Reason - A Technical Journal
ISSN 2277–1654
Vol - XII ● 2013

REDUCING SHAPING BURR BY BEVELING EXIT EDGE OF 45C8 STEEL

Partha Pratim Saha[1] and Santanu Das[2]

Department of Mechanical Engineering, Kalyani Government Engineering College, Kalyani, Nadia-741 235, West Bengal, India
Email: [1]ppsaha.ip@gmail.com, [2]sdas.me@gmail.com

Manuscript received on: November 17, 2013, acceped after revision on: February 26, 2014.

Abstract : Production of high precision components needs constant attention to both the generation of machined surfaces without a burr and undertaking deburring operation. A machining process usually produces burr. In shaping, burr formation occurs when the cutting tool exits the workpiece. Absence of necessary back up support around an edge is the possible reason behind it. Several research works have been done on burr formation mechanism, its minimization, and deburring. A number of experiments is performed in this work on medium carbon steel (45C8) flats in dry condition to note the effects of burr formation on the workpiece with beveled exit edge. The experimental result shows that at 15^{o} edge bevel, negligible burr formation is obtained. Analysis of variance is conducted on the experimental results to find out the relative influence of each process parameter on burr height observed. The regression analysis is also done with the experimental data and the regression equation gives fairly good estimate of experimental results.

Keywords: Machining, shaping, edge beveling, exit edge, burr

1. INTRODUCTION

Machining burrs are deformed workpiece materials adhered to workpiece edges, and are built up during machining operations. Occurrence of burr formation poses considerable problems in manufacture of different components. It increases cycle time, scrap, rework time and problems of handling. Cost of deburring can be reduced to a large extent by using the knowledge about burr formation mechanism. It causes difficulty in assembly stages and hampers maintaining product quality. Burr formation mechanism and its appearance are varied with the methods of manufacturing [1-5]. Nakayama and Arai [2] observed that burrs may cause groove wear of a cutting tool, and accelerate burr growth. Lin [3] found out the correlation between the height of the manufacturing burrs, and the deterioration of the cutting tools. When Chern [4] experimented on the relationship between the pattern of burr and manufacturing parameters during the manufacture of aluminium, Dornfeld et al. [5] carried out finite element analysis using machining data related to burr formation to simulate the pattern of burr formation.

Olvera and Barrow [6] defined the burr formation mechanism, categories and patterns of burrs, and the effects of different manufacturing parameters on the burr height. Dornfeld and Lee [7] developed a combined artificial intelligence and optimization approach to predict burr types formed in face milling. They designed artificial neural network (ANN) to apply to machining of aluminium alloy, and Taguchi method for optimizing the prediction system. In another work, Lee et al. [8] reported about the possible improvement of exit edge beveling of the workpiece but no experimental results were presented.

Pandey and Relekar [9] found empirically the effect of various drilling parameters (feed, hole size and hardness) on burr height, sizes and thickness. In another work [10], modified Taguchi method for multi-objective drilling problem was used to minimize burr size. Jackson et al. [11] studied three methods of preventing burr formation and tool failure by controlling flow stress, selecting a workpiece with small amount of dislocations to prevent plastic deformation, and by using coated tools. Dependence of burr formation process on yield strength and ultimate strength was also experimentally observed [12]. Formation of higher burr height at lower feed rates, and smaller burr at moderate feed rates were also reported. Effect of burr formation on hole punching process of ceramic sheet was investigated [13] and it was found out that burr occurs with the increase in ceramic thickness and tool clearance.

An analytical tool for ductile material was formulated as an alternative choice of burr study, and it was successfully applied to drilling burr formation. The model did not show catastrophic fracture during plastic deformation of workpiece material for burr formation. Narayanaswaami and Dornfeld [15] presented a strategy for minimizing burrs in face milling. They developed a CAD framework to consider the edges of a part into primary and secondary burr zones, and constructed an algorithm to minimise primary burrs along the edges of the part. Experimental studies by some researchers [16,17] in face milling showed formation of two types of exit burrs as (i) primary burr, and (ii) secondary burr depending on cutting conditions, cutting tool geometry, part edge geometry and workpiece material properties. Iwata et al. [18] observed the burr formation mechanism through SEM and FEA. They reported that at the exit end of the work piece, a crack separates the chip along with the part of the workpiece above the negative shear, and the rest portion forms a burr. Some works were also reported for controlling the machining burr by Pekelharing [19], Sikdar [20], Saha et al. [21], Saha and Das [22-24], Pratim and Das [25] and Saha et al. [26].

