

Research Article

Geometrical Defect in Precision Blanking/Punching: A Comprehensive Review on Burr Formation

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Abstract: Burr is the main problem in precision blanking. Uncontrolled burr not only affects the geometrical precision of the blanked parts, it also ruins their assembly. In this study, a comprehensive review on burr formation and the parameters that become the source of its occurrence are discussed. The analysis was made on the most relevant literatures and categorized based on key words and the methodology used. Based on the analysis, it is found that die clearance is the most relevant parameters, which carried out experimentally. The paper also presented the current challenges facing by the manufacturer as well as researcher on burr problem and outlined some of the solutions suggested to overcome this problem. In addition, the authors raised the problem on measurement of the burr as the size of the component become smaller and level of precision is higher.

Keywords: Burr, die clearance, precision blanking, punching

INTRODUCTION

A burr is a raised edge or small pieces of material remaining attached to a workpiece after a modification process. There are three types of burrs that can be formed from machining operations: Poisson burr, rollover burr and breakout burr. The rollover burr is the most common (Ingarao *et al.*, 2011). Burrs may be classified by the physical manner of formation. Plastic deformation of material includes lateral flow (Poisson burr), bending (rollover burr) and tearing of material from the workpiece (tear burr). Solidification or redeposition of material results in a recast bead. Incomplete cutoff of material causes a cutoff projection. Burrs can be minimized or prevented by considering materials, function, shape and processing in the design and manufacturing engineering phases of product development (Aoki and Sasada, 2004) (Fig. 1).

Aoki and Sasada (2004) proposed a new method for burr free blanking using pushback blanking method. They found that the success of this method depends on the clearance and rigid control of punch penetration depth. A piezoelectric actuator is utilized in this method, which has good controllability and repeatable stability. However, due to the limitation of the piezoelectric element, a displacement magnifying mechanism needs to be created. The mechanism was analyzed using the FEM and experimental method. In fact, both of the methods agreed very well. Quazi and Shaikh (2012) proved that blanking clearance, the wear state of the tool and the thickness of the sheet are three

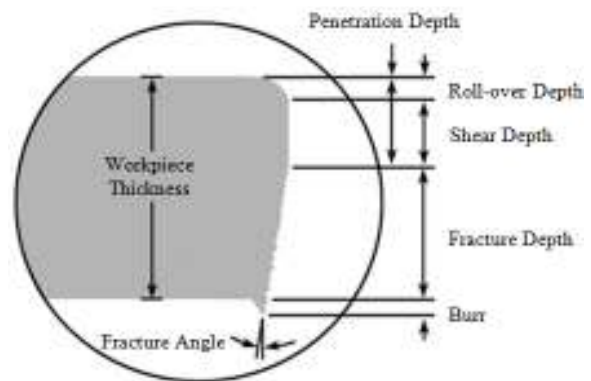


Fig. 1: Sheared-cut edge terminologies

main factors that can influence the mechanical and geometrical aspect of the sheared edge during the blanking operation. They obtained optimum clearance based on the direction of crack propagation coincides with the line joining the points of crack initiation, hence the formation of secondary crack is prevented. In their study, the diagonal angle and the angle of the direction of crack propagation for different clearances were selected to determine the optimum clearance. The optimum clearance for the values of the parameters used in this study is between 11 and 12%. It is observed that punch penetration increases as the clearance/thickness ratio increases. Consequently, with larger clearance, the material can deform more easily, so that greater punch penetration is necessary before cracks are

