Lecture Notes on Multidisciplinary Industrial Engineering
Series Editor: J. Paulo Davim

M. S. Shunmugam
M. Kanthababu *Editors*

Advances in Simulation, Product Design and Development

Proceedings of AIMTDR 2018

Springer

Lecture Notes on Multidisciplinary Industrial Engineering

Series Editor

J. Paulo Davim, Department of Mechanical Engineering, University of Aveiro, Aveiro, Portugal

"Lecture Notes on Multidisciplinary Industrial Engineering" publishes special volumes of conferences, workshops and symposia in interdisciplinary topics of interest. Disciplines such as materials science, nanosciences, sustainability science, management sciences, computational sciences, mechanical engineering, industrial engineering, manufacturing, mechatronics, electrical engineering, environmental and civil engineering, chemical engineering, systems engineering and biomedical engineering are covered. Selected and peer-reviewed papers from events in these fields can be considered for publication in this series.

More information about this series at http://www.springer.com/series/15734

M. S. Shunmugam · M. Kanthababu
Editors

Advances in Simulation, Product Design and Development

Proceedings of AIMTDR 2018

Springer

Editors
M. S. Shunmugam
Manufacturing Engineering Section
Department of Mechanical Engineering
Indian Institute of Technology Madras
Chennai, Tamil Nadu, India

M. Kanthababu
Department of Manufacturing Engineering
College of Engineering, Guindy,
Anna University
Chennai, Tamil Nadu, India

ISSN 2522-5022 ISSN 2522-5030 (electronic)
Lecture Notes on Multidisciplinary Industrial Engineering
ISBN 978-981-32-9486-8 ISBN 978-981-32-9487-5 (eBook)
https://doi.org/10.1007/978-981-32-9487-5

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

AIMTDR 2018 Conference's Core Organizing Committee

Patrons

Dr. M. K. Surappa, Vice Chancellor, Anna University
Dr. J. Kumar, Registrar, Anna University

President (NAC-AIMTDR)

Mr. P. Kaniappan, Managing Director, WABCO India Ltd.

Vice-President (NAC-AIMTDR)

Dr. Uday Shanker Dixit, Professor, IIT Guwahati, India

Co-patrons

Dr. A. Rajadurai, Dean, MIT Campus, Anna University
Dr. T. V. Geetha, Dean, CEG Campus, Anna University
Dr. L. Karunamoorthy, Chairman, Faculty of Mechanical Engineering, Anna University
Dr. S. Rajendra Boopathy, Head, Department of Mechanical Engineering, Anna University

Chairman

Dr. S. Gowri, Honorary Professor, Department of Manufacturing Engineering, Anna University

Co-chairman

Dr. P. Hariharan, Professor, Department of Manufacturing Engineering, Anna University

Organizing Secretary

Dr. M. Kanthababu, Professor and Head, Department of Manufacturing Engineering, Anna University

Joint Organizing Secretaries

Dr. M. Pradeep Kumar, Professor, Department of Mechanical Engineering, Anna University
Dr. A. Siddharthan, Associate Professor, Department of Production Technology, Anna University

International Scientific Committee

Prof. Abhijit Chandra, Iowa State University, USA
Prof. Ajay P. Malshe, University of Arkansas, USA
Prof. Andrew Y. C. Nee, NUS, Singapore
Prof. Chandrasekar S., Purdue University, USA
Prof. Dean T. A., University of Birmingham, UK
Prof. Hong Hocheng, National Tsing Hui University, Taiwan
Prof. John Sutherland, Purdue University, USA
Prof. Kamlakar P. Rajurkar, University of Nebraska, USA
Prof. Kornel Ehmann, Northwestern University, USA
Prof. Liao Y. S., National Taiwan University, Taiwan
Prof. McGeough J. A., University of Edinburgh, UK
Prof. Mustafizur Rahman, NUS, Singapore

Prof. Philip Koshy, McMaster University, Canada
Prof. Rakesh Nagi, University of Buffalo, USA
Prof. Shiv Gopal Kapoor, University of Illinois, USA
Prof. Srihari Krishnasami, Binghamton University, USA
Prof. Tae Jo Ko, Yeungnam University, South Korea
Prof. Tugrul Ozel, University of New Jersey, USA

