Faculty of Manufacturing Engineering

AN APPROACH TO BURR FREE PRECISION METAL STAMPING

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DECLARATION

I declare that the thesis entitle "An Approach to Burr Free Precision Metal Stamping" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……

Name : Boey Kok Hoong

Date : 5 August 2020

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Engineering.

Signature : ..……..

Supervisor Name : Prof. Datuk Ts. Dr. Mohd Razali Bin Muhamad

Date : 5 August 2020

DEDICATION

I dedicate my research work to my beloved parents for their support. I am taking this opportunity to dedicate this work to my loving wife and daughter, who have given me the everlasting momentum to pursue my Engineering Doctorate and endless supports to complete my thesis. Not forgetting also to dedicate this work to my family members, colleagues and many friends who have rendered supports to me throughout the research process. I will always appreciate all their efforts. Without their supports, this work would not have been made possible.

ABSTRACT

The research study presented in this thesis is to evaluate the approach of burr-free in precision metal stamping. The primary process of the metal stamping always start from the metal separation process which may include the blanking operation and the piercing operation. These operations are to produce a cut-off blank of the intended geometry. The rationale of the inability to produce a burr-free blank lies on the understanding that burrs are the function of material's ductility. The increasing popularity of the six sigma philosophy among original equipment manufacturers also has forced all metal components manufacturers to take in an interest in what most previously have considered unimportant – the burr edge. Now they must adjust their thinking to view burrs as a source of variation that can have adverse effects on product quality aside from added cost in the attempt to remove them. This formed a concrete motivation platform to continue and pursue on this research to derive a Burr-Free Technology (BFT) tool for a blanking operation gearing towards burr-free blank in one operation of the stamping process. Commercial package of LS-DYNA was used for the finite element modelling on blanking operation. The concluded numerical model was further validated with the experimental samples. The agreable numerical model was used to evaluate the potential inputs factors such as punch-die clearances, punch and die plate corner radius and the blanking load to the shear edge geometries such as die roll parameter, smooth shear zone parameter, the fracture initiation point and the fracture propagation patterns. The results obtained were used as a foundation for the BFT blanking tool design and fabrication. The fabricated BFT blanking tool was run under normal mass production mode to evaluate the effectiveness of the burr-free characteristic on the 1.0mm thick, JIS G3313 SECC work material. All experimental studies by BFT concept was performed under the conventional air clutch power press with the capacity of 110 ton. The presence of die rolls on edges at both planes of the blank signifies the onset of burr-free characteristic. The burr-free blanks finally was concluded with the BFT blanking tool structure on the case of lower punch protrude of 0.7mm with the correct pairing of positive clearances of 5% on upper punch and lower die and a negative clearance for lower punch and upper die. Aside, the optimum spring loads used for the upper die and lower punch forms an important parameter to the success of the burr-free blanking operation. The output of this BFT parameters produced the most desirable outputs in terms of the edge quality on burr-free blank. This was validated statistically through ANOVA method on the variance of the produced die rolls.

PENDEKATAN BEBAS GERIGI KETEPATAN HENTAKAN LOGAM

ABSTRAK

Kajian penyelidikan yang dibentangkan dalam tesis ini adalah untuk menilai pendekatan bebas gerigi ketepatan hentakan logam. Proses utama ketepatan hentakan logam ini selalu bermula dari proses pemisahan logam termasuk operasi pemotongan lembaran logam dan operasi pelubangan. Operasi-operasi ini adalah untuk menghasilkan geometri sampel yang dikehendaki. Rasional ketidakupayaan untuk menghasilkan sampel yang bebas gerigi terletak pada pemahaman bahawa gerigi adalah fungsi kemuluran bahan logam dan semua logam mempunyai faktor keanjalan. Popularity yang semakin meningkat mengenai falsafah enam sigma di antara pengeluar peralatan asal juga memaksa pembekal komponen logam untuk mengambil perhatian dalam kes yang sebelum ini dianggap tidak penting – gerigi sisi. Kini kilang pembuatan perlu menyesuaikan pemikiran masing-masing untuk melihat gerigi sebagai sumber sampingan yang boleh memberi kesan buruk kepada kualiti produk selain dari kos tambahan dalam usaha untuk menghapuskannya. Ini membentuk satu platform motivasi yang kukuh untuk meneruskan kajian ini dalam menghasilkan acuan bebas gerigi (BFT) bagi operasi pemotongan lembaran logam ke arah sampel bebas gerigi dalam operasi hentakan tunggal. Pakej komersial LS-Dyna digunakan untuk pemodelan unsur terhingga mengenai operasi hentakan lembaran logam. Hasilan model berangka dari unsur terhingga akan disahkan hubung-kaitnya dengan sampel ujikaji. Model berangka akhir akan digunakan untuk menilai potensi faktor-faktor input seperti kelegaan acuan dan sudut jejari acuan kepada geometri planar ricih seperti parameter die rol, zon licin planar ricih, titik permulaan retakan dan polar retakan. Keputusan yang diperolehi akan digunakan sebagai asas untuk reka bentuk dan fabrikasi acuan bebas gerigi (BFT). Acuan bebas gerigi ini akan beroperasi di bawah mod pembuatan komersial untuk menilai keberkesanan ciri bebas gerigi pada sampel dengan bahan mentah berketebalan 1.0mm atas gred JIS G3313 SECC. Semua kajian ujikaji dengan acuan konsep BFT akan beroperasi pada mesin penebukan konvensional jenis klac udara berkapasiti 110 ton. Proses pemotongan lembaran logam bebas gerigi mutlak dapat disimpulkan melalui struktur BFT pada kes penonjolan punch sebanyak 0.7mm. Kelegaan positif sebanyak 5% dikenakan pada punch atas dan die bawah, manakala kelegaan negatif dikenakan pada punch bawah dan die atas. Pemilihan bebanan spring yang optimum diperlukan pada die atas dan punch bawah untuk memastikan kejayaan hasilan acuan bebas gerigi. Keluaran dari parameter BFT yang disimpulkan berupaya menghasilkan sampel yang paling wajar dari segi kualiti sisi yang bebas gerigi. Ini telah disahkan secara statistik melalui kaedah ANOVA megenai varian die rol yang dihasilkan.