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initiated. Brokken *et al.* (2000) predicted the shape of blanked products using an elasto-plastic finite element model. For extremely large deformations, it is handled by using an operator split Arbitrary Lagrange-Euler (ALE) method combined with remeshing. Meanwhile for ductile fracture, local criterion is adopted and it is simulated by discrete fracture approach. Discrete crack model is based on Rice and Tracey's void growth model and it has to be performed striving for consistency between applied load and crack length. Hilditch and Hodgson (2005) found that, in general the burr height and rollover depth increased with increasing clearance for all examined materials. However, there were differences in the fracture surface profile shape, the burr shape and the mechanism of burr formation, between the two steels and the two light alloys. The major cause of these differences appeared to be the rate of crack propagation through the sheet material. Meanwhile, rollover is also affected by material's ductility and work hardening. Different burr formation mechanisms existed for the two classes of materials. Rapid crack propagation and part/scrap separation at a low punch penetration in both the aluminum and magnesium alloy samples resulted in a curved fracture profile and 'right-angle' shaped burr. From their research, they found that slow crack propagation after crack initiation in the steel samples and subsequent part/scrap separation at a significantly higher punch penetration, resulted in a straight fracture profile and a 'v' shaped burr. Kim *et al.* (2005) found counter blanking process can produce the hole without any burr, but the fracture face was relatively large and rough due to the growth of micro voids. Therefore, they proposed a hydro-mechanical punching method to delay fracture initiation by applying pressure medium in the place of counter punch or the backpressure on the piercing punch. However, new problem on hole diameters discrepancies occurs. They solved the problem using backpressure on the upper withdrawing piercing punch method. Comparatively, the conventional punching hole have relatively large portion of fracture surface and burr compared with the propose hydro-mechanical punching method. Hambli (2002) observed that burr height depends on clearance, wear state of tool and thickness of sheet. The research done focuses on the prediction of tool wear changes and relationship to clearance using a combination of numerical analysis and Artificial Neural Network (ANN) modelling. The numerical results were utilized to train the developed simulation environment based on back propagation neural network modelling. The major advantage of the developed model is faster and accurate burr height estimation. In addition, it can reduce the trial and error. The developed model has been validated with experimental observation. Wang *et al.* (2013) proposed a method called as fine hydro-mechanical blanking to investigate the influence of blanking on the shear zone length under different design factor conditions. Optimization based on the integrated Taguchi method and Genetic Algorithm (GA) was used to determine the

longest shear-zone length. In addition, the influence of the hydraulic pressure in the V-ring cavity and the shear-zone length also was investigated. As a conclusion, this new approach was proven able to cut the surface of a workpiece and the burnishing surfaces were influenced by hydraulic pressure in the V-ring cavity and in the ejector chamber. Furthermore, the magnitudes of the hydraulic pressures in the V-ring cavity and ejector chamber are controllable and adjustable, which can provide a new way of evaluating the significant parameters of the blanking process. Tekiner *et al.* (2006) carried out experimental study to examine the effect of different clearances on smooth-sheared depth, burr height and blanking force. There are several conclusions can be made based on the experiment results. First, the smooth-sheared value increases when the clearance value decreases. Second, the burr depth value increases when the clearance value increases. Third, when the clearance increases, the roll over depth increases. Forth, the punch force value increases when diameter of material increases. Fifth, decrease in clearance value only will increase the punch force value by about 5 to 10%. Hence, in overall, it is necessary to keep the clearance low in order to get a more qualified surface roughness.

Maiti *et al.* (2000) evaluated the influence of tool clearance, friction, sheet thickness, punch/die size and blanking layout on the sheet deformation. As expected, the blanking load increases with a reduction in the tool clearance in the case of both single and double blanking. Furthermore, change in the clearance in the range $0\pm 20\%$ of the sheet thickness does not affect the growth of plastic zone for both cases. The blanking load also increases with an increase in the coefficient of friction at the tool sheet interfaces. Meanwhile, for the same diameter to sheet thickness ratio, the change in thickness does not affect the blanking load. However, for the same sheet thickness, with an increase in the blank diameter, the blanking load reduces. As a conclusion, they suggested that an intermediate range of tool clearance (about 10% of the sheet thickness) appears good from the point of view of requirement of load and sheet deformation. Makich *et al.* (2008) identified a relationship between burrs and punch wear, based on 3D topographical images namely Infinite focus Alicona. Meanwhile punch wear was calculated by combination of a mathematical model to the geometric shape of punch. They defined the height of burr as the difference between the highest point of burr and the surface of the sheet metal immediately adjacent to the burr. Begins with straightening of the image around the blanked shape, follow by extracting the profile that vertically from the contour of the blanked shape. Then again, the profiles are extracted in multiples to build a rectangular matrix. Finally, the volume is determined only in the burr presence on the image. As a conclusion, burr volume increases with the increasing of number of press stroke.

Picart *et al.* (2005) simulated a blanking process and predicted geometrical and mechanical

characteristics of the blanked component utilizing the damage modeling or fracture criterion. A finite element separation method denoted discrete cracking method is performed to describe the crack propagation. Numerical results showed that a first crack is initiating near the die corner at punch penetration of 76% then a second crack is appearing on the punch side before two cracks eventually propagate to one another and the crack initiation is correctly predicted at 2 mm of punch penetration. They validated the result through experimental method. Rachik *et al.* (2002) found that the maximum punch force is strongly related to the plastic flow but that the burr height estimation requires damage modeling. In addition, Gurson's modified model greatly improves the punch force prediction. Bubphachot (2009) investigated the microstructure of fine blanking process to avoid fracture surface on blank. Study observed that optimum condition will result in higher elongation while having small decrease in tensile strength. It revealed that fracture surface became shear surface after heat treatment over 10 h. Goijaerts *et al.* (2002) investigated both process and force and fracture initiation for blanking of a ferrite stainless steel in various geometries. The numerical simulation carried out based on the rate-independent elasto-plastic constitutive model combined with a fracture criterion and extended with respect to rate-dependence by employing an elasto-viscoplastic constitutive model. The result shown that the blanking speed has no influence on the punch displacement at ductile fracture initiation up to blanking velocities of 10 mm/sec. Meanwhile, the maximum blanking force will increase as the punch speed increasing. However, for the larger blanking speed the numerical predictions start to deviate from the experiments. This may be caused by thermal softening and the material parameters that were quantified by performing different tensile tests with strain rates varying.