National Advisory Committee

Prof. Ahuja B. B., Government College of Engineering Pune
Prof. Amitabha Ghosh, BESU
Prof. Bijoy Bhattacharyya, Jadavpur University, Kolkata
Prof. Biswanath Doloi, Jadavpur University, Kolkata
Prof. Chattopadhyay A. K., IIT Kharagpur
Prof. Deshmukh S. G., IIT Gwalior
Shri. Dhand N. K., MD, Ace Micromatic, Bangalore
Prof. Dixit U. S., IIT Guwahati, Guwahati
Prof. Jain P. K., IIT Roorkee, Roorkee
Prof. Jain V. K., IIT Kanpur
Prof. Jose Mathew, NIT Calicut
Shri. Lakshminarayan M., WABCO India Pvt. Ltd.
Prof. Lal G. K., IIT Kanpur
Prof. Mehta N. K., IIT Roorkee
Prof. Mohanram P. V., PSG Institute of Technology and Applied Research
Shri. Mohanram P., IMTMA, Bangalore
Dr. Mukherjee T., Tata Steel Ltd., Jamshedpur
Shri. Muralidharan P., Lucas TVS Ltd., Vellore
Prof. Narayanan S., VIT University, Vellore
Mr. Niraj Sinha, Scientist 'G', PSA, GOI
Prof. Pande S. S., IIT Bombay, Mumbai
Dr. Prasad Raju D. R., MVGREC
Prof. Radhakrishnan P., PSG Institute of Advanced Studies, Coimbatore
Prof. Radhakrishnan V., IIST, Trivandrum
Prof. Ramaswamy N., IIT Bombay (Former)
Prof. Ramesh Babu N., IIT Madras
Shri. Rangachar C. P., Yuken India Ltd., Bangalore
Prof. Rao P. V., IIT Delhi
Dr. Santhosh Kumar, IIT BHU
Dr. Sathyan B. R., CMTI, Bangalore
Prof. Satyanarayan B., Andhra University (Former)
Prof. Selvaraj T., NIT Trichy
Prof. Shan H. S., IIT Roorkee (Former)
Prof. Shunmugam M. S., IIT Madras

Shri. Shirgurkar S. G., Ace Designers Ltd., Bangalore
Dr. Sumantran V., Celeris Technologies
Dr. Suri V. K., BARC, Mumbai
Shri. Venu Gopalan P., DRDL Hyderabad
Prof. Vinod Yadav, Motilal Nehru National Institute of Technology, Allahabad

Foreword

It gives us immense pleasure to present the Advances in Manufacturing Technology and Design—Proceedings of All India Manufacturing Technology, Design and Research (AIMTDR) Conference 2018.

We would like to express our deep gratitude to all the members of Organizing Committee of AIMTDR 2018 Conference and also to authors, reviewers, sponsors, volunteers, etc., for their wholehearted support and active participation. Our special thanks to Mr. P. Kaniappan, Managing Director, WABCO India Ltd, Chennai, who kindly agreed to act as President of National Advisory Committee (NAC) of the AIMTDR 2018 Conference. We also express our sincere thanks to Chairman Dr. S. Gowri, Honorary Professor, and Co-chairman Dr. P. Hariharan, Professor, Department of Manufacturing Engineering, Anna University, Chennai, for their wholehearted support. We would like to express our sincere thanks to Research Scholars Mr. K. R. Sunilkumar, Mr. U. Goutham, Mr. V. Mohankumar and Mr. R. Prabhu and also UG/PG students of the Department of Manufacturing Engineering, Anna University, for their contributions in the preparation of this volume.

High-quality papers have been selected after peer review by technical experts. We hope you find the papers included in the Proceedings of AIMTDR 2018 Conference are interesting and thought-provoking.

We also like to express our gratitude for the support provided by WABCO India Ltd., Chennai; Kistler Instruments India Pvt. Ltd., Chennai; AMETEK Instruments India Pvt. Ltd., Bengaluru; Central Manufacturing Technology Institute, Government of India, Bengaluru; Defence Research and Development Organisation, Government of India, New Delhi; and Ceeyes Engineering Industries Pvt Ltd., Trichy.

