OPTIMIZATION OF PROCESS PARAMETERS IN SHEET METAL FORMING BY USING TAGUCHI METHOD

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SUPERVISOR DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :
Name :
ID Number :
Date :

Dedicated to my beloved father, mother,

sister, and brothers

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ABSTRACT

Sheet metal is one of the most important semi finished products used in the steel industry, and sheet metal forming technology is therefore an important engineering discipline within the area of mechanical engineering. The development of new sheet metal forming processes, tooling and so on has up till now to a large extent been based on experience, rules of thumb and trial-error experiments without or with only little use of scientifically based engineering methods. As mentioned above, experience is not enough, and trial-error experiments are very expensive with regard to both money and time. There is therefore great need for the development of both theoretical and experimental engineering methods. In this case, Taguchi method was selected to design of experiment using the statistica software version 7 which enables the problems to be tackled effectively; the punching process has been chosen to form the sheet metal. The objective of the project is to determine the optimize parameters. The parameters to be considered in this study are punching tonnage, the sheet thickness, the sheet length and the sheet width.

ABSTRAK

Kepingan logam adalah salah satu sebahagian produk siap yang penting yang digunakan dalam industri keluli dan kerana itu teknologi pembentukkan kepingan logam merupakan salah satu disiplin dalam bidang kejuruteraan mekanikal. Pembangunan dalam proses pembentukkan kepingan logam, alatan dan lain-lain sehingga sekarang adalah semakin meluas berdasarkan pengalaman, peraturan ibu jari dan eksperimen cuba jaya tanpa atau dengan hanya sedikit sahaja penggunaan saintifik berdasarkan kaedah kejuruteraan. Sebagaimana diberitahu di atas, pengalaman sahaja tidak mencukupi, dan eksperimen cuba jaya adalah terlalu mahal dan ini membazirkan duit dan masa. Oleh yang demikian, keperluan yang besar untuk pembangunan termasuk kedua - dua kaedah kejuruteraan iaitu teoritikal dan eksperimen. Dalam kes ini, kaedah Taguchi telah dipilih untuk mereka eksperimen dengan menggunakan perisian STATISTICA versi 7 yang mana membolehkan masalah dapat diselesaikan dengan secara berkesan. Proses tumbukan (punching) telah dipilih untuk membentuk kepingan logam. Objektif projek ini ialah untuk mengenal pasti parameter-parameter yang terbaik dalam proses tumbukan (punching). Parameter-parameter yang dipertimbangkan dalam kajian ini adalah daya tumbukan, ketebalan kepingan, panjang kepingan, dan lebar kepingan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background

Sheet metal is one of the most important semi finished products used in the steel industry, and sheet metal forming technology is therefore an important engineering discipline within the area of mechanical engineering.

Sheet metal is an "old" material, and one could be tempted to believe, that all the necessary knowledge and methods within the area of sheet metal forming have been established to such a degree, that no further research in this area is required. This is not so, on the contrary, research in this area is of high demand and this is partly due to during the last decade, there has been a tremendous development of sheet materials and sheet forming technology. A large number of new sheet qualities, for example HSLA-steel and pre-coated steel, have come into the market place. These new sheet materials have other properties, example higher strength and more ductility, than conventional sheet steel, and have therefore to be worked differently. The experience with the forming of conventional sheet steel can only partly be transferred to the forming of the new sheet steel types. There is therefore a great need for research regarding how these new sheet steels behave in different forming processes in order to be able to fully utilize these new improved sheet steels.

The development of new sheet metal forming processes, tooling and so on has up till now to a large extent been based on experience, rules of thumb and trial-error experiments without or with only little use of scientifically based engineering methods. As mentioned above, experience is not enough, and trial-error experiments are very expensive with regard to both money and time. There is therefore great need for the development of both theoretical and experimental engineering methods which enable the problems to be tackled effectively; this is necessary to reduce production cost and to reduce the lead time between design and production.

The demands required from the sheet metal processes are increasing both with regard to the tolerance requirements of the finished part and with regard to the complexity (example near net shape forming). To meet these requirements, a detailed knowledge about the material properties, the friction conditions and the forming process is needed. This knowledge can only be obtained by using advanced theoretical and experimental engineering methods.

1.2 Problem Statements

Sheet metal forming is a major fabrication process in many sectors of industry. Throughout the years, technological advances have allowed the production of extremely complex parts. Sheet metal forming refers to various processes used to convert sheet metal into different shapes for a large variety of finished parts such as aluminum cans and automobile body panels. So, the optimize parameters in machines such as punching process in sheet metal forming must be to determine to get the optimal value. So that the production rate can be increased without increase the cost operation and reduce the cycle time. Then, the manufacturer can get the high demand and more profitable.

1.3 Objective

There are 2 main objectives in this study:

(a) To determine the optimize parameters in punching process.

(b) To analyze the parameters by using Taguchi Method.

1.4 Scope of Study

The scope of study is divided in three sections:

(a) Process parameters,

(b) Sheet metal forming and,

(c) Taguchi method.

1.5 Taguchi Designs

Genichi Taguchi, a Japanese engineer, proposed several approaches to experimental designs that are sometimes called "Taguchi Methods." Taguchi proposed several approaches to experimental designs called Taguchi method This method utilizes an orthogonal array, which is a form of fractional factorial design containing a representative set of all possible combination of experimental conditions. Using Taguchi method, a balanced comparison of levels of the process parameters and significant reduction in the total number of required simulations can both be achieved.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Products made by sheet-metal forming processes are around us. They include metal desks, file cabinets, appliances, car bodies, aircraft fuselages, and beverage cans. Sheet forming dates back to 5000 B.C, when household utensils and jewelry were made by hammering and stamping gold, silver and copper.

Compared to those made by casting and by forging, sheet-metal parts offer the advantages of light weight and versatile shape. Because of its low cost and generally good strength and formability characteristics, low-carbon steel is the most commonly used sheet metal. For aircraft and aerospace application, the common sheet materials are aluminum and titanium.

There are 2 stages of sheet metal processes consist:

- Cutting the large rolled sheets and,
- Further processed into desired shape.

For such huge production volumes of the same part during long product life cycles, well-established forming methods enable a secure, cost-effective manufacturing of complex parts, compensating high investments in required complex tools and equipment as well as long preliminary development times until production [1] But the current market demand for individualization of products has activated research in the development of faster and cost-effective tool manufacturing techniques suitable for low production volumes.

This demand along with strong competition among several producers and the continuous reduction of product's life cycle requires a faster and cost-effective development of high quality products with high flexibility for design changes supporting the innovation imposed to those products [2].

As a result, sample parts, prototypes and low volume series parts have to be available at very short term.