In other work, Goijaerts *et al.* (1999) elaborated two approaches using a local ductile fracture model to the ductile fracture initiation, in order to predict product shapes in the blanking process. The first approach incorporates the characterization of a ductile fracture model in a blanking experiment and should take place under loading conditions, comparable to the application. Meanwhile, the second approach uses a tensile test to characterize the fracture model, instead of a complex and elaborate blanking experiment. Hence, this approach is more favorable for industry. As a conclusion, it can be stated that for the investigated material, the first approach gives very good results within the experimental error. The second approach, the more favorable one for industry, yields results within 6% of the experiments over a wide, industrial range of clearances, when a newly proposed criterion is used. Khadke *et al.* (2004) studied the effect of various

process parameters on the extent of burr formation and optimal process parameters which would yield minimum burr formation. They found that shear failure model to be the most suitable model for the numerical simulations of the shearing process. The results show that the burr heights are at a minimum at small clearances close to 5% and for cutting angle greater than 17°. Furthermore, burr height will be insensitive to the blade radius at these clearances and cutting angles. Hambli and Richir (2003) compared a damage model is more representative of crack initiation and propagation simulation than the Lemaitre damage models and found that they can be predicted accurately. Totre *et al.* (2013) stated that there are several factors affecting in blanking process. First factor is the clearance. With correct clearance, the angle of fractures will permit clean break below the burnish zone because the upper and lower fracture will extend toward one another. The second factor is punch geometry since it will affects the punch stresses and temperature as well as punch life. The third factor is tool wear. This is because it somehow similar to the punch corner radii. The fourth factor is sheet thickness. Sheet thickness is highly related to the energy requirement in blanking and proportions of the different depth characteristics of the sheared profile. The last factor is material. Materials with large ductility, low yield strength and homogeneity will have better blanked edge quality, dimensional tolerances and longer tool life. Nishad *et al.* (2013) combined Design of Experiments, Finite Element Method, Neural Network Analysis and Genetics Algorithm approaches to predict optimum parameters involved in the sheet metal blanking process. They found that, Design of experiments technique helps to find the most effective parameter leading towards optimal combination of parameters setting. While, finite element simulation give the best tool setting for the optimum process output. For Neural Network Analysis, a network using artificial intelligence have to be trained which is an costly and time consuming procedure. Next, the genetics algorithm technique consists of a series of mathematical formulae's and algorithms to come out with optimum results. Similarly Al-Momania and Rawabdeh (2008) integrate a Finite Element Method (FEM) and Design of Experiments (DOE) approached to optimize the sheet metal blanking process. The process parameters such as the material type, the punch-die clearance, the thickness of the sheet and the blank holder force and their interactions on the burrs height have been investigated. The results show that the higher the clearance the higher the burrs height and the lower the blank holder force the lower the burr height. The material type has effect but the thickness effect is insignificant. In order to minimize the burrs height, the clearance should be set at about 5% with almost no blank holder force. When blank holder force is set to

zero, the process is slightly more robust to clearance changes than when a high blank holder force is used. However a small value in the order of about 2% of the blanking force is favorable since it can prevent the remaining skeleton from moving out of plane. In other work, Goijaerts *et al.* (2000) have developed finite element model to optimize the blanking process and validate using a planar experimental set-up. They not only measured the punch load, but also the logarithmic strain-fields. Besides that, they measured the displacement fields, coupled with a second order method to calculate strain-fields by using a digital image correlation. The results show that a change in clearance influences the experimental and numerical techniques similarly, both in the strain-field and in the punch load. The numerical simulation predicts a plane strain strain-field about 10% larger than the experimental strain-field. Quazi *et al.* (2013) employed the Taguchi Method to evaluate the influence of tool clearance, sheet thickness and sheet material thus optimizing clearance which affects other process parameters in blanking process of aluminum and brass material. The experiment results were analyzed using ANOVA and regression analysis. For aluminum, clearance was found to be the major factor affecting the burr height (23%). A percent contribution of sheet thickness is much lower, being (1.4%). The minimum burr height (0.0602468) corresponds to clearance value of (0.04531). While for brass, clearance was found to be the major factor affecting the burr height (22%). A percent contribution of sheet thickness is much lower, being (1.1%). The minimum Burr height (0.077876) corresponds to clearance value of (0.05844). In conclusion, the clearance should be set at about 5% with almost no blank holder force to minimize the burrs height. Sandwikar and Chandgude (2012) have conducted experimental studies under varying sheet thickness, clearance and wear radius. Taguchi quality design concept of L27 orthogonal array has been used to determine main effect, Signal to Noise ratio (S/N), Analysis of Variance (ANOVA) for determining most significant parameters affecting the blanking process. Based on the ANOVA method, the highly effective parameters on burr height were found as tool wear radius and clearance, whereas sheet thickness was less effective factor. The result show that tool wear radius was about two times more important than the clearance for controlling burr height. An optimum parameter combination for the minimum burr height was obtained by using S/N ratio.