Finally, we would like to express our gratitude to the National Advisory Committee (NAC) members of AIMTDR 2018 Conference for providing the necessary guidance and support.

Guwahati, India

Uday Shanker Dixit
Vice-President
National Advisory Committee
AIMTDR

Preface

All India Manufacturing Technology, Design and Research (AIMTDR) Conference is considered globally as one of the most prestigious conferences held once in two years. It was started in 1967 at national level at Jadavpur University, Kolkata, India, and achieved the international status in the year 2006. It was organized by various prestigious institutions such as Jadavpur University, IIT Bombay, IIT Madras, CMTI Bangalore, PSG iTech, IIT Kanpur, CMERI, IIT Delhi, NIT Warangal, IIT Kharagpur, BITS Ranchi, VIT Vellore, IIT Roorkee, Andhra University, IIT Guwahati and College of Engineering Pune.

The recent edition of the AIMTDR Conference, 7th International and 28th All India Manufacturing Technology, Design and Research (AIMTDR) Conference 2018, was jointly organized by the Departments of Manufacturing Engineering, Mechanical Engineering and Production Technology during 13–15 December 2018 at College of Engineering Guindy, Anna University, Chennai, India, with the theme 'Make in India – Global Vision'. A major focus was given on recent developments and innovations in the field of manufacturing technology and design through keynote lectures. About 550 participants registered for the conference. During the conference, researchers from academia and industries presented their findings and exchanged ideas related to manufacturing technology and design.

Of the 750 papers received initially, 330 papers were finally selected after rigorous review process for publication in the Springer Proceedings. Selected papers from the conference are being published by Springer in the series Lecture Notes on Multidisciplinary Industrial Engineering in five volumes, namely **Volume 1**—Additive Manufacturing and Joining, **Volume 2**—Forming, Machining and Automation, **Volume 3**—Unconventional Machining and Composites, **Volume 4**—Micro and Nano Manufacturing and Surface Engineering and **Volume 5**—Simulation and Product Design and Development.

Chennai, India
May 2018

M. S. Shunmugam
M. Kanthababu

Contents

About the Editors

M. S. Shunmugam is a Professor (Emeritus) in the Manufacturing Engineering Section in the Department of Mechanical Engineering, Indian Institute of Technology (IIT) Madras. After receiving his PhD in Mechanical Engineering from IIT Madras in 1976, he has worked in IIT Bombay (from 1977 to 1980) and in IIT Madras from 1980 onwards. He was a visiting faculty member at Michigan Technological University during 1989-1991 and was a member in the board of governors of IIT Madras during 2012-2013. Dr. Shanmugam's research interests include metrology, machine tools, manufacturing, gears, micro-machining and computer applications in manufacturing. He has published about 130 peer-reviewed international journal papers, 15 peer-reviewed national journal papers, 75 international conferences and about 80 national conferences.

M. Kanthababu is a Professor in the Department of Manufacturing Engineering in Anna University, Chennai, India and the Director of the Centre for Intellectual Property Right and Trade Marks in Anna University. He has completed his MS in Mechanical engineering and PhD in Advanced Manufacturing Technology from IIT Madras. Prof Kanthababu's research interests include manufacturing technology, composite materials and machining, and automation in manufacturing. He has published more than 30 peer reviewed international journal papers and 2 books, and holds one patent.

Part I
Simulation

Chapter 1
Some Investigations on Drilling of Aluminium Alloy from FEA-Based Simulation Using DEFORM-3D

R. Sreenivasulu and Ch. Srinivasa Rao

Abstract The production of holes is one of the most common operations among all the machining processes and is more complex than the other metal removal processes. During the drilling, burrs form on both the entry and exit side of the hole as a result of plastic deformation of the material. In order to investigate the burr height, finite element analysis (FEA)-based DEFORM-3D simulations are performed during drilling of aluminium 6061 and 7075 alloys. The influence of variable drill geometry and machining conditions on burr height, thrust force, stresses and strain rates apart from thermal aspects between the drill bit and work pieces are examined. Simulated results analyse the reduction in burr height which can be achieved using the selection of input parameters to attain multiple performance characteristics of output responses, will have a wide range of application prospects saving time and cost of post finishing operation of a drilled hole.

