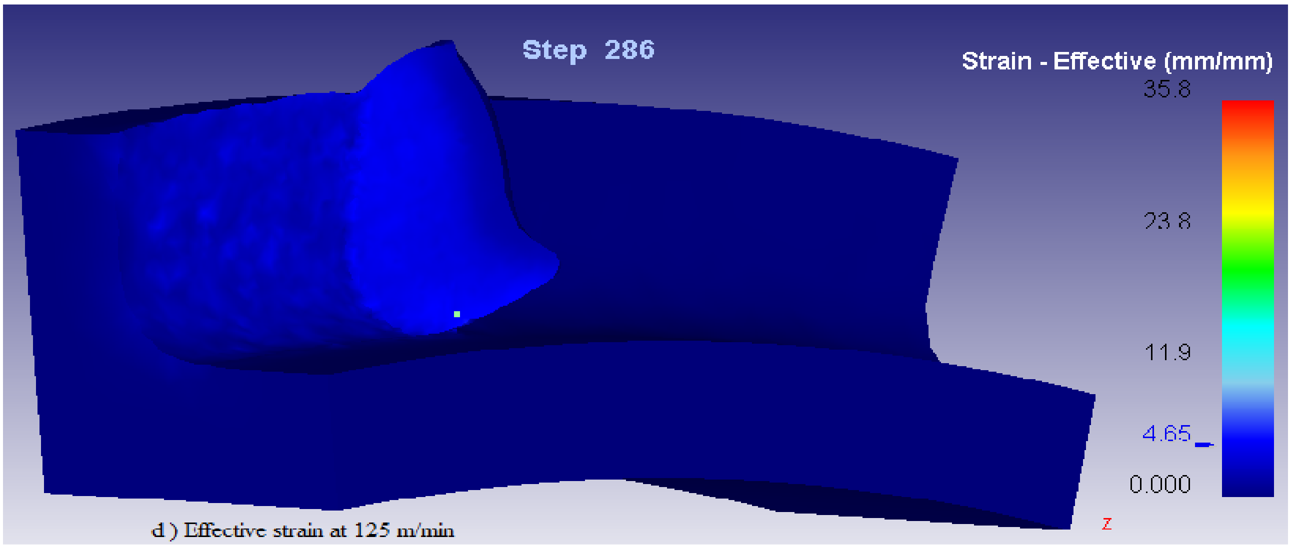


Figure 28 : Effective strain at 2 mm cutting depth with various cutting speed (Rough turning)

Table 13: Effective stress and strain for both finishing and rough turning

FINISHING			ROUGH TURNING		
CUTTING SPEED in m/min	**EFFECTIVE STRESS in (MPa)**	**EFFECTIVE STRAIN in mm/mm**	**CUTTING SPEED in m/min**	**EFFECTIVE STRESS in (MPa)**	**EFFECTIVE STRAIN in mm/mm**
75	1050	3.89	50	991	4.57
100	1020	4.36	75	968	4.14
125	1010	4.06	100	940	5.32
150	999	4.57	125	925	4.56