Hambli (2002a) carried out a Design of Experiment of blanking process using tools with four different wear states and four different clearances. The study focus on the effects of the interaction between the clearances, the wear state of the tool and the sheet metal thickness on the evolution of the blanking force and the geometry of the sheared profile. The results were analyzed using

response surface methodology and the result shown that the clearance should be set at 10%, in order to minimize the blanking force. However, it is advisable to set the clearance at 5% to minimize the fracture angle and the fracture depth. When the clearance is set at 10%, the process is slightly more robust to tool wear, as far as the blanking force response is concerned and it is considerably more robust to tool wear and sheet thickness as far as the fracture depth response is concerned. Whether clearance should be set at 5 or 10% ultimately depends on the priorities of the practitioners.

Franke *et al.* (2010) had performed a round robin test to compare different burr measurement systems. The burr can be quantified based on burr height, burr area, burr thickness and burr radius. Six measurement methods were compared, including the digital fringe projection, Confocal measurement system Depth of Focus (DoF), Confocal White Light Interferometer, Non-Contact 3D Measurement System, Stylus Profilometer and Metallographic Cross Sections. The results show that the burr height measured in cross sections differed from the results of non-destructive measurement methods. It has to be taken into account that cross sections only regard one specific burr position and not the whole burr. The workpiece position has a large impact on the results of burr measurement. Further work is necessary to develop approaches for standardization burr measurements to enable comparison.

Ko and Park (2006) had employed Triangulation method, conoscopic holography method and interferometry method are analyzed for effective measurement of micro burr geometry. The authors had measured cylinder with 0.5 mm diameter in order to select a proper sensor. Then, burr with 1.0 mm height and 30 μm height are measured by all methods. The results show that the conoprobe sensor by conoscopic holography method is most recommended to measure the sharp edges of burr. This is because laser triangulation method produces unstable signal in measuring the surface with high slope. Interferometry method also fails in producing proper interference pattern at sharp edge near the top of burr. As a first step of development of burr measurement system, proper sensor must be determined considering measuring range and accuracy.

Nakao and Watanabe (2006) had developed a drilling burr measurement system based on image processing techniques to measure the burr profiles (burr height and thickness). An image of the measured burr specimen is taken with a CCD camera located right above the burr specimen. The angle between mirror surface and setup base is 45°, located around the measured burr. Then the images of the side surfaces of the burr by means of the set of four mirrors are taken. Binary image processing, the noise reduction and the labeling are applied before burr analysis measurement is performed. Total measurement accuracy of the

system depends on the accuracy of both the measurement process using developed instrument and the analyzing processes using developed software. Besides that, by using this developed method, it is possible to investigate repeatability of the drilling burr formation by same machining condition and classify types of created burrs such as “uniform-type burr” and “crown-type burr”. In other case, Jana and Ong (1989) examined the effects of varying the punch-die clearance and hardness of the specimen on the surface finish and quality of blanked specimens for a variety of metals. The blanking speeds used were both low (0.13 m/sec) and high (10 m/sec) by using a developed accelerator. The materials used were aluminium alloy 2024-T4, brass (60/40), copper (0.99 Cu), mild steel and Thyssen 1730 steel (AISI 1045), all of 9.5 mm thickness. The results show that the use of high punch-speeds has resulted in blanks being produced with an improved surface finish as compared to those obtained at low speed, over the range of radial clearances tested. This improvement is particularly marked for mild-steel blanks, as secondary shears are eliminated when a high speed is used. Less distortion was obtained also as a result of a high punch speed. Although there is no significant difference in the surface finish of blanks produced at high punch speeds, for all the clearances tested the distortion of the blanks increases with increase in the radial clearance.