Keywords Thermal effect · Thrust force · Effective stress and strain rates · Burr height · FEA-based DEFORM-3D

1.1 Introduction

Manufacturing sector facing lot of problems due to abrupt changes in the design from day to day changes in taste of customers in their modern life in every aspect. Entrepreneurs who are entered newly in the competitive market were faced by a problem with capital investment incurred on development of design, data analysis followed by testing through experimentation. For conducting experimental tests, it takes more investment and wasting of time once it fails in testing. So, traditional

R. Sreenivasulu (✉)
Department of Mechanical Engineering, R.V.R. and J.C. College of Engineering, Guntur, Andhra Pradesh 522019, India
e-mail: rslu1431@gmail.com

Ch. Srinivasa Rao
Department of Mechanical Engineering, College of Engineering, Andhra University, Visakhapatnam, Andhra Pradesh, India

M. S. Shunmugam and M. Kanthababu (eds.), *Advances in Simulation, Product Design and Development*, Lecture Notes on Multidisciplinary Industrial Engineering,
https://doi.org/10.1007/978-981-32-9487-5_1

manufacturing support systems are not sufficient to meet the above-stated problems. Simulation, modelling and analysis help to fulfil the drawbacks of conventional systems by reducing experimental tests, flexibility in design of products according to customers satisfaction with less capital investment. This is possible only by adopting design software, controlled machining parameters using sensor-based technology with feedback system and optimizes the entire processes at every stage using advanced optimization techniques. Guo and Dornfeld stated in their work by controlling persuade of process parameters such as feed, depth of cut and tool geometry, then only optimization of output responses can be possible [1, 2]. The finite element modelling of machining was published by Strenkowski and Carroll [3], and a comprehensive review of general FEM code as applied towards machining has been reported by Marusich and Ortiz [4]. The author works reveal the detail improvements in the mathematical theory and how to apply them towards machining. DEFORM applies FEM theory in a user-friendly graphical user interface (GUI) that is very robust when compared to many custom FEM codes. DEFORM-3D software is a FEM-based system which works on simulation of manufacturing process, especially in designing and analysing the three-dimensional material flow in forming processes. The DEFORM-3D software club the automatic framework regenerator that can activate without human intervention, producing optimized network. The best choice of lattice system can be separated in the more accurate requisite areas; thus, the level of issue is compact and computation is noticeably enhanced [5]. However, this software is limited to guide template of turning and boring simulation in cutting aspects until now. Drilling and other kind of machining simulations have to be built up by individual. Hence, with the aid of this platform, its pre-processing unit is used to simulate the drilling operation with HSS twist drill and process the information data with the post-processing section [6]. In this paper, a FEM-based DEFORM-3D for drilling of aluminium alloys is first constructed, and then, simulations are drawn under different drilling speeds and feed rates in order to analyse and compare the influence of drilling parameters on drilling thrust force, torque, stresses, strain rates and temperature.

1.2 Modelling of Drilling Process

The work piece is modelled after assuming the material as perfectly plastic material where the material constitutive model of this deformable body is represented with Johnson–Cook material flow model. In the present analysis, Al 6061 and Al 7075 alloys are selected as work piece materials, and its properties are widely estimated in the literature. The parameters of Johnson–Cook model (JC model) obtained from the literature related to the same material during drilling operation under similar cutting conditions [7, 8]. JC model is one of the most extensively employed in a wide variety of manufacturing processes and engineering materials and a benchmark for comparison of different constitutive models. The original JC constitutive model, i.e. the combined form considering the strain, strain rate and temperature effect on flow stress, can be mathematically expressed with the relation as presented in Eq. 1.1.