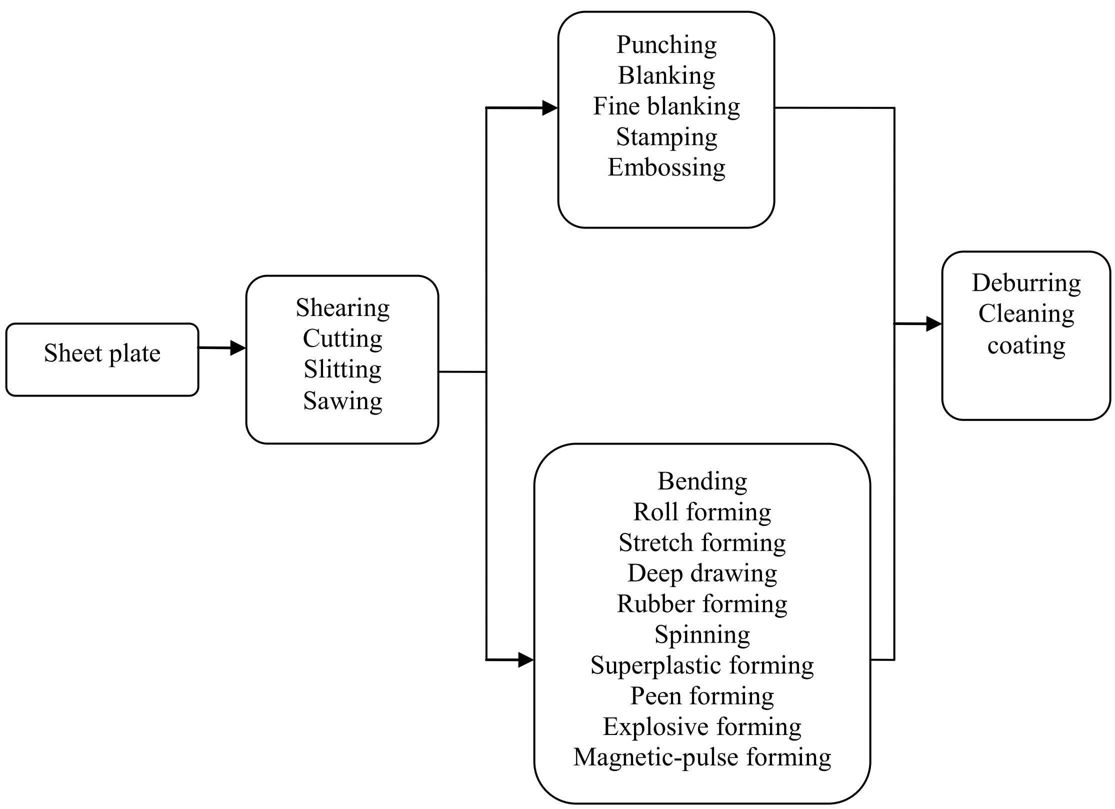


Figure 2.1: Outline of sheet-metal forming process

2.2 Sheet Metal forming

2.2.1 Sheet-metal working terminology

There are 3 main ideas about sheet-metal working terminology:

1. "Punch-and-die"
   - Tooling to perform cutting, bending, and drawing.
2. "Stamping press"
   - Machine tool that performs most sheet metal operations.
3. "Stampings"
   - Sheet metal products.

2.2.2 Three Major Categories of Sheet Metal Processes

The three main categories of sheet metal processes include:

1. Cutting
   - Shearing to separate large sheets; or cut part perimeters or make holes in sheets.
2. Bending
   - Straining sheet around a straight axis.
3. Drawing
   - Forming of sheet into convex or concave shapes.

The table 2.1 show that typically the characteristics of sheet-metal forming processes.

Table 2.1: Characteristics of Sheet-Metal Forming Processes

Process	Characteristics
Roll forming	• long parts with constant complex cross-sections; • good surface finish; • high production rates; • high tooling costs.
Stretch forming	• large parts with shallow contours; • suitable for low-quantity production; • high labor costs; • tooling and equipment costs
Drawing	• shallow or deep parts with relatively simple shapes; • high production rates; • high tooling and equipment costs.
Stamping	• includes a variety of operations, such as punching, embossing, bending, flanging, and coining; • simple or complex shapes formed at high production rates; • tooling and equipment costs can be high, but labor cost is low.
Rubber forming	• drawing and embossing of simple or complex shapes; • sheet surface protected by rubber membranes; • flexibility of operation; • low tooling costs.
Spinning	• small or large axisymmetric parts; • good surface finish; low tooling costs, but labor costs can be high unless operations are automated.

Source: Manufacturing and Engineering Technology

2.2.3 Sheet- metal characteristics and their formability

Some characteristics of sheet metal will effects on the overall manufacturing process and their characteristics are shown on table 2.2. The characteristics of metals are important in sheet-metal forming operations.

Table 2.2: Characteristics of Metals Important in Sheet-Forming Operations

Characteristics	**Importance**
Elongation	Determines the capability of the sheet metal to stretch without necking and failure.
Yield-point elongation	Typically observed with mild-steel sheets, flame like depressions on the sheet surface, can be eliminated by temper rolling but sheet must be formed within a certain time after rolling.
Anisotropy (planar)	Exhibits different behavior in different planar directions, present in cold-rolled sheets because of preferred orientation or mechanical fibering, causes caring in deep drawing, can be reduced or eliminated by annealing but at lowered strength.
Residual stresses	Typically caused by no uniform deformation during forming, results in part distortion when sectioned, can lead to stress-corrosion cracking, reduced or eliminated by stress relieving.
Springback	Due to elastic recovery of the plastically deformed sheet after unloading, causes distortion of part and loss of dimensional accuracy, can be controlled by techniques such as overbending and bottoming of the punch.
Wrinkling	Causes by compressive stresses in the plane of the sheet, can be objectionable, depending on its extent, can be useful in imparting stiffness to parts by increasing their section modulus, and can be controlled by proper tool and die design.

2.3 Taguchi method

2.3.1 Introduction to Taguchi Method

Genichi Taguchi (born January 1, 1924 in Tokamachi, Japan) is an engineer and statistician. Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods and, more recently, to biotechnology, [3] marketing and advertising.

2.3.2 Description of the Taguchi method

Taguchi is the developer of the Taguchi method [4]. He proposed that engineering optimization of a process or product should be carried out in a three-step approach:

- system design,
- parameter design, and
- tolerance design.

In system design, the engineer applies scientific and engineering knowledge to produce a basic functional prototype design, this design including the product design stage and the process design stage. In the product design stage, the selection of materials, components, tentative product parameter values, etc., are involved. As to the process design stage, the analysis of processing sequences, the selections of production equipment, tentative process parameter values, etc., are involved. Since system design is an initial functional design, it may be far from optimum in terms of quality and cost.

Following on from system design is parameter design. The objective of parameter design is to optimize the settings of the process parameter values for improving quality characteristics and to identify the product parameter values under the optimal process parameter values. In addition, it is expected that the optimal process parameter values obtained from parameter design are insensitive to variation in the environmental conditions and other noise factors.

Finally, tolerance design is used to determine and analyze tolerances around the optimal settings recommend by the parameter design. Tolerance design is required if the reduced variation obtained by the parameter design does not meet the required performance, and involves tightening tolerances on the product parameters or process parameters for which variations result in a large negative influence on the required product performance. Typically, tightening tolerances means purchasing better-grade materials, components, or machinery, which increases cost.

However based on the above discussion, parameter design is the key step in the Taguchi method to achieving high quality without increasing cost. Basically, experimental design methods [5]were developed originally by Fisher [6]. However, classical experimental design methods are too complex and not easy to use.

Furthermore, a large number of experiments have to be carried out when the number of the process parameters increases. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. The experimental results are then transformed into a signal-to-noise (S/N) ratio.

2.3.3 Taguchi Methods for Design of Experiments

Taguchi methods of experimental design provide a simple, efficient and systematic approach for the optimization of experimental designs for performance quality and cost. It has been proved successful to many manufacturing situations [7, 8, 9, 10, 11 and 12].