On the other hand, Balasubramaniam et al. [27] developed a non-traditional technique for deburring, named, projection grinding technique, while Choi et al. [28,29] developed cubic boron nitride as the grinding tool. Although a number of chemical, electrochemical, mechanical and other processes were reported for deburring, minimization and control of burr at work edges need special attention so that deburring time and cost becomes minimum, or eliminated altogether. Experimental investigations, as well as stress analyses, were done [30-33] to explore burr and foot formation in different materials in shaping operation. Although no clear correlation could be obtained between machining parameters and burr formation, an appropriate exit edge bevel angle was found to reduce bur height remarkably.

The objective of this paper is to study the influence of machining conditions and exit edge bevel angle of 45C8 steel flats on burr formation during orthogonal shaping operation, and to find out the optimum condition when burr formation becomes minimum or insignificant.

2. EXPERIMENTAL INVESTIGATIONS

2.1. Experimental Details

Experiments were done on a shaping machine with brazed HSS tipped tool to investigate the effect of exit edge beveling of medium carbon steel (45C8) flats on burr formation under dry environment. Exit edge bevel angle of the workpiece was varied from 15^0 to 35^0 at an interval of 5^0. An exit edge bevel angle, θ was schematically indicated in Fig.1 showing depth of bevel, *te*.

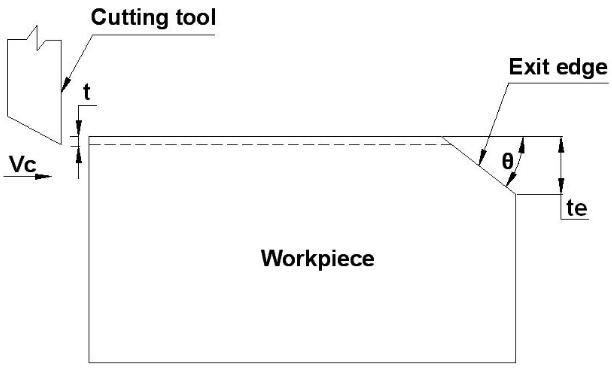


Fig. 1 A schematic diagram indicating exit edge bevel angle, θ and depth of bevel, te

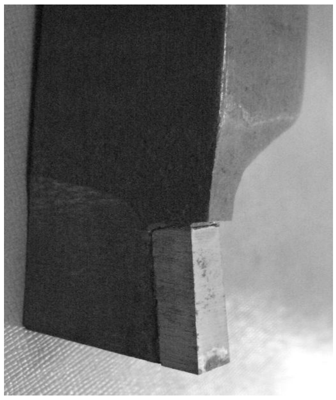


Fig. 2 Photograph of the shaping tool used

Table 1 Details of the experimental set up and conditions

Machine tool	Shaping machine, Main motor power: 10 HP Make: Meehanits Metal Cooper Engineering Limited, Satara, India			
Cutting tool	Brazed HSS tipped broad nose tool, Style of Tool: ISO 7 L.H			
Tool geometry	Orthogonal clearance angle: 3°, Inclination angle: 0° Orthogonal rake angle: - 3°, 0° and 5°			
Job material	Medium carbon steel (45 C8) Hardness: 175 BHN, Size: 90 mm X 65 mm X 2.5 mm Composition: C (0.455%), Si (0.3%), Mn (0.7%), S (0.03%), P (0.03%)			
Machining condition	Type of machining: Orthogonal shaping, Environment: Dry Cutting velocity (Vc): 10 m/min, 15 m/min and 22 m/min Depth of cut (t): 0.05mm (constant), width of cut: 2.5 mm (constant)			
Experiment set	Set No.	Cutting velocity (m/min)	Rake angle (degree)	Exit edge bevel angle (degree)
	1	22	5	0, 15, 20, 25, 30, 35
	2	22	-3	0, 15, 20, 25, 30, 35
	3	15	0	0, 15, 20, 25, 30, 35
	4	15	0	0, 15, 20, 25, 30, 35
	5	10	5	0, 15, 20, 25, 30, 35
	6	10	-3	0, 15, 20, 25, 30, 35