Rai *et al.* (2013) found that the factors causing burr can be summarized into man (operator awareness, skill of operator), material (raw material grade and thickness), machine (alignment, clearance) and method (part handling). Besides that, the authors also explain how the selection of tool material will affect the tool life, part quality and tool sharpening frequency. A brief guideline about the correct die-punch alignment and tool assembly also had been included in this study.

Gréban *et al.* (2007) had carried out a blanking test on different copper alloys to show that the blanking profile was strongly influenced by the mechanical characteristics and the microstructure of the alloys. The experiment results show that the roll-over is hardly influenced by the geometry of the blanking process (blanking punch/die clearance). The sheared and fracture zones are mainly influenced by the mechanical properties of the sheet. The more work hardened it is, the greater the fracture zone is. It can be easily understood that the fracture occurs all the earlier as resilience is weak. Therefore, it leads to a weaker sheared zone, more detrimental to the overall good quality of the blanking process. Besides that, burr growth is independent of the work hardening state of the sheet; it is hardly influenced, on the contrary, by the precipitates.

Taupin *et al.* (1996) had performed several blanking simulations and the results were compared with the previous experimental studies. It was shown that the influence of process variables such as punch-die clearance, material properties and punch and die wear could be simulated with a good correlation to

experimental results. It was experimentally and simulation observed that with a decreased clearance of 4.5% the roll over, the rupture zone and the burr height decrease, whereas the shear zone increases to approximately 75% of the material thickness. A decreasing clearance also results in a slight increase in blanking force. Besides that, the simulation outcome shows almost the same characteristics as were observed after 150,000 hits during wear experiments. The dull cutting edges cause more plastic deformation before shearing starts. The result is an increased roll over and burr height, while the shear zone is decreasing. Compared to the simulation with a sharp punch and die, the maximum load increased approximately 10% and the punch penetration until fracture 15%.

DISCUSSION

Analysis carried out by categorizing the studies done on burr in various manufacturing process, especially blanking process, so that the extraction of important information can be easier in future. In addition, categorizing also will make better use of data. Data need to be organized and coordinated so that it is readily accessible. Hence, two categorizing technique are used to categorize the literatures. The two techniques are as following i.e., based on keywords and methodology used.

Keywords: Most journals require the author to identify three or four key words which represent the major concept of the paper. These are used for indexing purposes and the key words selected should be widely-accepted terms. Total keyword collected from all literatures is 120 words. The keywords collected can be categorized into 44 groups. The categorizing result is shown in Fig. 2.

The result shows that the keyword of Blanking/Double Blanking/Fine Blanking/Planar Blanking/Punching/Shearing/Trimming has the highest occurrence number-25 literatures. It is followed by keyword of Burr/Burr Amount/Burr Height/Burr Formation which has 14 literatures involved. The third highest occurrence keyword is Finite Element Modeling which has 10 literatures related. The detail of analysis is tabulated in Fig. 2.

Methodology used: Various methodologies can be used by the author to carry out their research or experiment. The methodologies are as following.

Experiment investigation: A test under controlled conditions that is made to demonstrate a known truth, examines the validity of a hypothesis, or determines the efficacy of something previously untried.

Design of Experiments (DOE) method: Designed experiments are a systematic approach to optimizing