The traditional experimental design procedures focus on the average product or process performance characteristics. But the Taguchi method concentrates on the effect of variation on the product or process quality characteristics rather than on its averages [13and 14]. That is, the Taguchi's approach makes the product or process performance insensitive (robust) to variation to uncontrolled or noise factors. Taguchi recommends that this can be done by the proper design of parameters during the 'parameter design' phase of off-line quality control. He designed certain standard orthogonal arrays (OAs) by which simultaneous and independent evaluation of two or more parameters for their ability to affect the variability of a particular product or process characteristic can be done in a minimum number of tests. Subsequently, decision is made for the optimum combination of these parameters.

The parameter design phase of the Taguchi method generally includes the following steps:

(1) identify the objective of the experiment;
(2) identify the quality characteristic (performance measure) and its measurement systems;
(3) identify the factors that may influence the quality characteristic, their levels and possible interactions;
(4) select the appropriate OA and assign the factors at their levels to the OA;
(5) conduct the test described by the trials in the OA;
(6) analysis of the experimental data using the signal-to-noise (S/N) ratio, factor effects and the ANOVA (analysis of variance) to see which factors are statistically significant and find the optimum levels of factors;
(7) verification of the optimal design parameters through confirmation experiment.

2.4 Conclusion

To summarize, the parameter design of the Taguchi method includes the following steps:

(1) identification of the quality characteristics and selection of design parameters to be evaluated;
(2) determination of the number of levels for the design parameters and possible interactions between the design parameters;
(3) selection of the appropriate orthogonal array and assignment of design parameters to the orthogonal array;
(4) conducting of the experiments based on the arrangement of the orthogonal array;
(5) analysis of the experimental results using the S/N and ANOVA analyses;
(6) selection of the optimal levels of design parameters; and
(7) verification of the optimal design parameters through the confirmation experiment.

Therefore, three objectives can be achieved through the parameter design of the Taguchi method:

(1) determination of the optimal design parameters for a process or a product;
(2) estimation of each design parameter to the contribution of the quality characteristics; and
(3) prediction of the quality characteristics based on the optimal design parameters.

2.5 STATISTICA (DESIGN OF EXPERIMENTS) VERSION 7

2.5.1 Introduction

STATISTICA Design of Experiments offers an extremely comprehensive selection of procedures to design and analyze the experimental designs used in industrial (quality) research: 2**(k-p) factorial designs with blocking (for over 100 factors, including unique, highly efficient search algorithms for finding minimum aberration and maximum unconfounding designs, where the user can specify the interaction effects of interest that are to be unconfounded), screening designs (for over 100 factors, including Plackett-Burman designs), 3**(k-p) factorial designs with blocking (including Box-Behnken designs), mixed-level designs, central composite (or response surface) designs (including small central composite designs), Latin square designs.

Taguchi robust design experiments via orthogonal arrays, mixture designs and triangular surfaces designs, vertices and centroids for constrained surfaces and mixtures, and *D*- and *A*-optimal designs for factorial designs, surfaces, and mixtures. The specific types of available designs, and methods for generating and analyzing them, are described in the following sections.

The content of the statistica software are:

- Design of Experiments
- Analysis of experiments: General features
- Residual analyses and transformations
- Optimization of single or multiple response variables: The response (desirability) profiler
- Standard two-level 2**(k-p) fractional factorial designs with blocks (Box-Hunter-Hunter minimum aberration designs).

- Minimum aberration and maximum unconfounding 2**(k-p) fractional factorial designs with blocks: General design search
- Screening (Plackett-Burman) designs
- Mixed-level factorial designs
- Three-level 3**(k-p) fractional factorial designs with blocks and Box-Behnken designs
- Central composite (response surface) designs
- Latin squares
- Taguchi robust design experiments
- Designs for mixtures and triangular graphs
- Designs for constrained surfaces and mixtures
- D- and A-optimal designs
- Alternative procedures for analyzing data collected in experiments

In this case of the experiment, the Taguchi robust design has been chosen to analysis of data. The analysis consists of two parts that is analysis of signal noise to ratios and analysis of the variance (ANOVA).

2.5.2 Taguchi Robust design

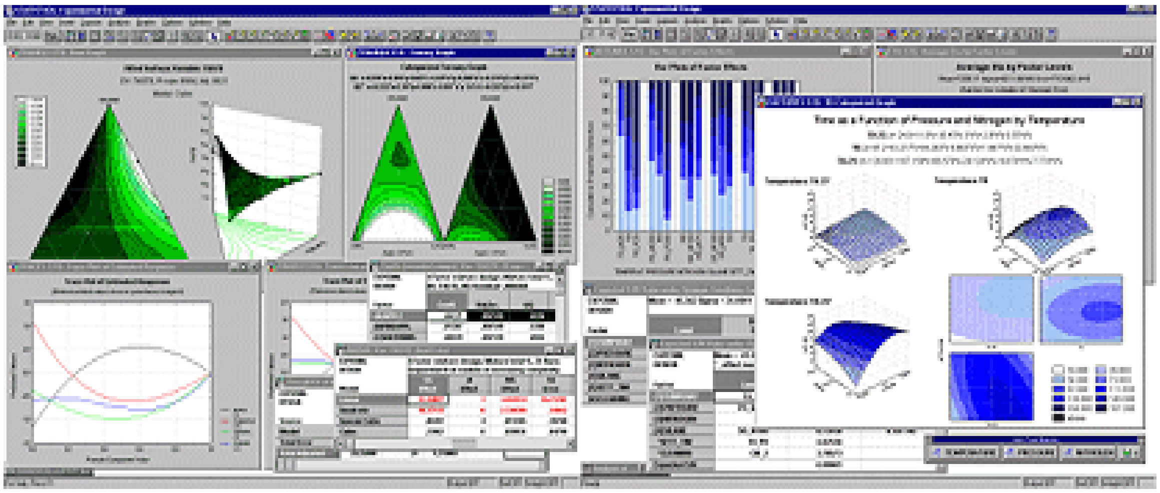


Figure 2.2: Taguchi robust design experiments.

STATISTICA Design of Experiments will generate orthogonal arrays for up to 31 factors; designs with up to 65 factors can be analyzed. As in all other types of designs, the runs of the experiment can be randomized, and the user can add blank columns to the Spreadsheet to generate convenient data entry forms. The user can also examine the aliases of two-way interactions.

STATISTICA Design of Experiments will automatically compute the standard signal-to-noise (S/N) ratios for problems of these types:

(1) Smaller-the-better,
(2) Nominal-the-best,
(3) Larger-the-better,
(4) Signed target,
(5) Fraction defective, and
(6) Number defective per interval (accumulation analysis).

In addition, untransformed data can also be analyzed; thus, the user can produce any type of customized S/N ratios via *STATISTICA Visual Basic* and analyze them with this procedure. In addition to comprehensive descriptive statistics, the user can review the computed S/N ratios. The full ANOVA results are displayed in an interactive Spreadsheet in which the user can "toggle" effects into or out of the error term. A similar interactive Spreadsheet allows the user to predict Eta (the S/N ratio) under optimum conditions, that is, settings of levels of factors. Again, the user can "toggle" effects into or out of the model, and specify particular levels for factors.