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LIST OF ABBREVIATIONS

MEMS	-	Micro electro mechanical system
UL	-	Underwriters Laboratories
BFT	-	Burr-free technology
JIS	-	Japanese industrial standards
ANOVA	-	Analysis of variance
FEA	-	Finite element analysis
pp	-	Lower punch protrusion
UTM	-	Universal testing machine
WEDM	-	Wire electro discharge machine
VMM	-	Video measuring machine
FS	-	Static coefficient of friction
FE	-	Finite element
FD	-	Dynamic coefficient of friction
DR	-	Die roll
SSZ	-	Smooth shear zone

LIST OF PUBLICATION

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CHAPTER 1

INTRODUCTION

1.1 Background

Precision metal stamping processes form an important integral in many manufacturing based industries. The main characteristic of placing metal stamping parts as preference from other metal related manufacturing modes is due to its competitive process cost and its productivity (Gronostajski, 2019). Nevertheless, there exist some constraints in terms of its sharp cutting edges or commonly refers as burr edge condition. Burr is the surplus residue of the sheet metal cutting operation. Extensive studies had been performed in minimizing the burr condition as they are very costly to be fully eliminated even by high end secondary de-burring processes. Metal stamping process, being one of the oldest technologies in metal cutting industries is still being challenged to get rid of burr in one go, especially in stamping of thin sheet metal below 3.0mm. Many electronics, consumers and computer related parts with burr-free condition from one go of material separation process not only able to save money from the secondary de-burring processes, but also the extremely high amount of energy consumed by the respective secondary de-burring operating machines. On the other hand, for those Micro-Electro-Mechanical Systems (MEMS) with high number of tiny stamped parts within its assembly would work in greater precise operational performance and hence will be able to enhance product life span if they can be ensure of burr-free parts assembly.

1.2 Sheet metal blanking and piercing

In metal stamping processes, both the sheet metal blanking and piercing are types of material separation process. Both processes are using a set of well-designed punch and die to produce the desired geometry or blank (Choomlucksana, 2015). Blanking commonly refers to a process that produces a blank from the punched out geometry, whereas in piercing, the punched out geometry is the waste material or scrap. Both processes are being challenged by the occurrences of burr at the cutting edges. The physical property of metal both for ferrous and non-ferrous grades are carrying elasto-plastic nature. During the initial phase of blanking operation, the punch penetrates the elastic zone of the work material, therefore a die roll was formed at this stage. When the punch overcome the elasticity of the work material, pure shear will initiates throughout the entire elastic zone of the work material. A smooth shear zone will be formed at this phase. Crossing into the plastic zone of the work material, a ductile fracture begins. The further adjacent of the blanking punch towards the die causing a ductile fracture. The ductile fracture will further propagate to the oppose plane of the work material. The ductile fracture propagation will be ended with a burr edge. A set of well-maintained punch and die condition only will ensure the minimum burr condition which normally known as burr-less condition but not the burr-free. The edge condition of the blank is very much dependent on the condition of the sharpness of the interacting tool components – the punch and the die opening. Regular sharpening only able to ensure minimum burr occurrence that defined as less burr or burr-less condition. The wear on the punch or die opening will stimulates the occurrence of burrs (Fernandes et. al., 2017). The life of the punch and die can be extended through various approaches such as cryogenic treatment of the tool components, tribology approaches and many more (Gurnam *et. al.*, 2017). Attempts to remove burrs from stamped parts will incurred

additional unplanned cost and time spent. Hence, the presence of die roll on burr edge plane will enable the derivation of burr-free blank.

