JOINING OF PLASTIC BY USING LOW POWER CO_2 LASER

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ABSTRACT

Very less work has been done on laser welding of polymer materials. This project related to the optimization of process parameters in laser welding operations. Larger pieces of Polycarbonates were cut into small pieces. The dimension of small pieces is 80 mm × 50 mm × 2 mm were cut from larger pieces. Good surface finish required for laser welding. So the small pieces must not have a gap when it is placed nearly between one another. The small pieces were machined by bend saw machine. Very less burr can also affect the welding output. The small pieces were welded on the welding table. Experimental design using the Taguchi method. Based on the Taguchi method, the number of experiments can be reduced from the total actual experiment. For the analysis, tensile test and microstructural tests were performed on each specimen. This analysis is also based on the Taguchi method calculation. Finally, the optimum parameters for the tensile test and bubble size have been predicted.

Key words: Polycarbonate; laser welding; Taguchi method; tensile test; bubble size

ABSTRAK

Kerja yang sangat kurang telah dilakukan ke atas kimpalan laser bahan polimer. Projek ini berkaitan pengoptimuman parameter proses dalam operasi kimpalan laser. Kepingan besar Polycarbornat dipotong kepada kepingan kecil. Kepingan kecil berukuran 80 mm × 50 mm × 2 mm telah dipotong dari kepingan yang lebih besar. Kemasan permukaan yang baik diperlukan untuk kimpalan laser. Jadi kepingan kecil mesti tidak mempunyai jurang apabila ia diletakkan berhampir antara satu sama lain. Kepingan kecil telah dimesin oleh mesin gergaji selekoh. Sangat kurang serpihan juga boleh menjejaskan output kimpalan. Kepingan kecil telah dikimpal pada meja kimpalan laser. Reka bentuk eksperimen menggunakan kaedah Taguchi. Berdasarkan kaedah Taguchi, jumlah eksperimen boleh dikurangkan daripada jumlah eksperimen yabg sebenar. Untuk membuat analisis, ujian tegangan dan ujian mikrostruktur telah dilakukan kepada setiap spesimen. Analisis ini juga berdasarkan kaedah Taguchi pengiraan. Akhirnya, parameter optimum untuk ujian tegangan dan saiz gelembung telah diramalkan.

Kata kunci: Polycarbonat; kimpalan laser; kaedah Taguchi; ujian tegangan; saiz buih

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LIST OF SYMBOLS

η	Signal to noise ratio
W	Watt
μm	Micrometre
nm	Nanometre
mm	Millimetre
w	Width
l	Length
s	Second
mm/s	Millimetre per second
v	Volt
MPa	Megapascal
y	Tensile test value or bubble size value
dB	Decibel
$\sum$	Sum

LIST OF ABBREVIATIONS

CO_2	Carbon Dioxide
OA	Orthogonal Array
S/N	Signal to Noise
ANOVA	Analysis of Variance
ASTM	American Standard for Testing and Material
DOE	Design of Experiment
DF	Degree Of Freedom
SS	Sum of Square
MS	Mean of Square
F	F-value
P	P-value
OP	Optimum Parameter

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

This project title is “Joining of Plastic by Using Low Power CO_2 Laser”. The project is intended to see the possibility of joining plastic and to propose a new method of joining plastic by using low power CO_2 laser. It is also about investigating optimization parameter for joining the plastic.

The material that is used in this project is thermoplastic. The thermoplastic is very popular in the industry of manufacturing (automotive) and processing. The product that produced by thermoplastic in the industry are keyless go card and electronic key assemble in the electronic and automotive industry (U.A. Russek et al., 2001, F.G. Bachmann et al., 2002, U.A. Russek et al., 2003). By using the laser as a heat source to join the plastic, the strong joint could be produced.

The project is using the laser heat source to join the thermoplastic polymer because the number of laser applications increases every year as this technology evolves, offering new advantages. The benefit from using the laser welding is better than another option of welding because the weld quality is consistent, no melt injection and very short processing time required.

1.2 PROBLEM STATEMENT

Currently, joining of plastic by using adhesive and mechanical tools methods. These methods however, produce weak joining. The adhesive bonding is joining using glues and it is no bonding between particles of the plastic polymer. The joining using mechanical tools are using bolts, rivet, and welding (K.T. Kedward, 1981, S. Katayama, 2008). This joining also not combines the particles between two workpiece of polymer. Thus, without bonding between particles, the joint of the workpiece is not strong and easy to break. Therefore, to overcome this problem, the new technique needs to be developed by using the new method.

1.3 PROJECT OBJECTIVES

The project objectives of this project are:

a) To investigate the joining properties of plastic by using low power CO_2 laser.
b) To investigate the optimization parameter condition by using Taguchi method.