Finally, the means can be summarized in a standard main effect plot of Eta or signal to noise ratio by factor level; if an accumulation analysis on categorical data is performed, the results can be summarized in a stacked bar plot as well as line plots of the cumulative probabilities across categories for the levels of selected factors.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Taguchi method is a powerful tool for the design of a high-quality system. It provides not an efficient, but a systematic approach to optimize designs for performance and quality. Further, Taguchi parameter design can optimize the performance through the settings of design parameters and reduce the fluctuation of system performance to source of variation.

3.2 Process of Sheet- Metal forming

After consider the machine that has in the Ump mechanical lab, the punching process has been chosen to form the sheet metal. This is a machine that use of computer numerically controlled (CNC) punching machines which are used to make arrays of sheet metal parts directly from individual sheets. These machines usually have a range of punches available in rotating turrets and are referred to as turret presses. The method of operation is to first produce all of the internal part features in positions governed by the spacing of parts are then produced through punching with curved or rectangular punches or by profile cutting.

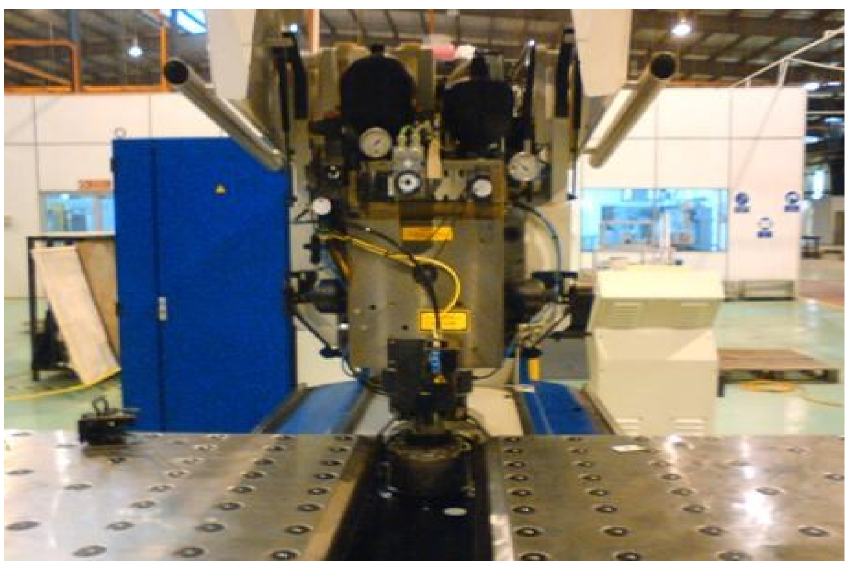
Figure 3.1: Example of the Parts of Product Produce by Punching Process

3.3 Equipment for Sheet-Metal forming

For most pressworking operations, the basic equipment consists of mechanical, hydraulic and pneumatic. The proper design, construction and stiffness of such equipment is essential to efficient operation, high production rate, good dimensional control, and high product quality.

Figure 3.2: Sheet-metal forming machine

Figure 3.3: The tool of sheet-metal forming machine



3.4 Taguchi Methodology

The steps to accomplish the Taguchi experimental design are:

(1) Identify the objective of the experiment;

- To determine the optimize parameters.

(2) identify the quality characteristic (performance measure) and its measurement systems;

- A large metal sheet placed onto press bed can thus slide easily to different positions between the two turret faces. This sliding is accomplished by gripping an edge of the sheet in two clamps which are attached to linear (X,Y) slideways. The turret is also controlled numerically so that while the sheet is moving to the next punching position, the turrets can be rotated to bring the desired punch and die into play.

(3) Identify the factors that may influence the quality characteristic, their levels and possible interactions;

- An exhaustive evaluation of the factors that could influence on the optimization of the quality characteristic was carried out. The main factors can be divided into two categories:
- control factors and,
- noise factors.

The table below shows the control factors and level that has been chosen.

Table 3.1: Control factors and levels

Symbol	Control factors	Level		
		1	**2**	**3**
A	Punching tonnage	1	2	3
B	Sheet thickness	1	2	3
C	Sheet length	1	2	3
D	Sheet width	1	2	3

(4) select the appropriate OA and assign the factors at their levels to the OA;

- Before selecting a particular OA to be used for conducting the experiments, the following two points must be considered:
- The number of parameters and interaction of interest.
- The number of levels for the parameters of interest.

Among the process parameters can only be studied if more than two levels of the parameters are used. Therefore, each parameter was analyzed at three levels. The number of process parameters and their level values are already decided and are given in 3.2. To limit the study, it was decided not to study the second order interaction among the parameters. Each three level parameter has 2 degrees of freedom (DOF) (number of level − 1), the total DOF required for four parameters, each at three levels is 8 [=4 × (3 − 1)]. As per Taguchi's method the total DOF of selected OA must be greater than or equal to the total DOF required for the experiment. So an L9 OA (a standard three-level OA) having 8 (=9 − 1) degrees of freedom was selected for the present analysis in table (3.2).

(5) conduct the test described by the trials in the OA;

This OA has four columns and nine experiment-runs. The four parameters at three levels can be assigned to these four columns.

Table 3.2: The L_9 (3^4) OA (parameters assigned) with response.

Experiment number	Parameter			
	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

(6) analysis of the experimental data using the signal-to-noise (S/N) ratio, factor effects and the ANOVA (analysis of variance) to see which factors are statistically significant and find the optimum levels of factors;

(7) verification of the optimal design parameters through confirmation experiment.

- This step (6) and (7) doing by statistica software to easy to get the value and the time to analysis the data is less compare to manually calculation.
- STATISTICA Design of Experiments will automatically compute the standard signal-to-noise (S/N) ratios.
- In addition, untransformed data can also be analyzed; thus, the user can produce any type of customized S/N ratios via STATISTICA Visual Basic and analyze them with this procedure. In addition to comprehensive descriptive statistics, the user can review the computed S/N ratios.
- The full ANOVA results are displayed in an interactive Spreadsheet in which the user can "toggle" effects into or out of the error term.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Design and Analysis of Punching Parameters

In this section, the use of an orthogonal array to reduce the number of punching experiments for design optimization of the punching parameters is reported. Results of the punching experiments are studied using the S/N and ANOVA analyses. Based on the results of the S/N and ANOVA analyses, optimal settings of the punching parameters for cycle time and cost operation are obtained and verified.

4.2 Orthogonal Array Experiment

To select an appropriate orthogonal array for the experiments, the total degrees of freedom need to be computed. The degrees of freedom are defined as the number of comparisons between design parameters that need to be made to determine which level is better and specifically how much better it is. For example, a three-level design parameter counts for two degrees of freedom. The degrees of freedom associated with the interaction between two design parameters are given by the product of the degrees of freedom for the two design parameters. In the present study, the interaction between the punching parameters is neglected. Therefore, there are eight degrees of freedom owing to there being four punching parameters in the punching operations.

Once the required degrees of freedom are known, the next step is to select an appropriate orthogonal array to fit the specific task. Basically, the degrees of freedom for the orthogonal array should be greater than or at least equal to those for the design parameters. In this study, an L9 orthogonal array with four columns and nine rows was used. This array has eight degrees of freedom and it can handle three-level design parameters. Each punching parameter is assigned to a column, nine cutting-parameter combinations being available. Therefore, only nine experiments are required to study the entire parameter space using the L9 orthogonal array. The experimental layout for the four punching parameters using the L9 orthogonal array is shown in table . Since the 1.L9 orthogonal array has four columns.