The global metal stamping market is valued at USD 133,500.00 Million and will be reaching USD 161,100.00 Million by end of year 2025. These industries are expected to grow at a Compound Annual Growth Rate (CAGR) of 2.4% during the period of year 2018 to year 2025 (GQYR, 2018). Technological innovations in the form of improved stamping processes have seen commercial usage in the recent past. In addition, regulatory policies aimed at process optimization, safety standard, lean processes and greener processes are imperative for shaping growth and sustainability of the metal stamping company.

Metal stamping industry is highly influenced by the consumption patterns of sheet metals in various end-use industries such as consumer electronics, telecommunications, automotive and others. As summarizes from the Political, Economic, Social and Technological (PESTEL) analysis conducted by Grand View Research (2017), it is reported that an emphasis was highlighted on potential enforcement on waste generation and disposability by the US Resource Conservation and Recovery act in metal stamping processes especially the post processes residual and pollutants from the secondary burr removal processes. This further driven an initiative to continue developing a more environmental friendly metal stamping processes among all the industries players. Major metal stamping processes are blanking or piercing, embossing, bending and coining. Among these key processes, the blanking and piercing dominated the global market in terms of share revenue. Figure 1.1 shows on the blanking and piercing taken a toll of 24.93% which followed by the embossing on 21.02% and others as the remaining populations (Technovio Research, 2017). The main obstacle in blanking or piercing processes is the occurrences of burr and control of its cutting edge quality.

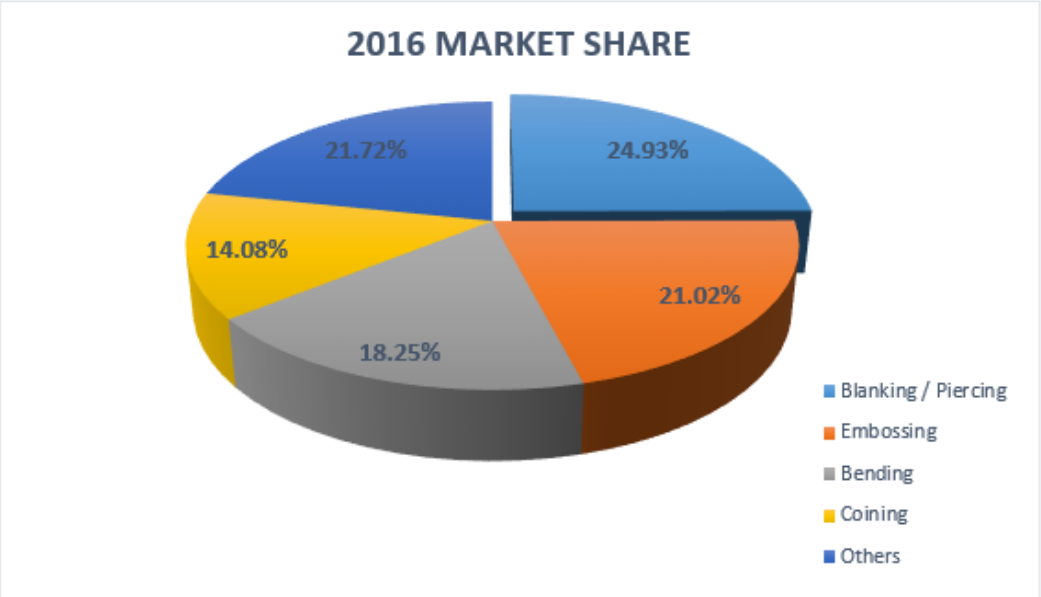

Figure 1.1: Metal Stamping Market Share by Process (courtesy of Business Wire)

1.3 Problem statement

The ideal case is to derive an absolute burr-free parts in one go of the blanking or piercing operations in precision metal stamping process. This will eliminate the needs of removing any potential burr or sharp edges resulting from the above material separation processes by any forms of secondary de-burring processes, either by mechanical tumbling, chemical de-burring or even by high end laser sharp edge removal processes.

Even though lots of studies have been done in this area, but all the attempts are geared towards quantifying or findings the solutions of minimizing the burr condition. All these efforts are confined in producing burr-less instead of burr-free parts. The UL 1439 (Underwriters Laboratories, 2004) are the common standard used in accepting the burr condition in industries.

The consequences from the burr existence, the stamped parts need to undergo secondary de-burring process which eventually incurred added process cost, higher defect rate due to additional part handling and longer processing lead time.