$$\overline{\sigma} = \left(A + B(\varepsilon)^n\right)\left(1 + C * \ln\left(\frac{\dot{\overline{\varepsilon}}}{\dot{\overline{\varepsilon_0}}}\right)\right)\left(1 - \left(\frac{T - T_0}{T_{\text{melt}} - T_0}\right)^m\right) \quad (1.1)$$

where $\overline{\sigma}$ is the flow stress, ε is the plastic strain, $\dot{\overline{\varepsilon}}$ is the plastic strain rate, $\dot{\overline{\varepsilon_0}}$ is the reference plastic strain rate (0.001 s^{-1}), T is the temperature of the work piece, T_{melt} is the melting temperature of the work piece material and T_0 be the room temperature (293 K); material constant A is the yield strength, B is the hardening modulus, C be the strain rate sensitivity, 'n' is the strain-hardening exponent and 'm' is the thermal softening exponent. Although a more realistic simulation model for the machining process should also take, the parameters for Al 6061 alloy are $A = 304.1$ MPa, $B = 113.8$ MPa, $n = 0.42$, $C = 0.002$, $m = 1.34$ and $T_{\text{melt}} = 785$ K, and values for Al 7075 alloy are $A = 317.37$ MPa, $B = 166.95$ MPa, $C = 0.00736$ $n = 0.5091$ and $m = 1.5724$ and $T_{\text{melt}} = 900$ K. The work piece is represented by a cylindrical model of 10 mm radius, where the twist drill bit is modelled as a rigid body, which rotates at the specified spindle speed. A fine mesh density is defined with an input size of 0.075 mm and size ratio 2 for work piece. Thermal boundary conditions are defined keeping in view that it will allow heat transfer from work piece to cutting tool. Heat transfer between the work piece and the tool is dependent on the pressure developed during machining.

1.2.1 Set the Characteristics of Tool and Work Piece Model

The geometric model of drill is imported from CATIA V5 R19 package, and then, the high-speed steel twist drill is set as adamant with respect to work piece. DEFORM-3D V11.0 can create a simple work piece model. In this software package, the adaptive meshing grid (AMG) technology is used to separate the grids. The framework of drill bit and work piece utilize the fixed type. The element size is set to 0.25 mm, the scale ratio of drill bit as set to 0.25 mm, the parent material web frame scale is set to 5, the side length is set to 0.25 as minimum and the web framework at the part of the parent material (Fig. 1.1).

Aluminium 6061 and 7075 alloy materials are chosen as work piece model includes 100,000 elements of polygon shape with 20,000 nodes. The bottom surface of the work piece is fixed in all directions. The twist drill bit is modelled as a rigid body using 30,000 (polygon) elements with 20,000 ports which move at the specified rotational speed. The work piece is represented by a cylindrical model of 10 mm diameter, where the cutting tool is modelled as a rigid body which moves at the specified cutting speed. A fine mesh density is defined with an input size of 0.075 mm and size ratio 2 for work piece. Thermal boundary conditions are defined keeping in view that it will allow heat transfer from work piece to the cutting tool.

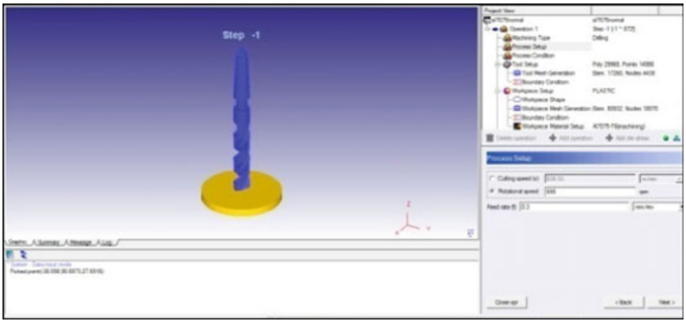


Fig. 1.1 FEA model of twist drill with work piece [9, 10]

Heat transfer between the work piece and the tool is dependent on the pressure developed during machining.

1.2.2 *Boundary Conditions Setting to the Work Piece and Drill Bit*

The initial setting of boundary conditions between the work piece especially at the bottom side and the drill bit along *X*, *Y* and *Z* directions assumed to be zero. Drill bit feeds along the *Z*-direction and rotates about *Z*-axis. Surrounding surfaces of parent work material and drill bit are set to heat dissipation into atmosphere, and the work piece dimensions' reparation is activated. When the networks are reseparated, the volume of deformable body will be altered. The reparation of volumetric change is utilized to compensate the loss of volume of material. The reparation volume of material is relative to two segments of volume fractions, one is the factual volume of the parent work piece and the other is the equivalent network fraction of volumetric change.