Table 4.1: L9 Orthogonal Array

Experiment num.	**A Punching tonnage**	**B The sheet thickness**	**C Sheet length**	**D Sheet width**
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 4.2: Control Factor and Their Level

Symbol	Control factors	Level		
		1	**2**	**3**
A	Punching tonnage, kN	1	2	3
B	The sheet thickness, mm	1	2	3
C	Sheet length, cm	1	2	3
D	Sheet width, cm	1	2	3

Table 4.3: Control Factor and Their Level Value

Symbol	Control factors	Level		
		1	**2**	**3**
A	Punching tonnage, kN	100	150	200
B	The sheet thickness, mm (al alloys)	0.41	3.025	5.64
C	Sheet length, L, cm	75	217.5	360
D	Sheet width, W, cm	75	97.5	120

Table 4.4: Factor and Levels with Unit

Factor	Level 1	Level 2	Level 3	unit
A Punching tonnage	100	150	200	kN
B The sheet thickness	0.41	3.025	5.64	mm
C Sheet length	75	217.5	360	cm
D Sheet width	75	97.5	120	cm

Table 4.5: Typical Turret Press Manufacturing Characteristics

Machine set up time	20 min
Loading plus unloading time per sheet	
One 750 x 750mm sheet	24s
One 1200 x 3600mm sheet	72s
Average speed between punching	0.5m/s
Nibbling speed	120 stroke/minute
Maximum form height	6mm
Machine rate, including programming costs	72$/h

If the time for sheet loading plus unloading is assumed to be proportional to the sheet perimeter, it can be expressed as:

- ti = 2.0+0.15(L+W)s
- where ti is the initial time

The equation of the turret press cycle time per part is:

- cycle time, t = 14.5+ ti/135, in seconds
- where 135 equal to maximum parts.

Then, the cost of turret press operations per part, using the machine rate of $72/hour,

- cost operation, C= t x (72%)/3600, in $

4.3 Analysis of the S/N Ratio

In the Taguchi method, the term `signal' represents the desirable value (mean) for the output characteristic and the term `noise' represents the undesirable value (S.D.) for the output characteristic. Therefore, the S/N ratio is the ratio of the mean to the S.D. Taguchi uses the S/N ratio to measure the quality characteristic deviating from the desired value. The S/N ratio η is defined as:

$$\eta = -10 \log (M.S.D \quad \ldots\ldots (4.1)$$

where M.S.D. is the mean-square deviation for the output characteristic.

As mentioned earlier, there are three categories of quality characteristics, i.e. the-lower-the-better, the-higher-the-better, and the-nominal-the-better. To obtain optimal punching performance, the- lower-the-better quality characteristic for cycle time must be taken. The mean-square deviation (M.S.D.) for the-higher-the-better quality characteristic can be expressed as:

$$\eta = -10 \log \left[\frac{1}{n} \sum_{i=1}^{n} y_i \right] \quad \ldots\ldots (4.2)$$

where η is the S/N ratio for the lower-the-better case, yi the measured quality characteristic for the i’th repetition, and n the number of repetitions in a trial.

Table 4.6 shows the results for cycle time and the corresponding S/N ratio. Since the experimental design is orthogonal, it is then possible to separate out the effect of each punching parameter at different levels. For example, the mean S/N ratio for the punching speed at levels 1, 2 and 3 can be calculated by averaging the S/N ratios for the experiments 1–3, 4–6, and 7–9, respectively. The mean S/N ratio for each level of the other punching parameters can be computed in the similar manner. The mean S/N ratio for each level of the punching parameters is summarized and called the S/N response table for cycle time (Table 7). In addition, the total mean S/N ratio for the nine experiments is also calculated. Fig.1 shows the S/N response graph for cycle time, the greater is the S/N ratio, the smaller is the variance of cycle time around the desired (the lower-the-better) value. However, the relative importance amongst the cutting parameters for cycle time still needs to be known so that optimal combinations of the cutting parameter levels can be determined more accurately. This will be discussed in the next section using the analysis of variance.

Table 4.6: Result for Cycle Time and S/N ratio

Set no	**A**	**B**	**C**	**D**	**Cycle time, s**	**S/N ratio(cycle time)**
1	1	1	1	1	14.68	-23.3345
2	1	2	2	2	14.86	-23.4404
3	1	3	3	3	15.05	-23.5507
4	2	1	2	3	14.9	-23.4637
5	2	2	3	1	15	-23.5218
6	2	3	1	2	14.71	-23.3523
7	3	1	3	2	15.02	-23.5334
8	3	2	1	3	14.73	-23.3641
9	3	3	2	1	14.84	-23.4287

Table 4.7: S/N ratio Response Table for Cycle Time

	Level	Means	Parameter Estimate	St.Dev.	St.Error
punching tonnage	100	-23.4419	0.001409	0.108112	0.14424
	150	-23.4459	-0.002650	0.086174	0.12878
	200	-23.4420	0.001241	0.085459	0.12824
sheet thickness	0.41	-23.4439	-0.000597	0.100913	0.13935
	3.025	-23.4421	0.001199	0.078899	0.12322
	5.64	-23.4439	-0.000602	0.100109	0.13880
sheet length	75	-23.3503	0.093008	0.014866	0.05348
	217.5	-23.4443	-0.000975	0.017844	0.05860
	360	-23.5353	-0.092033	0.014548	0.05291
sheet width	75	-23.4283	0.014943	0.093652	0.13425
	97.5	-23.4420	0.001275	0.090584	0.13203
	120	-23.4595	-0.016219	0.093409	0.13407

Average S/N Ratio by Factor Levels, Mean = -23.443 Sigma = .081292

Table 4.8: Different between Max and Min S/N ratio response for Cycle Time

Symbol	Punching parameter	Mean S/N ratio (dB)			
		Level 1	**Level 2**	**Level 3**	**Max-min**
A	Punching tonnage	-23.4419	-23.4459	-23.4420	0.004
B	The sheet thickness	-23.4439	-23.4421	-23.4421	0.002
C	Sheet length	-23.3503	-23.4443	-23.5353	0.094
D	Sheet width	-23.4283	-23.4420	-23.4595	0.031