Photograph of the shaping tool used was shown in Fig.2. Detailed experimental set up and machining parameters were shown in Table 1. At one end of the workpiece, a bevel was pre-machined to a height, *te* of 3 mm. Machining conditions was chosen with three different cutting velocities, such as 22 m/min, 15 m/min, and 10 m/min, and three different rake angles of tool of $+5^0$, 0 and -3^0. The depth of cut of 0.05 mm was taken constant throughout the experiments. At a cutting velocity of 15 m/min and orthogonal rake angle of 0^0, the experiment set was repeated twice (experiment set 3 and 4) to observe the repeatability. Following six experiments, the assessment of burr height under a tool makers microscope was observed and classified using a 10 point scale detailed in Table 2.

2.2. Results and Discussion

After conducting orthogonal shaping experiments, observed burr was classified following a 10 point scale after Table 2, and was detailed in Table 3. During shaping of specimens without exit edge bevel angle, burr height was seen to be of medium to large size, and this may had occurred due to absence of any back up material at the exit edge. At no back-up support condition, positive shear plane might have reoriented into a negative shear plane favouring formation of an exit burr.

Table 2 Qualitative assessment of burr height in 10-point scale

Scale value	Height of burr observed
1	Negligible burr up to 0.025 mm height
2	Tiny burr having height from 0.025 mm to less than 0.05 mm
3	Very small visible burr having height from 0.05 mm to less than 0.1 mm
4	Small burr having height from 0.1 mm to less than 0.15 mm
5	Significant burr having height from 0.15 mm to less than 0.2 mm
6	Medium size burr having height from 0.2 mm to less than 0.225 mm
7	Medium to large size burr having height from 0.225 mm to less than 0.25 mm
8	Quite large burr having height from 0.25 mm to less than 0.5 mm
9	Large burr having height from 0.5 mm to less than 1 mm
10	Very large burr having height greater than 1mm.

Table 3 Results obtained in shaping of medium carbon steel

Experiment set	Cutting velocity, Vc (m/min)	Orthogonal rake, α_0 (degree)	Qualitative assessment of burr height in 10 point scale at different exit edge bevel angles (degree)					
			0^o	15^o	20^o	25^o	30^o	35^o
1	22	+5	8	1	3	3	5	6
2	22	-3	9	1	2	2	4	5
3	15	0	6	1	3	5	6	6
4	15	0	6	1	3	5	6	6
5	10	+5	7	1	3	4	5	5
6	10	-3	8	1	2	2	3	4

At 22 m/min cutting velocity and a rake angle of -3°, maximum burr formation was observed when no exit edge bevel was provided. This might be due to requirement of large cutting force with negative rake tool and availability of no back up support. It was observed in each experiment that burr height increased with the increase in exit edge bevel angle. It was due to increasing need of backup support material with respect to increase in exit edge bevel angle, causing steep reduction in depth of cut. On the other hand, for all the six experiments, negligible burr had been observed at 15° exit edge bevel angle. This might be due to less requirement of back up support material, as there was gradually decreasing need of cutting force when the tool advanced towards the exit end along the bevel. Slow gradual decrease in force might not allow change in orientation of shear plane, thereby suppressing burr formation as experienced in the previous works [21-26, 30-33] reported by a research group lead by Das.

3. ANALYSIS OF VARIANCE ON EXPERIMENTAL RESULTS

Analysis of variance (ANOVA) has been done on the experimental data obtained to evaluate relative significance of different parameters followed by Montgomery [34]. Relationship between these parameters and dependent variable is also tried to formulate. The result of the analysis of variance (ANOVA) is detailed Table 4. This table shows that the relation existing between the dependent variable, Qfit (qualitative burr height found through regression equation) and the independent variables (Vc in m/min, α_0 in degree and θ in degree) has high level of confidence, shown as 0.00 level of significance. The value of co-efficient of correlation in the regression analysis comes out to be 0.81 that gives the validity and reliability of the experiment.