1.3 Simulation Using DEFORM-3D

1.3.1 *Set the Relations Between the Tool and the Objects*

The relationship between master servant and workbench of DEFORM-3D software package is taken as the objects which are rigid (drill bit) are master parts and the distortable objects (parent work piece material) are servant parts. The heat transfer coefficient is set as 45 W/(m^2 K), coefficient of friction is taken as 0.6 constant throughout simulation by chosen shear friction and can be adopted in the simulation. However, the utmost spoil of the material arrived to a critical value to identify the

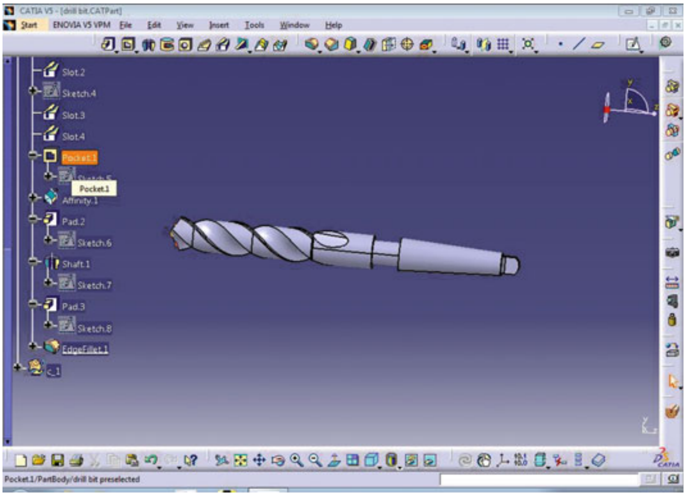


Fig. 1.2 Twist drill 3D model developed in CATIA

fracture or not, the Johnson–Cook convergence principle is applied, which can be predicted the critical situations in the deformation of work piece materials. Hence, the settings of simulation data parameters are tested. All developed simulations in this section are generated by running the programme from DEFORM-3D software at the similar conditions for machining of aluminium 6061 and 7075 alloys.

1.3.2 Import the Drill Bit from Modelling Software

The twist drill 3D model developed in CATIA-V5R-19 (shown in Fig. 1.2), which is saved as a standard template library format and imported to DEFORM-3D. The data is set to zero for drill bit flute height and helix angle, and then, the file is saved in the subroutine program.

1.3.3 Selection of Data Set-Up for Simulation Control

The menu command provides in the selection of various control set-ups such as 100,000 simulation steps with a step size of 0.02 because a number of steps are more, then better simulation results obtained. But step size selection is more as it reduces the accuracy and the network frame collapses rapidly without any notice. The menu stop command is used to stop the simulation according to our requirement. At every 20 steps, the increment in the simulation took the new value up to depth of the material which is set to 5 mm, either the depth of parent work material reached or total steps meet then the simulation stops automatically. The atmosphere temperature is set to 293 K, and the heat transfer convection coefficient selected as 0.03 W/(m^2 K) from menu set-up. The SI system of units are considered for selection of magnitudes of numerical data required to run the simulation from menu set up.

1.4 Results and Discussion

Simulation of drilling of aluminium alloys (6061 and 7075 series) using DEFORM-3D V11.0 is applied and data as acquired, viz. stresses, strain rates, thrust force and torque.

1.4.1 Simulation Results of Al 6061 Alloy

Effective Stress and Strain Rates The effective stress and strain rates are acquired from the simulation at a simulation step of 2886 for Al 6061 alloy which is plotted in Figs. 1.3 and 1.4 with respect to time in steps. The obtained value of effective stress is 216 MPa and effective strain at the rate of 0.461 mm/mm. At the beginning of drilling operation the initial stress is more, once it attains yielding point then material plastically deformed, indicates that no noticeable influence on burr height by variation of input parameters.