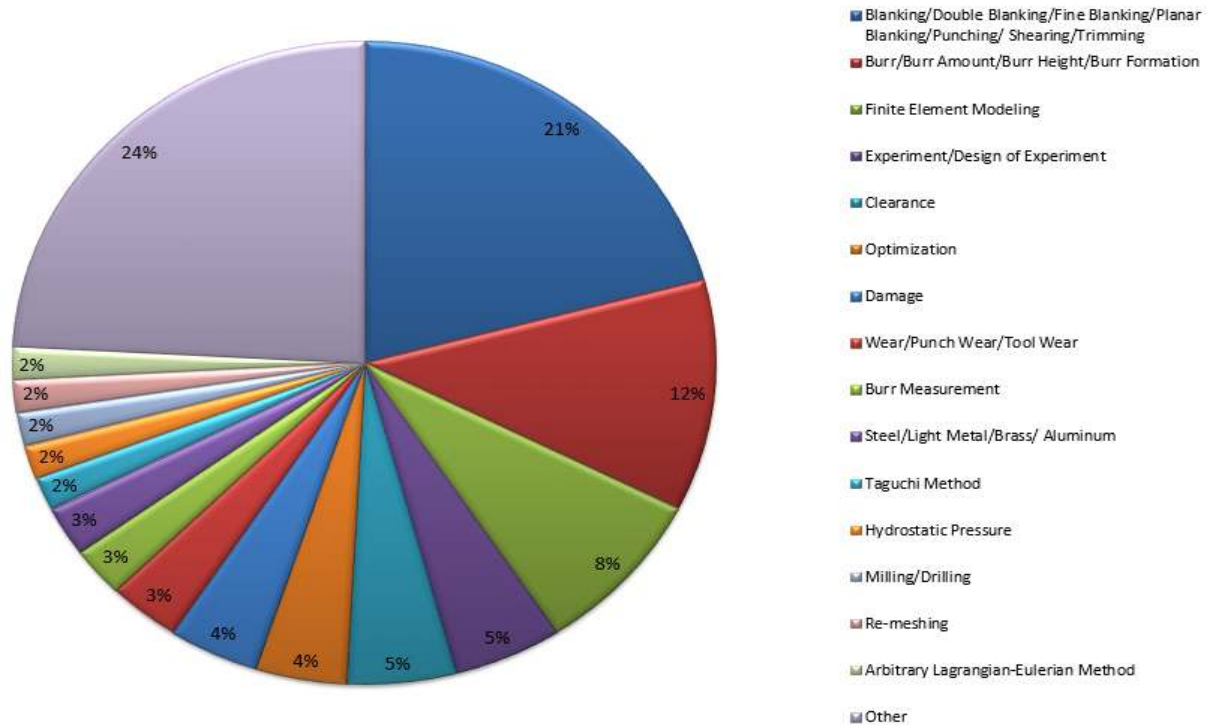


Fig. 2: Analysis of literature categorizing based on keywords

process performance, they are also used for knowledge acquisition. Traditionally, the setting of a single factor is changed at a time until the response is improved.

Finite Element Method (FEM): Finite Element Method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for differential equations. It uses variation methods (the calculus of variations) to minimize an error function and produce a stable solution.

Genetic algorithm: In a genetic algorithm, a population of candidate solutions (called individuals, creatures, or phenotypes) to an optimization problem is evolved toward better solutions.

Neural network analysis: The networks are employed as numerical devices for substituting the finite element code needed for the optimum clearance prediction of the sheared part. Since the main material variable describing the fracture initiation and propagation conditions is the strain at rupture, the input data for the artificial neural network is the material elongation A% and the output data is the optimum clearance. The methodology used can be categorized into 9 groups. The result is shown in Fig. 3.

The result shows that the method of Experimental Investigation has the highest occurrence number i.e., 9 literatures. It is followed by method of Experimental Investigation + FEM which has 4 literatures involved. The third highest occurrence method is Finite Element

Modeling which has 4 literatures related. The detail of analysis is tabulated in Fig. 3.

PROCESS/DESIGN PARAMETERS THAT MAY CAUSE THE BURR

Mechanical and geometrical aspects of the sheared edge during the blanking operation are the main concern of many researchers. It is affected by several parameters such as the clearance, material properties/work hardening/microstructure, thickness of material, wear state of the tool/tool radius, punch/die size/geometry, friction, layout, blank holder force, punch speed, punch-die alignment and cutting angle. The detail of parameter suggested by various literatures is tabulated in Table 1. Based on the literatures, die clearance become main parameter that has been studied. Followed by mechanical and physical properties of the workpiece material.

RECENT CHALLENGES

Presence of burr will affect assembly, which result in possible part jamming and misalignment and in most cases may cause injury to the operator due to sharp edges. For bigger part such automotive parts, the problem of burr may not critical. But for miniature component especially in optics, electronic and medical industries, this problem may affect their productivity. Debris of the burrs can cause serious damage on the moving parts. In electrical components, they can cause