Table 4 The ANOVA table

Model	Sum of Squares	Degree of Freedom (DOF)	Mean Square	F-value	Significance
Regression	73.705	3	24.568	32.325	0.00[a]
Residual	19.761	26	0.760		
Total	93.467	29			

a. Predictors : Constant, Vc, θ and $\alpha_{0,}$ b. Dependent Variable : Qfit

Table 5 The ANOVA table showing regression coefficients

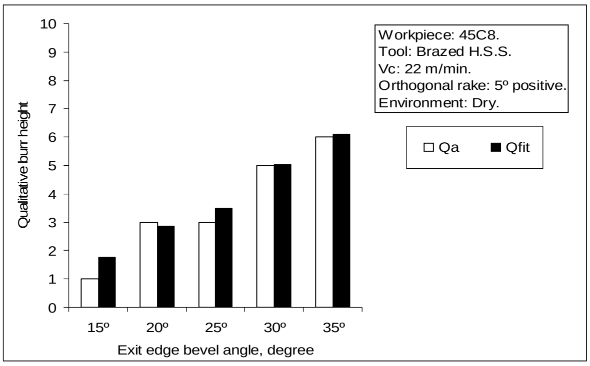
Model	Unstandardized Coefficients		Standardized Coefficients Beta	t-value	Significance
	Coefficient	Standard			
Constant	-2.103	0.774		-2.716	0.012
Exit edge bevel angle, θ	0.217	0.023	0.868	9.625	0.000
Orthogonal rake, α_0	0.099	0.048	0.187	2.071	0.048
Cutting velocity, Vc	0.0055	0.032	0.015	0.170	0.866

Dependent variable: Qualitative burr height, Qfit

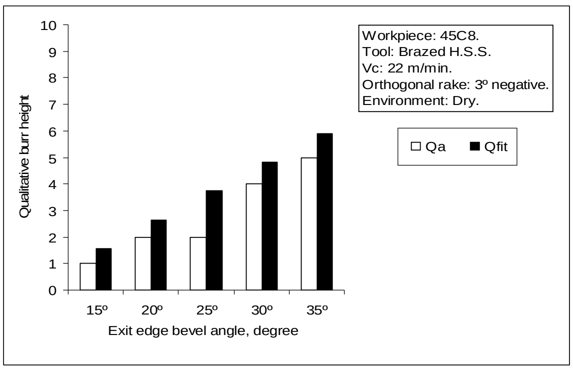
Regression coefficients are obtained following Table 5, and with these, the regression equation evaluated and is shown as Equation (1) for this experiment set.

$$Qfit = -2.103 + 0.0055\,Vc + 0.099\,\alpha_0 + 0.217\,\theta \quad \textbf{(1)}$$

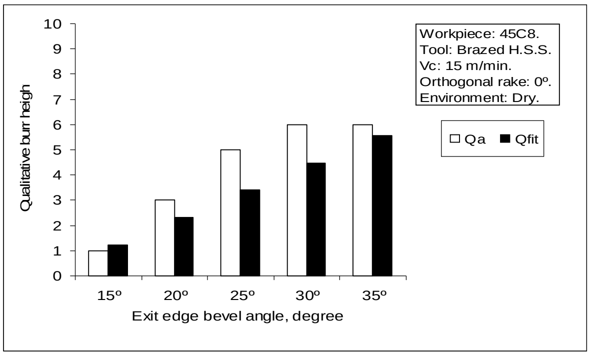
Table 5 shows that the variable, exit edge bevel angle *(θ)* has quite high confidence level as it has 0.000 level of significance, whereas cutting velocity, *Vc* and orthogonal rake angle, α_0 have less confidence level having significance of 0.866 and 0.048 respectively. It means that exit beveled edge angle, *θ* has the maximum influence on burr formation compared to that with cutting velocity, *Vc* and orthogonal rake angle, α_0, and orthogonal rake has higher effect than cutting velocity on burr formation of in this domain of work.