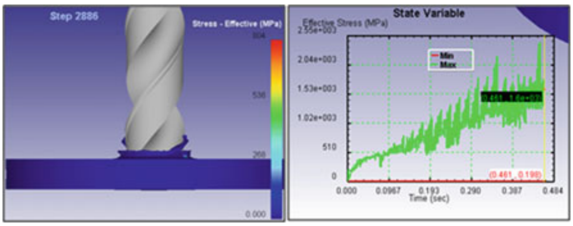


Fig. 1.3 Effective stress variation in drilling [9, 10]

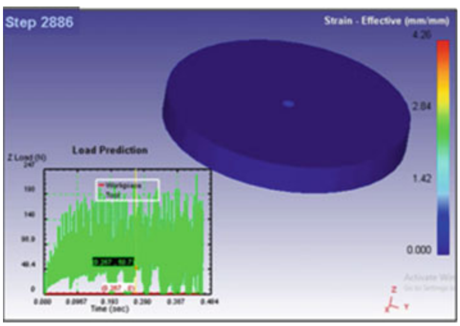


Fig. 1.4 Strain variation in drilling

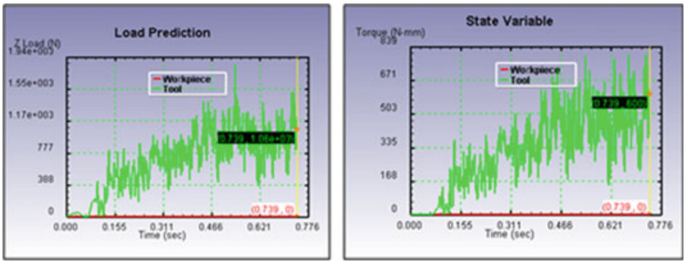


Fig. 1.5 Thrust and torque in drilling of Al 6061 alloy

Thrust and Torque During Drilling From Fig. 1.5, it is revealed that load (thrust force) prediction during drilling of aluminium 6061 alloy at the simulation step 2886 interval is obtained as the maximum of 319 N and maximum torque is obtained as 268 N mm at the same step interval. From the simulation, it is observed that burr height is minimum at minimum thrust load exerted between the drill bit and parent material. Also, little bit influence of point and clearance angles on drill geometry observed on burr height corresponding to thrust load.

Thermal Effect During Drilling At the step interval of 2886, generation of heat occurs between tool and work piece in the shear deformation zone, which leads to enhance the temperature in the range of 31–304 °C during drilling of Al 6061 alloy, depicted in Fig. 1.6. There is no significant effect of temperature on burr height by variation of input parameters while drilling, observed in the simulation steps.

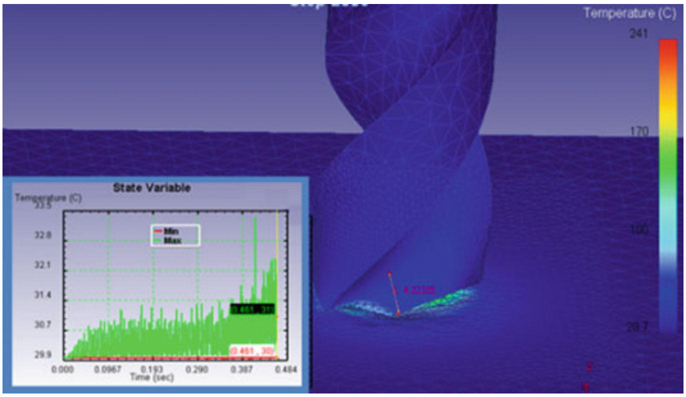


Fig. 1.6 Thermal variation in drilling of Al 6061 alloy

1.4.2 Simulation Results of Al 7075 Alloy

Effective Stress and Strain Distribution From the simulation, it reveals that burr height is increased for Al 7075 compared with Al 6061, and reason may be that the influence of composition elements in Al 7075 alloy. Stresses and strain rates are also proportionally increased. The effective stress and strain data acquired from the simulation based on finite element analysis using DEFORM-3D at a simulation step of 2981 for aluminium 7075 alloy and are captured an image shown in Figs. 1.7 and 1.8 with respect to time in seconds. The obtained value of effective stress is 378 MPa and effective strain at the rate of 0.347 mm/mm.