The total mean S/N ratio=-23.443 dB. @ Sum of S/N ratio (from exp. 1-9) / 9

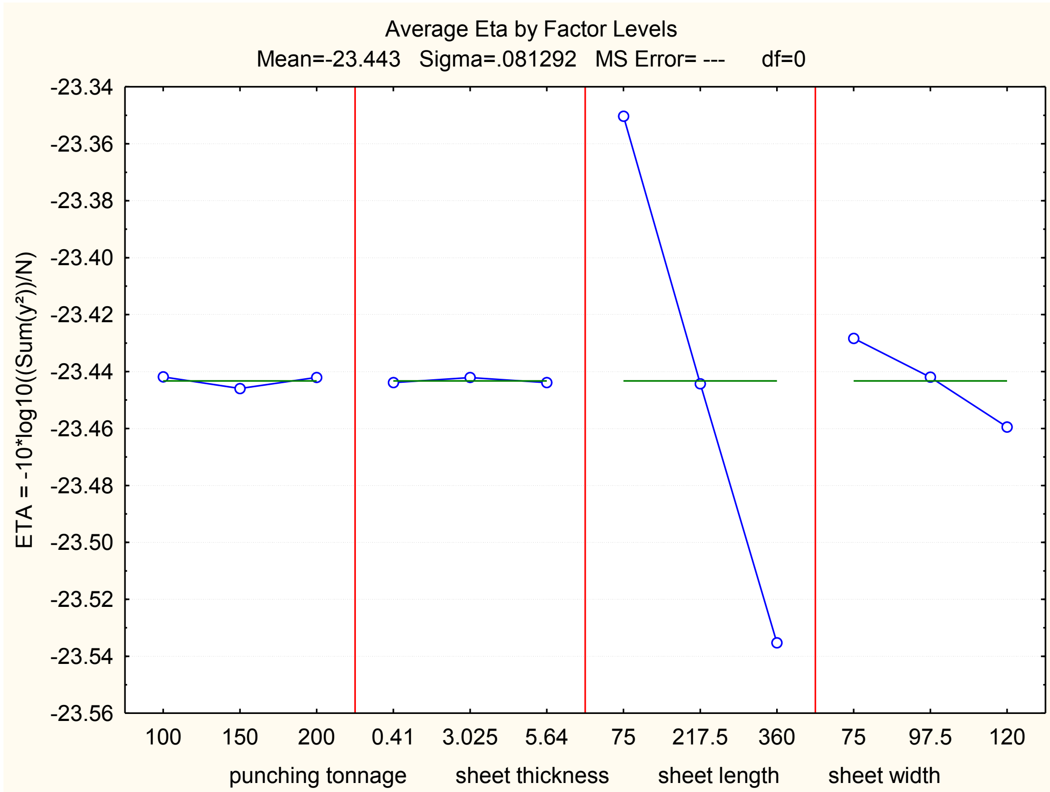


Figure 4.1: S/N ratios Graph for Cycle Time

On the other hand, the-lower-the-better quality characteristics for cost operation should be taken for obtaining optimal punching performance. The M.S.D. for the-lower-the-better quality characteristic can be expressed as:

$$\text{M.S.D.} = \frac{1}{M} \sum_{i=1}^{m} S_i^2 \qquad \text{....................................(4.3)}$$

*Si is the value of cost operation for the I th test.

The S/N response table and S/N response graph for cost operation are shown in Table 4.10 and Fig. 4.2. Regardless of the-lower-the-better of the-higher-the-better quality characteristic, the greater S/N ratio corresponds to the smaller variance of the output characteristic around the desired value.

Table 4.9: Average S/N ratio by Factor Level

	Level	**Means**	**Parameter Estimate**	**St.Dev.**	**St.Error**
punching tonnage	100	-29.4645	0.000098	0.102511	0.140458
	150	-29.4646	0.000001	0.089392	0.131162
	200	-29.4647	-0.000098	0.073458	0.118899
sheet thickness	0.41	-29.4646	0.000001	0.089392	0.131162
	3.025	-29.4647	-0.000098	0.073458	0.118899
	5.64	-29.4645	0.000098	0.102511	0.140458
sheet length	75	-29.3768	0.087788	0.017028	0.057246
	217.5	-29.4649	-0.000295	0.016856	0.056956
	360	-29.5521	-0.087494	0.016688	0.056671
sheet width	75	-29.4548	0.009733	0.087740	0.129944
	97.5	-29.4548	0.009733	0.087740	0.129944
	120	-29.4840	-0.019466	0.087445	0.129726

Table 4.10: Result for Cost Operation and S/N ratio

Set no	A	B	C	D	Cost operation, (cents)	S/N ratio(Db)
1	1	1	1	1	29.4	-29.3669
2	1	2	2	2	29.7	-29.4551
3	1	3	3	3	30.1	-29.5713
4	2	1	2	3	29.8	-29.4843
5	2	2	3	1	30	-29.5424
6	2	3	1	2	29.4	-29.3669
7	3	1	3	2	30	-29.5424
8	3	2	1	3	29.5	-29.3964
9	3	3	2	1	29.7	-29.4551

Table 4.11: The S/N response table (Max – Min) for Cost Operation

Symbol	Punching parameter	Mean S/N ratio (Db)			
		Level 1	Level 2	Level 3	Max-min
A	Punching tonnage	-29.4645	-29.7873	-29.7873	0.323
B	The sheet thickness	-29.7288	-29.5992	-29.7111	0.018
C	Sheet length	-29.7288	-29.5992	-29.7111	0.018
D	Sheet width	-29.4839	-29.8604	-29.6948	0.377

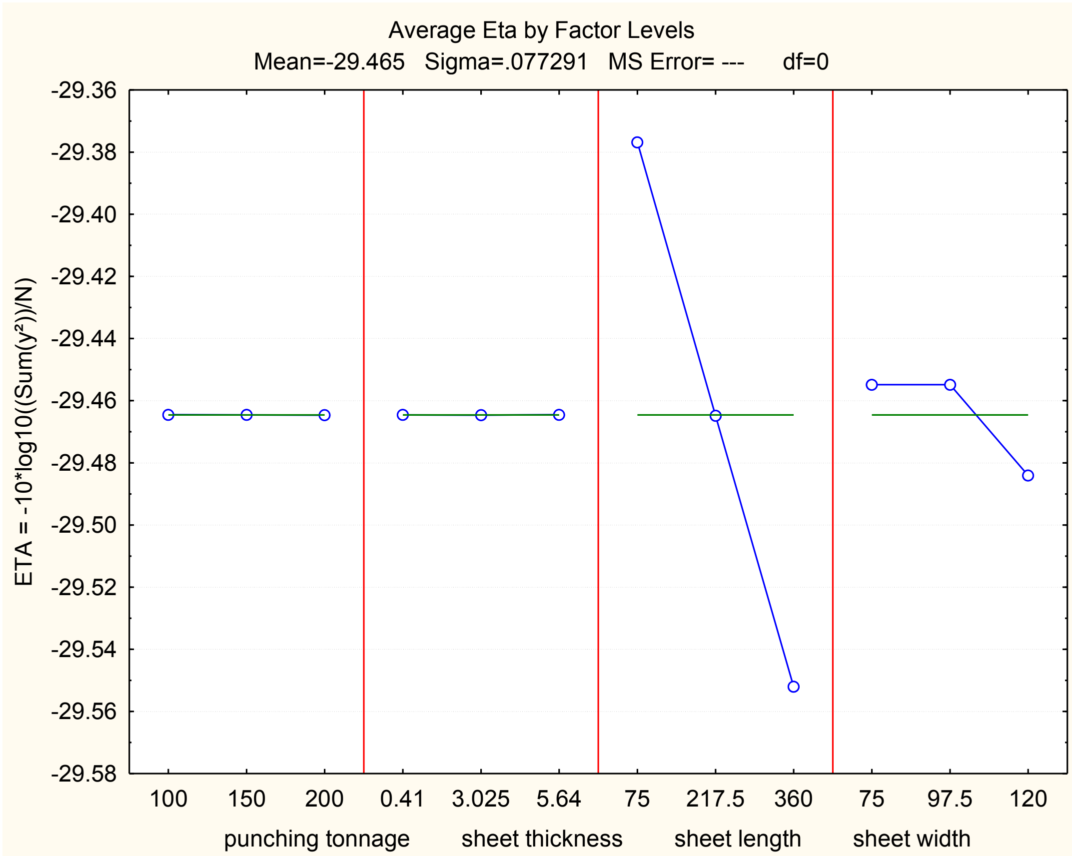


Figure 4.2: S/N ratios Graph for Cost Operation

4.4 Analysis of Variance (ANOVA)

The purpose of the analysis of variance (ANOVA) is to investigate which design parameters significantly affect the quality characteristic. This is to accomplished by separating the total variability of the S/N ratios, which is measured by the sum of the squared deviations from the total mean S/N ratio, into contributions by each of the design parameters and the error. First, the total sum of squared deviations SST from the total mean S/N ratio ηm can be calculated as:

$$SS_T = \sum_{i=1}^{n} (\eta_i - \eta_m)^2 \quad \text{.................................(4.4)}$$

where n is the number of experiments in the orthogonal array and ηi is the mean S/N ratio for the I th experiment.