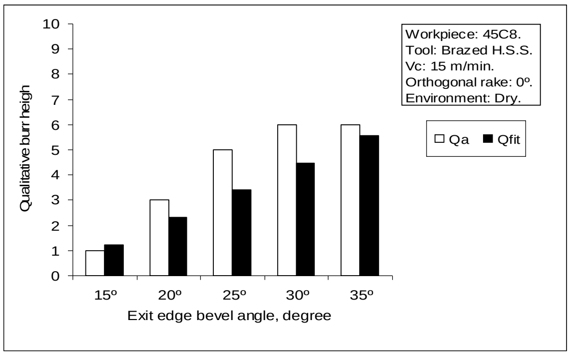
(a) at 10 m/min *Vc* and +5º α_0



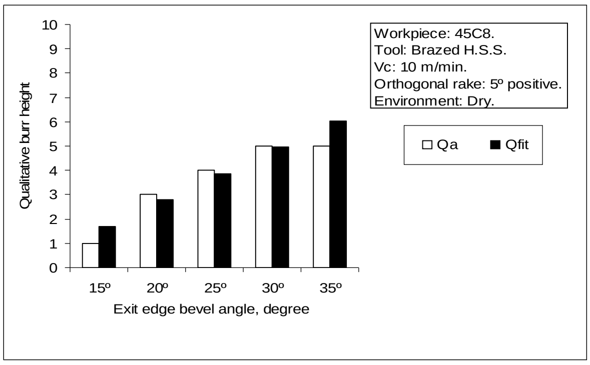
(b) at 10 m/min *Vc* and -3º α_0



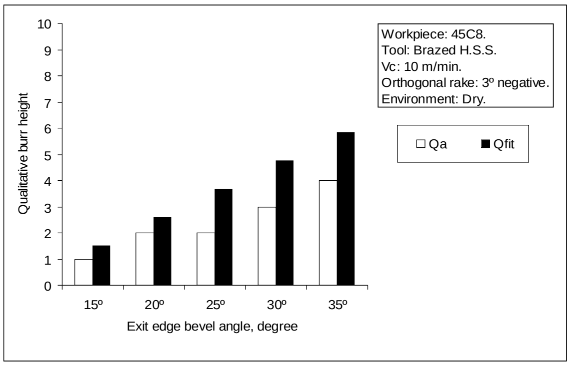
(c) at 15 m/min *Vc* and 0^0 α_0



(d) at 15 m/min *Vc* and 0^0 α_0



(e) at 10 m/min *Vc* and +5º α_0



(f) at 10 m/min *Vc* and -3º α_0

Fig. 3(a-f) Comparative study of qualitative burr height: actual *(Qa)* and estimated *(Qfit)*

Fig. 3(a-f) show the actual experimental observation of classified burr height (Qa) and that estimated through regression equation (Qfit) for all the six sets of experiments. Classified burr heights obtained from the regression equation are found to be matching fairly close to the experimentally obtained values, showing the degree of appropriateness of the evaluated relationship. Close matching of experimental observation with the regression analysis outputs with some deviations indicates the possibility of using the regression equation for predicting the extent of burr formation in shaping.

4. CONCLUSIONS

From the observation on experimental results on orthogonal shaping of medium carbon steel flats under dry condition, following conclusions may be drawn.

- Exit edge bevel shows remarkable effect on reduction of burr height.
- Within the domain of experimental conditions, negligible burr is observed at 15^0 exit edge bevel angle. This may be due to less requirement of back up support towards the exit bevel edge of the specimen with decreasing depth of cut that needs reducing cutting forces.
- Burr height is seen increasing with the increase in exit edge bevel angle due to less back up support material at the exit edge caused by steep reduction of depth of cut.
- Analysis of variance is carried out on the experimental findings, and it reveals that exit edge bevel angle has greater influence on burr formation than orthogonal rake angle and cutting velocity. Again, orthogonal rake angle has slightly greater effect on burr formation than cutting velocity within this experimental domain.