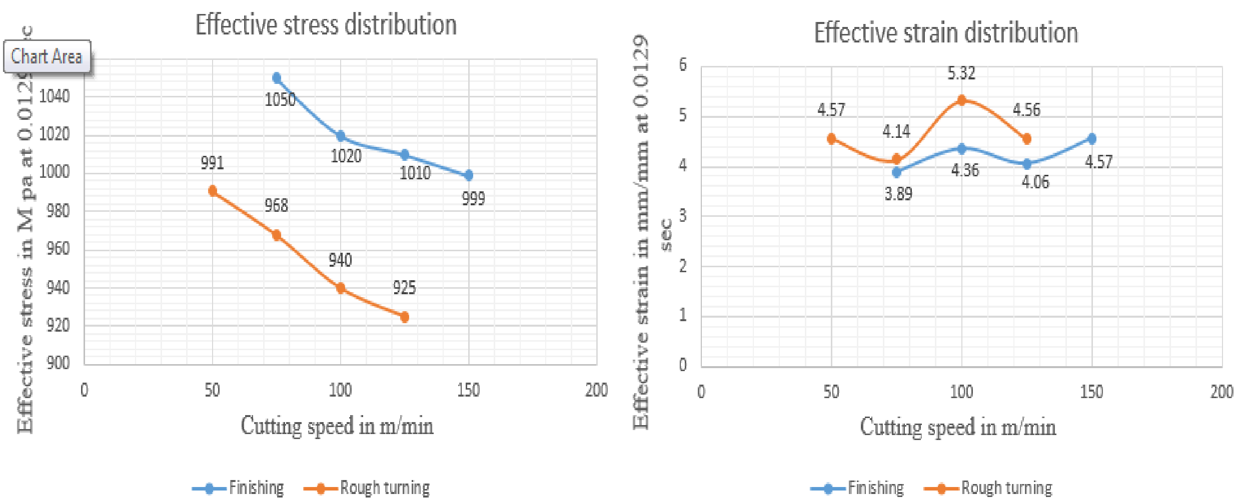


Figure 29 : Effective stress and strain with various cutting speed

From the above figure 29 we can observe the effective stress is decrease in both finishing and rough turning at specific time i.e. 0.0129 sec. Compare to the rough turning effective stress distribution is higher in the finishing. Also the effective strain is varying from increasing cutting speed.

3.4 Comparison of current thesis result with the previously existing results

The current results that are obtained has been compared with the previously existing result from the paper Modelling and Simulation of Turning operation [28]. The similarities are compared and the results are discussed below Table 14. The comparison is between the material AISI 304 and AISI 1015. As the same time the rough turning has-been done on the material AISI 1045, finishing is done on the material AISI 304. Depth of cut and cutting speed are similar for both materials. In this research work the temperature, stress and strain values are taken at particular time i.e. at 0.00129 sec, the same parameter are taken for the maximum values from the research paper.

Table 14: Details of the parameters

Results from my work **Finishing**		**Modelling and simulation of turning operation** [28] **Rough turning**	
Parameters	**Values**	**Parameters**	**Values**
Material used	AISI 304	Material used	AISI 1045
Feed in mm/rev	0.1	Feed in mm/rev	0.05
Depth of cut in mm	0.5	Depth of cut in mm	0.5
Cutting speed in m/min	100	Cutting speed in m/min	100
	125		125
	150		150
Temperature in °C at 0.00129 sec	675	Temperature in °C	743
	726		752
	754		821
Stress in Mpa at 0.00129 sec	1020	Stress in Mpa	1250
	1010		1220
	999		1200
Strain in mm/mm at 0.00129 sec	4.36	Strain in mm/mm	3.65
	4.06		3.56
	4.57		4.04

CONCLUSION

A study was carried out to predict Numerical analysis of turning with various cutting speed, feed rate in finish and rough turning. The main conclusions, deduced from the present work, can be summarized as follows:

1) AISI 304 stainless steel is simulated using FEM code of DEFORM 3D software. The simulation of the chip formation, development of temperature distributions as well as effective stress and effective strain distribution and predictions of the Cutting force surface are successfully achieved. Increases in cutting speed while finish and rough turning AISI 304.
2) For finish turning by theoretical calculations it was defined that the temperature in the 1st shear zone in workpiece AISI304 rises between 650˚C to 750˚C when cutting speed increases from 75 to 150 m/min with feed 0.1 mm/rev and depth of cut 0.5mm.
3) The cutting force and the temperature is high in rough turning compare to the finishing because of the change in parameter like depth of cut, cutting speed and feed rate.
4) However, Increase the cutting speed with cutting depth appeared to have more pronounced effect on the cutting force.
5) For rough turning by theoretical calculation it was defined that the temperature in 1st shear zone in work piece AISI 303 varies in the range 650˚C to 820˚C when the cutting speed increases speed from 50 to 125 m/min with feed 0.2 mm/rev and depth of cut 2mm.

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