The total sum of spared deviations SST is decomposed into two sources: the sum of squared deviations SSd due to each design parameter and the sum of squared error Sse. The percentage contribution ρ by each of the design parameters in the total sum of squared deviations SST is a ratio of the sum of squared deviations SSd due to each design parameter to the total sum of squared deviations SST.

Statistically, there is a tool called an F test named after Fisher [12]to see which design parameters have a significant effect on the quality characteristic. In performing the F test, the mean of squared deviations SSm due to each design parameter needs to be calculated. The mean of squared deviations SSm is equal to the sum of squared deviations SSd divided by the number of degrees of freedom associated with the design parameter. Then, the F value for each design parameter is simply the ratio of the mean of squared deviations SSm to the mean of squared error. Usually, when $F>4$, it means that the change of the design parameter has a significant effect on the quality characteristic.

Table 4.13 shows the results of ANOVA for cycle time. It can be found that the sheet lengths are the significant punching parameters for affecting cycle time. The change of the punching tonnage and sheet thickness in the range given in table 4.4 has an insignificant effect on cycle time. Therefore, based on the S/N and ANOVA analyses, the optimal punching parameters for cycle time are the punching tonnage at level 1, the sheet thickness at level 1, a the sheet length at level 1 and sheet width at level 1. Table 4.14 and 4.14 shows the results of ANOVA for cost operation. The sheet length and sheet width is most significant. However, the not contribution order of the punching parameters for cost operation is the sheet length and sheet width. The optimal cutting parameters for cost operation are the punching tonnage at level 2, the sheet thickness at level 3, the sheet length at level 1 and the sheet width at level 2 (set num.6) the sheet length and sheet width is more significant (if below 0.05).

Table 4.12: Results of the Analysis of Variance for Cycle Time

Analysis of Variance (Spreadsheet17) Mean = -23.443 Sigma = .081292					
	SS	**df**	**MS**	**F**	**p**
{1}punching tonnage	0.000032	2	0.000016		
{2}sheet thickness	0.000006	2	0.000003		
{3}sheet length	0.051365	2	0.025682		
{4}sheet width	0.001464	2	0.000732		
Residual		0			

Table 4.13: Results of the ANOVA for Cycle Time using Effect Pooled into Error term

Analysis of Variance (Spreadsheet17) Mean = -23.443 Sigma = .081292 * - effect pooled into error term					
	SS	**df**	**MS**	**F**	**p**
{1}punching tonnage	0.000032	2	0.000016	4.888	0.169828
*sheet thickness	0.000006	2			
{3}sheet length	0.051365	2	0.025682	7935.436	0.000126
{4}sheet width	0.001464	2	0.000732	226.164	0.004402
Residual	0.000006	2	0.000003		

- P=(significant) if <0.05 is significant

Table 4.14: Results of the Analysis of Variance for Cost Operation

Analysis of Variance (Spreadsheet1) Mean = -29.465 Sigma = .077291					
	SS	**df**	**MS**	**F**	**p**
{1}punching tonnage	0.000000	2	0.000000		
{2}sheet thickness	0.000000	2	0.000000		

{3}sheet length	0.046086	2	0.023043
{4}sheet width	0.001705	2	0.000853
Residual		0	

Table 4.15: Results of the ANOVA for Costs Operation using Effect Pooled into Error Term

Analysis of Variance (Spreadsheet1) Mean = -29.465 Sigma = .077291 * - effect pooled into error term					
	SS	**df**	**MS**	**F**	**p**
*punching tonnage	0.000000	2			
*sheet thickness	0.000000	2			
{3}sheet length	0.046086	2	0.023043	797320.7	0.000000
{4}sheet width	0.001705	2	0.000853	29499.0	0.000000
Residual	0.000000	4	0.000000		

4.5 Confirmation Test

Table 4.16: Results of Confirmation Tests For Cycle Time

	Initial punching parameter	**Optimal punching parameters**
Level	A2B2C3D1	A1B1C1D1
Cycle time, s	15	14.68
S/N ratio	-23.5218	-23.3345

- Improvement of S/N ratio = -0.1873 dB
- The cycle time decrease 1.021 times

  The estimated S/N ratio using the optimal level of the design parameters can be calculated as:

$$\hat{\eta} = \eta_m + \sum_{i=1}^{o} (\bar{\eta}_i - \eta_m)$$ **……………………….(4.3)**

where ηm is the total mean S/N ratio,ῆί at the optimal level, and *o* is the number of the main design parameters that affect the quality characteristic.

- Estimate S/N ratio = -23.226 dB , optimal level = -23.3345dB

Table 4.17: Results of Confirmation Tests for Cost Operation

	Initial punching parameters	**Optimal punching parameters**
Level	A2B2C3D1	A2B3C1D2
Cost operation, cent	30	29.4
S/N ratio(dB)	-29.5424	-29.3669

- Improvement S/N ratio = -0.1755 dB
- Cost operation decrease 1.02 times
- Estimate S/N ratio = -29.2693 ,
- Optimal S/N = -29.3669

CHAPTER 5

CONCLUSION

5.1 Conclusion

As a conclusion, this paper has discussed an application of the Taguchi method for optimizing the punching parameters in sheet metal forming operations. As shown in this study, the Taguchi method provides a systematic and efficient methodology for the design optimization of the punching parameters with far less effect than would be required for most optimization techniques. It has been shown that cycle time and cost operation can be improved significantly for punching operations. After using analysis with the S/N ratio, note that the optimum level fir cycle time is set experiment number 1 that is the punching tonnage at level 1, the sheet thickness at level 1, sheet length at level 2 and also sheet width at level 1. For the cost operation, the optimum value is set number 1 or 6. when using the ANOVA, note that in the term of cycle time, the sheet length is most significant parameter or most effected the cycle time follow by sheet width and sheet thickness. In the cost operation after using ANOVA, the most significant parameter is sheet length and sheet width that is has the same value (0.0000). So, when below 0.05, the parameters are most significant. All the analysis of the data is calculate by using statistica software version 7. It more efficient and easy to use compare to the manual analysis. It also can reduce the time to analyze the data