Acknowledgement: The authors wish to sincerely acknowledge Chief Works Manager, Eastern Railway, Kanchrapara Workshop, West Bengal for permitting to carry out experimental works at the workshop. The help extended by Mr. Ashis Kr. Bhattacharya for measuring burr height is also thankfully noted.

REFERENCES

[1] Gillespie, L.K. and Bolter, P.T., The Formation and Properties of Machining Burr, Transactions of the ASME, Journal of Engineering for Industry, Vol.98, No.1, pp.66-74, 1976.

[2] Nakayama, K. and Arai, M., Burr Formation in Metal Cutting, Annals of the CIRP, Vol.36, No.1, pp.33-36, 1987.

[3] Lin, T.R., Experimental Study of Burr Formation and Tool Chipping in the Face Milling of Stainless Steel, Journal of Materials Processing Technology, Vol.108, pp.12-20, 2000.

[4] Chern, J.L., Some Observation on Burr Formation in Single-Tooth Face Milling, Proceedings of Chinese Mechanical Engineering (Manufacturing Science), Taichung City, November 1994, pp.441-452.

[5] Dornfeld, D., Min, S., Kim, J., Hewson, J., Chu, C.H. and Tyler, P., Burr Prevention and Minimization for the Aerospace Industry, LMA Annual Report, University of California at Berkeley, pp.4-9, 1999.

[6] Olvera, O. and Barrow, G., An Experimental Study of Burr Formation in Square Shoulder Face Milling, International Journal of Machine Tools and Manufacture, Vol.36, No.9, pp.1005-1020, 1996.

[7] Dornfeld, D.A. and Lee, S.H., Prediction of Burr Formation during Face Milling

Using an Artificial Neural Network with Optimal Cutting Condition, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, Vol.221, No.12, pp.1705-1714, 2007.

[8] Lee, Y.M., Samath, Y.S. and Shaw, M.C., Tool Fracture Probability of Cutting Tools under different Exiting Conditions, Transactions of the ASME, Journal of Engineering for Industry, Vol.106, pp.168-170, 1984.

[9] Pandey, S.S. and Relekar, H.P., Investigations on Reducing Burr Formation in Drilling, International Journal of Machine Tool Design Research, Vol.26, No.3, pp.339-348,1986.

[10] Gaitonde, V.N., Karnik, S.R., Achyutha, B.T. and Siddeswarappa, B., Methodology of Taguchi Optimization for Multi-Objective Drilling Problem to Minimize Burr Size, International Journal of Advanced Manufacturing Technology, Vol.34, pp.1-8, 2007.

[11] Jackson, J.M., Robinson, M.G., Whitfield, D.M. and Ahmed, W., Burr Formation and Elimination in Micro Milling Process, International Journal of Nanomanufacturing, Vol.1, No.4, pp. 458-467, 2007.

[12] Saunders, L.K.L. and Mauch, C., An Exit Burr Model for Drilling of Metals, Transactions of the ASME, Journal of Manufacturing Science and Engineering, Vol.123, No.4, pp.562-566, 2001.

[13] Rhim, S.H., Shin, S.Y., Joo, B.Y. and Oh, S.I., Burr Formation during Micro via-Hole Punching Process of Ceramic and PET Double Layer Sheet, International Journal of Advanced Manufacturing Technology, Vol.30, pp.227-232, 2006.

[14] Kim, J. and Dornfeld, D.A., Development of an Analytical Model for Drilling Burr Formation in Ductile Materials, Journal of Engineering Materials and Technology, Vol.124, pp.192-198, 2002.

[15] Narayanaswami, R. and Dornfeld, D.A., Burr Minimization in Face Milling: Geometrical Approach, Journal of Manufacturing Science and Engineering, Vol.119, pp.170-177, 1997.

[16] Chern, G.L. and Dornfeld, D.A., Burr/Breakout Development and Experimental Verification, Transactions of the ASME, Journal of Engineering Materials and Technology, Vol.118, No.2, pp.201-206, 1996.

[17] Ko, S.L. and Dornfeld, D.A., A Study on Burr Formation Mechanism, Transactions of the ASME, Journal of Engineering for Industry, Vol.112, No.1, pp.66-74, 1991.