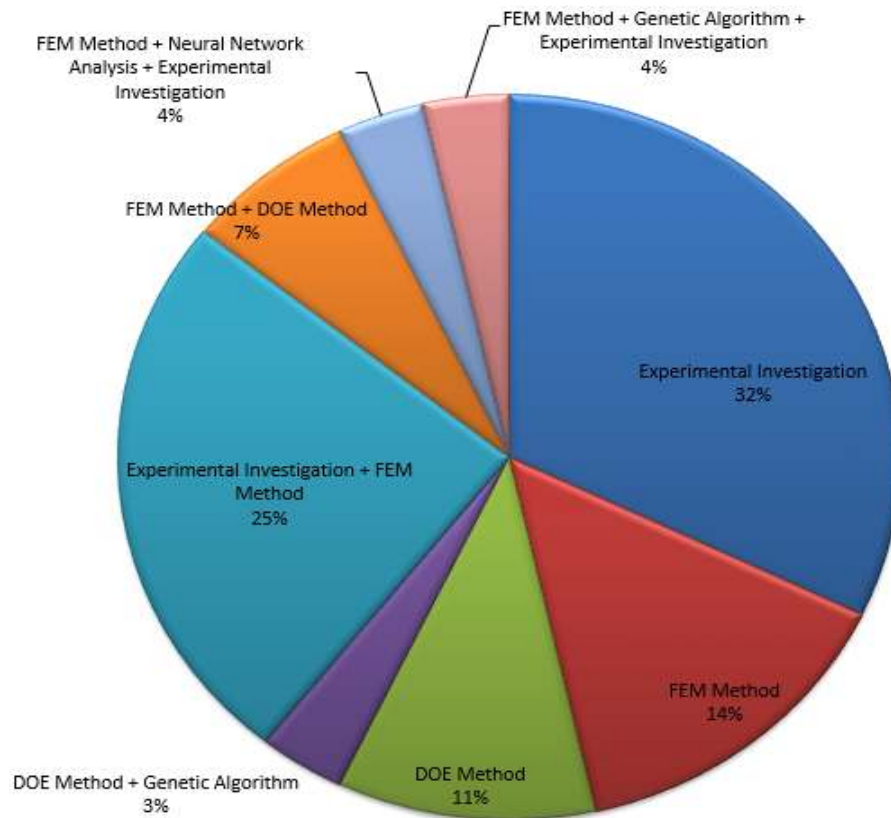


Fig. 3: Analysis of literature based on methodology used

Table 1: Process/design parameters that may cause the burr

Process/design parameters	No. of literatures related	References
Die clearance	19	Aoki and Sasada (2004), Quazi and Shaikh (2012), Brokken <i>et al.</i> (2000), Hilditch and Hodgson (2005), Hambli (2002a), Tekiner <i>et al.</i> (2006), Maiti <i>et al.</i> (2000), Khadke <i>et al.</i> (2004), Totre <i>et al.</i> (2013), Nishad <i>et al.</i> (2013), Al-Momania and Rawabdeh (2008), Goijaerts <i>et al.</i> (2000), Quazi <i>et al.</i> (2013), Sandwkar and Chandgude (2012), Jana and Ong (1989), Rai <i>et al.</i> (2013) and Taupin <i>et al.</i> (1996)
Material properties/work hardening/microstructure	10	Hilditch and Hodgson (2005), Hambli (2002b), Bubphachot (2009), Totre <i>et al.</i> (2013), Nishad <i>et al.</i> (2013), Quazi <i>et al.</i> (2013), Ko and Park (2006), Rai <i>et al.</i> (2013), Gréban <i>et al.</i> (2007) and Taupin <i>et al.</i> (1996)
Thickness of material	8	Quazi and Shaikh (2012), Maiti <i>et al.</i> (2000), Totre <i>et al.</i> (2013), Nishad <i>et al.</i> (2013), Al-Momania and Rawabdeh (2008), Quazi <i>et al.</i> (2013), Sandwkar and Chandgude (2012) and Rai <i>et al.</i> (2013)
Wear state of the tool/tool radius	7	Quazi and Shaikh (2012), Hambli (2002b) Makich <i>et al.</i> (2008), Khadke <i>et al.</i> (2004), Totre <i>et al.</i> (2013), Sandwkar and Chandgude (2012) and Taupin <i>et al.</i> (1996)
Punch/die size/geometry	3	Maiti <i>et al.</i> (2000), Totre <i>et al.</i> (2013) and Nishad <i>et al.</i> (2013)
Friction	2	Maiti <i>et al.</i> (2000) and Nishad <i>et al.</i> (2013)
Layout	2	Maiti <i>et al.</i> (2000) and Nishad <i>et al.</i> (2013)
Blank holder force	2	Nishad <i>et al.</i> (2013) and Al-Momania and Rawabdeh (2008)
Punch speed	2	Goijaerts <i>et al.</i> (2002) and Nishad <i>et al.</i> (2013)
Punch-die alignment	1	Nishad <i>et al.</i> (2013)
Cutting angle	1	Khadke <i>et al.</i> (2004)

short circuits. To address this problem, several deburring methods have been introduced, including ultrasonic, magnetic abrasive, abrasive jet and electrochemical machining methods. However, these methods all have some shortcomings, such as mechanical damage, over-machining, changes in the material properties of the finished surface, sharp edge blunting and the requirement for subsequent processing

to remove chemical residues (Aurich *et al.*, 2009; Gillespie, 1979).