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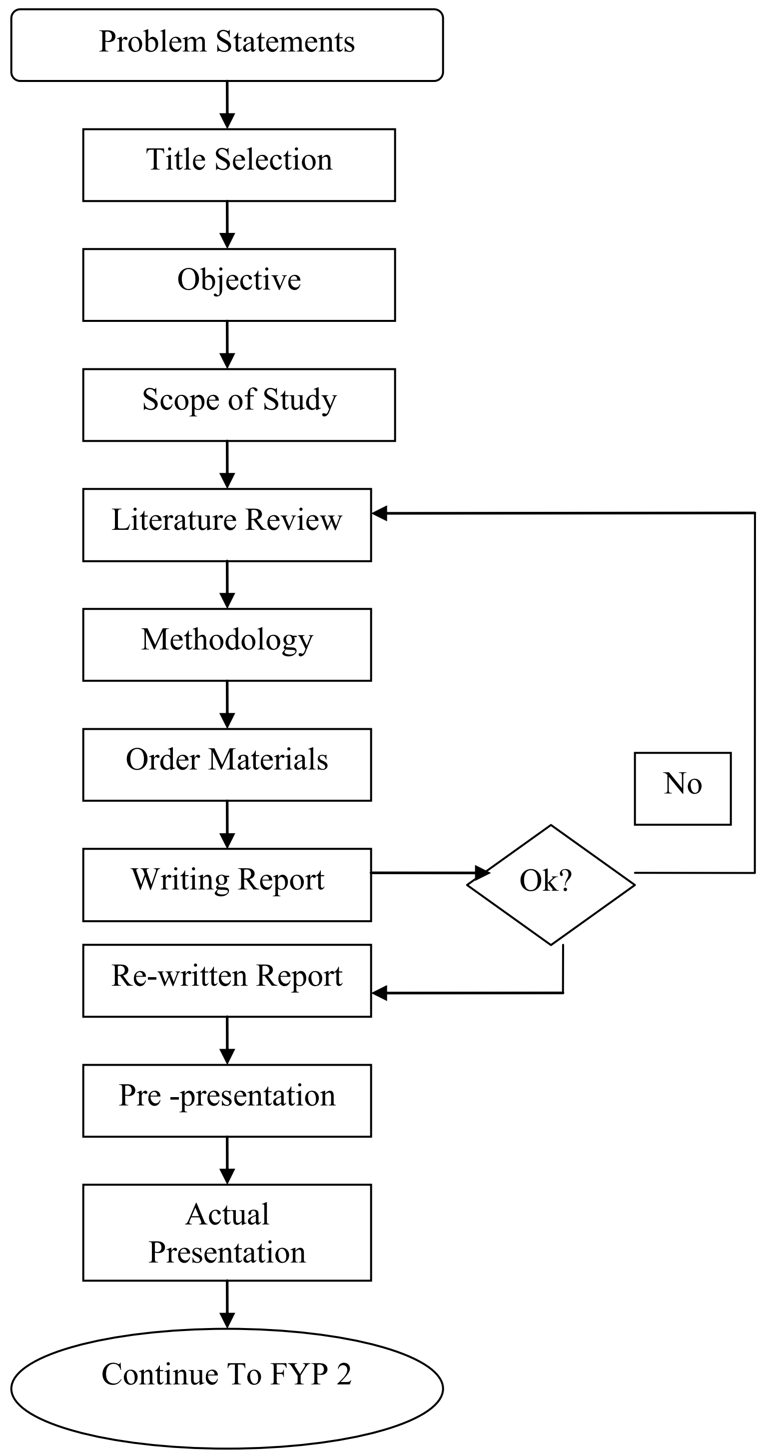
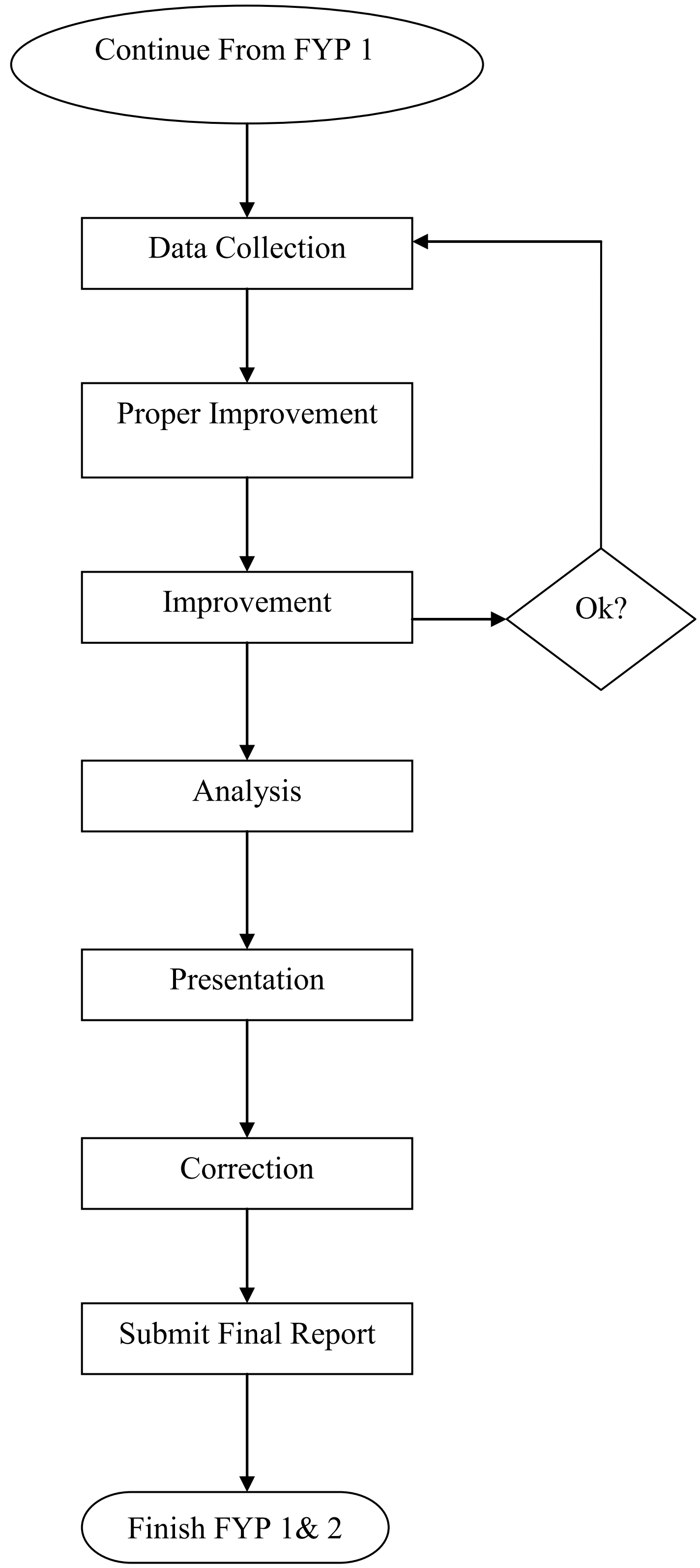
APPENDICES

FLOW CHART FYP 1



FLOW CHART FYP 2



GANTT CHART/PROJECT SCHEDULE FOR FYP 1

GANTT CHART / PROJECT SCHEDULE FOR FYP 1

PROJECT ACTIVITIES	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Propose the FYP title	■														
Recognize the objective & scope of study		■													
Present to supervisor			■												
Create the Gantt chart & flow chart				■											
Find the information about the title					■										
Literature review						■	■								
Last update literature review								■	■						
Perform methodology										■					
Order materials											■				
Writing report												■			
Re-written report												■			
Submit re-written report													■		
Pre-presentation														■	
Actual presentation															■

GANTT CHART/PROJECT SCHEDULE FOR FYP 2