Thrust Force and Torque Prediction Figure 1.9 shows Al 7075 alloy load (thrust force) prediction of the drilling process at 2981 simulation step interval. The maximum load observed is 251 N, and maximum torque obtained is 143 N mm at 2981 step interval. Both thrust and torque are suddenly increased at the middle of the

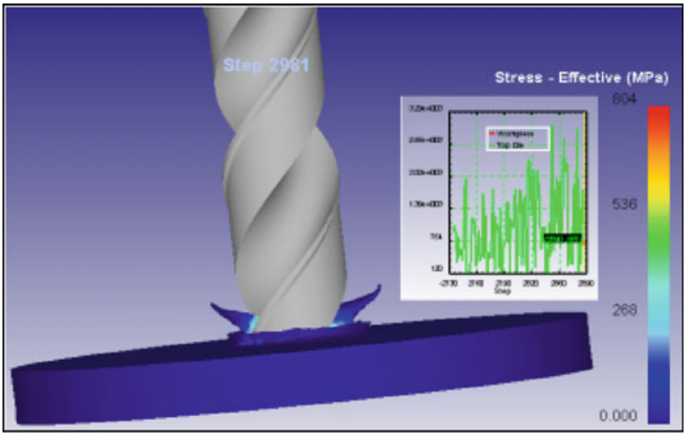


Fig. 1.7 Effective stress variation in drilling

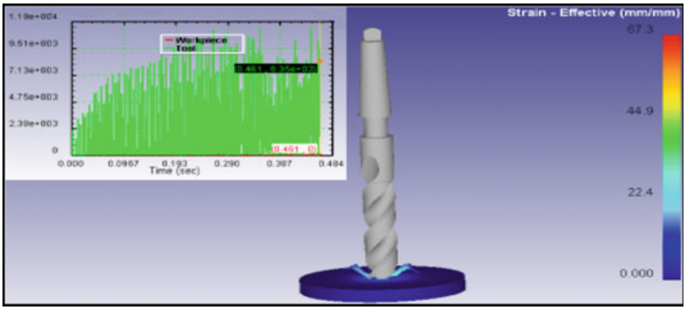


Fig. 1.8 Effective strain variation in drilling

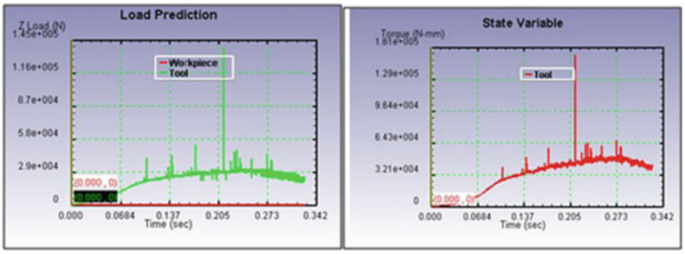
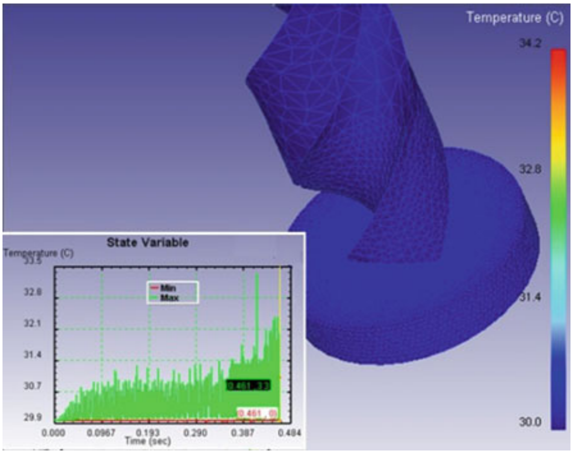


Fig. 1.9 Variation of thrust force and torque

Fig. 1.10 Temperature distribution during drilling of Al 7075 alloy



drilling operation that it is observed. The reason may be that moderate feed and spindle speed cause increase the load in between work and drill bit.

Temperature Variation At the step interval of 2981, generation of heat occurs between tool and work piece in the shear deformation zone, leads to enhance the temperature in the range of 33–358 °C during drilling of Al 7075 alloy, depicted in Fig. 1.10.

From simulation using DEFORM-3D, the burr size assessment is not possible to obtain directly from the software. So in the present work, burr height is measured in an alternate method using Java image processing program (ImageJ).

1.4.3 Burr Height Estimation Using ImageJ Software

ImageJ software can be able to found the area, perimeter and pixel value statistics of user-defined selections to measure distances and angles. It supports the standard