BURR FREE TECHNOLOGY

Recently researchers are striving to suggest the most reliable burr free technology to be used. Burr free can be described as producing blanked or punched part

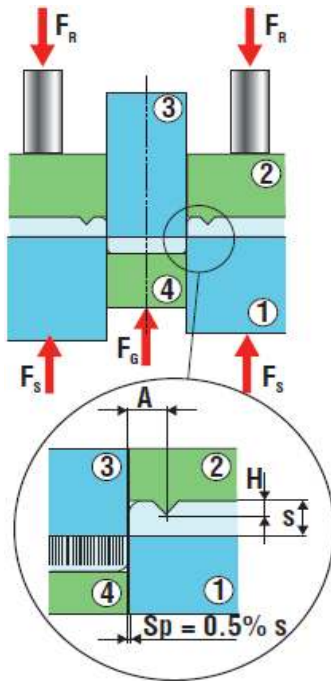


Fig. 4: Concept of counter blanking developed by Altan (2007)

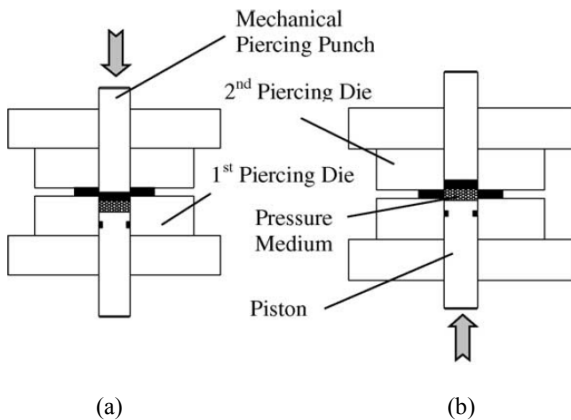


Fig. 5: Schematics of hydro-mechanical punching, (a) mechanical half piercing, (b) hydro counter punching (Aoki and Sasada, 2004)

without burr or at very minimal level. There numbers of methods proposed in achieving burr free in their blanking process. Wisselink *et al.* (2009) have successfully modeled the two steps burr free blanking process using LS-Dyna. Wang (2011) employed a cam technology in achieving fine blanking process. Counter blank is another effective to achieve fine blanking or blanked free from burr. Conventional for blanking process, only die, guide plate and punch are involve, but to carried out counter blanking steps, additional mechanism requires actuating the tools. In fine blanking, Altan (2007) proposed a new design of tooling that consist of an ejector or counterpunch and a

V-ring (4 and 2, respectively, in Fig. 4) are used. The main purpose of these tool components is to generate compressive stresses and hold the material against horizontal movement. Three forces, V-ring Force (F_R), counterforce (F_G) and blanking Force (F_S) act on the blank. In general, this operation is carried out on triple-action hydraulic presses on which the punch, guide plate and die movements are controlled individually. Forces in fine blanking have great influence on a part's quality. During the beginning of the process, F_R and F_G are applied. These forces provide a firm clamp on the material before blanking begins. F_S acts when the press moves down and completes the blanking operation.

Kim *et al.* (2005) utilized pressure by specially designed hydro actuated punching to achieve fine blanking without burr. The mechanism involves half piercing and counter hydro punching. The hydro-mechanical punching applies pressure medium in the place of counter punch. Figure 5 shows the schematics of hydro-mechanical punching. The exerted high pressure would increase hydrostatic pressure in shearing zone of the workpiece, which help delay fracture initiation. Then, the clean sheared surface is expected by postponing the fracture. In other case, Aoki and Masada (2004) employed a piezoelectric actuator to drive the counter punch mechanism and they successfully carried blanking process with burr-free on thin copper foil.

Another challenge is the measurement of the burr. The use of contact measurement may damage the burr. Hambli (2002a) predicted the height of burr using neural network. Makich *et al.* (2008) obtained the profile of the burr using 3D surface measurement method namely Alicona system and they managed to formula the relationship between the burr and the wear.

CONCLUSION

In conclusion, after carried out comprehensive literature, there are few observations that can be made:

- Most of studies are preferring experiment investigation as their methodology.
- Furthermore, die clearance and material properties are the most influential process/design parameters that may cause to the formation of burr.
- Recent demand on micro-blanking with burr-free becomes a major challenge to the manufacturer.
- Present discoveries on development of a method of producing burr-free technology using counter blanking process gives hope but the mechanism is still difficult to be used for mass production at lower cost.
- As the burr become very small, another challenge is on measurement of the burr, as the conventional contact may damage the burr during measurement.

- Most of the blanking and punching were carried out on metal. None of the literature discuss on application of the processes to the non-metal material such as composites, which has been widely used in various industries. Typically holes are produced using drilling, but the process is time consuming. Therefore, punching that is faster than drilling has good potential to be applied on composite to produce hole. The challenge is mainly on determination of the optimal process and design parameters to perform precision hole punching.

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