[18] Iwata, K., Ueda, K. and Okuda, L., Study of Mechanism of Burr Formation in Cutting Based on Direct SEM Observation, Journal of Japan Society for Precision Engineering, Vol.48, No.4, pp.510-515, 1982.

[19] Pekelharing, A.J., Cutting Tool Damage in Interrupted Cutting, Wear, Vol.62, pp.37-48, 1980.

[20] Sikdar, C., Effects of Cutting Edge Modification on Machining Characteristics and Performance of Coated Carbide Face Milling Insets, Ph.D. Dissertation submitted to Indian Institute of Technology, Kharagpur, pp.104-105, 1993.

[21] Saha, P.P., Das, D. and Das, S., Effect of Edge Beveling on Burr Formation in Face Milling, Proceedings of 35th International MATADOR Conference, Taipai, Taiwan, pp.199-202, 2007.

[22] Saha, P.P. and Das, S., A Study on the Effect of Process Parameters and Exit Edge Beveling on Foot and Burr Formation during Machining of Medium Carbon Steels, Proceedings of the National Conference on Recent Advances in Manufacturing Technology and Management, Jadavpur, Kolkata, India, pp.30-35, 2010.

[23] Saha, P.P. and Das, S., Influence of Exit Edge Beveling on Burr Formation in Shaping En25 Steels under Varying Machining Conditions, Poster Proceedings of the 3rd International and 24th All India Manufacturing Technology, Design and Research Conference, Visakhapatnam, India, pp.191-195, 2010.

[24] Saha, P.P. and Das, S., An Investigation on the Effect of Machining Parameters and Exit Edge Beveling on Burr Formation in Milling, Journal of Mechatronics and Intelligent Manufacturing, Vol.2, No.1/2, pp.73-84, 2010.

[25] Pratim, P.S. and Das, S., Burr Minimization in Face Milling: An Edge Beveling Approach, Proceedings of the Institute of Mechanical Engineering, Journal of Engineering Manufacture, Vol.225, No.9, pp.1528-1534, 2011.

[26] Saha, P.P., Das, A. and Das, S., On Reduction of Formation of Burr in Face Milling of 45C8 Steels, Materials and Manufacturing Processes, Vol.28, No.5, pp.550-556, 2013.

[27] Balasubaramaniam, R., Krishnan, J. and Ramakrishnam, N., Investigation of AJM for Deburring, Journal of Materials processing Technology, Vol.79, pp.52-58, 1998.

[28] Choi, I.H. and Kim, J.D., Electrochemical Deburring System Using Electroplated CBN Wheels, International Journal of Machine Tools and Manufacture, Vol. 38, No.1, pp. 29-40,1998.

[29] Choi, I.H. and Kim, J.D., A Study of the Characteristics of the Electrochemical Deburring of a Governor Shaft Cross Hole, Journal of Materials Processing Technology, Vol.75, pp.198-203, 1998.

[30] Saha, P.P., Das, A. and Das, S., Burr Minimization in Shaping EN25 Steels: Using Experimental and Stress Analysis Techniques, International Journal of Manufacturing Technology and Industrial Engineering, Vol.2, No.2, pp.61-65, 2011.

[31] Saha, P.P. and Das, S., An Experimental Approach to Investigate the Effect of Process Conditions on Exit Burr Formation in Shaping an Aluminium Alloy, Journal of the Association of Engineers, India, Vol.82, No.1-2, pp.52-60, 2012.

[32] Saha, P.P. and Das, S., Towards Minimization of Foot Formation of EN25 Steel Flats, Reason- A Technical Magazine, Vol. X, pp.27-30, 2011.

[33] Das, A., Saha, P.P. and Das, S., An Investigation on Reducing Burr in Shaping Medium Carbon Steel through Stress Analysis, Proceedings of the International Conference on Mechanical Engineering, Dhaka, Bangladesh, pp.AM-030/1-6, 2011.

[34] Montgomery, D.C., Design and Analysis of Experiments. Wiley India (P) Ltd., New Delhi, 2007.