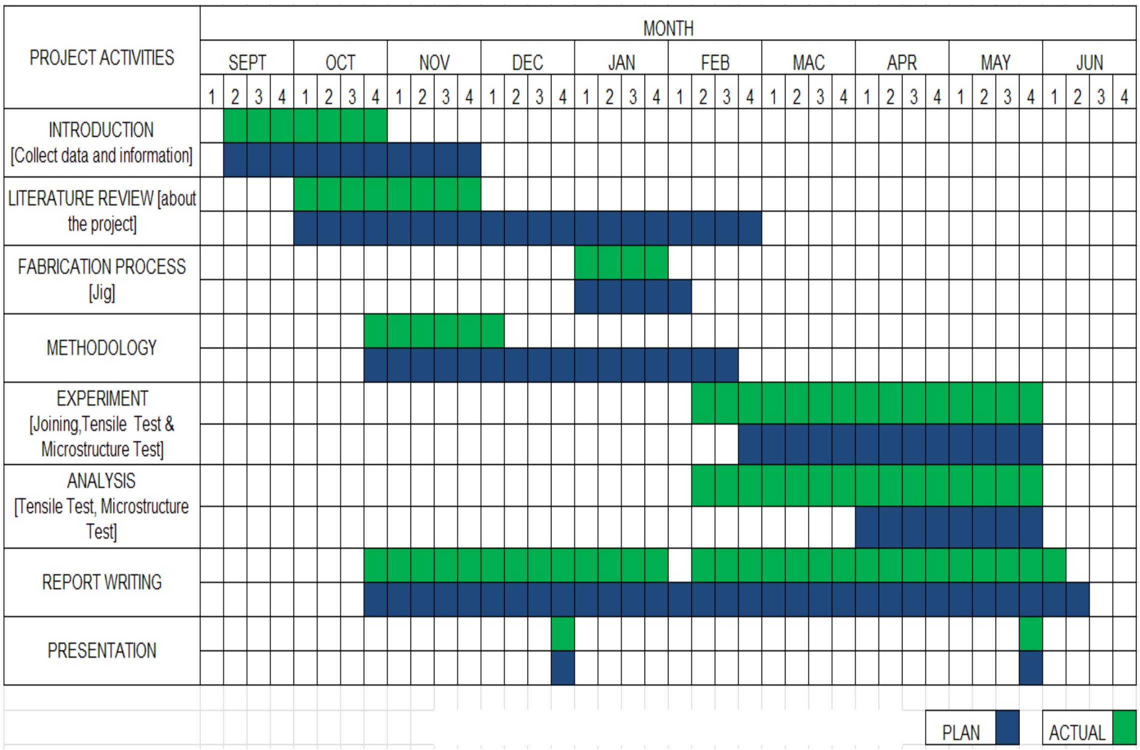
1.4 PROJECT SCOPE

The scopes of this project are as follows:

a) Fabricate the jig for this project.
b) Choosing and preparing the material.
c) Make joining of thermoplastic by using low power CO_2 laser.
d) Make an analysis of the joining and study the parameter that suitable for good result.

1.5 GANTT CHART

Table 1.1: Project Gantt chart



CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In the beginning years of laser technology to grow, alternative and innovative technologies have been included, laser beam welding of thermoplastics (R.M. Klein, 1990, P.A. Atanasov, 1995, U.A. Russek, 2003). The laser beam welding is a welding of the most accurate and very efficient method in the aerospace, aircraft, automotive and electronics industries (K. Kazemi, 2009, X. Cao, 2006). Besides that, the usually participate in the joining methods for polymer parts are screwing, snap-fitting, adhesive bonding and welding (K.T. Kedward, 1981, S. Katayama, 2008).

In last 10 years, laser welding thermoplastic has experienced increased interest and acceptance of industry. Several fields of applications in areas such as electronics and automotive industries have been established for years (U.A. Russek et al., 2001).

2.2 PROCESS TECHNICAL BASICS

The thermoplastic laser beam welding could structure though distinct points of view (U.A. Russek et al., 2001):

a) Geometries joint: butt joint and overlap joint.
b) Types of irradiation: contour, quasi-simultaneous, simultaneous, line and mask welding.
c) Be use laser source: powerful diode laser, CO_2-laser, Nd:YAG-laser, Holmium-YAG laser.

2.3 TYPES OF LASER WELDING

The two types of plastic laser beam welding process can be done. The types are overlap welding and butt welding.

2.3.1 Overlap Welding

Overlap welding is shown in Figure 2.1. The material is clamped by clamping before welding begins. The transparent material for laser radiation is at the top and the non-transparent laser material at the bottom. The laser beam across the top material with infra-red wavelengths between 800 nm and 1100 nm. After that, the laser radiation is absorbed at the upper of non-transparent laser surface and heated. The heat is removed to the lower surface of a transparent laser material. The both surfaces of the material are melting and after cooling and solidification, the material was formed.

Usually the transparent material for laser radiation is also transparent to the eye, which absorbs laser radiation, has the emergence of an opaque of red or black color. But there are some exceptions which can be used to improve the freedom of design with regard to color.

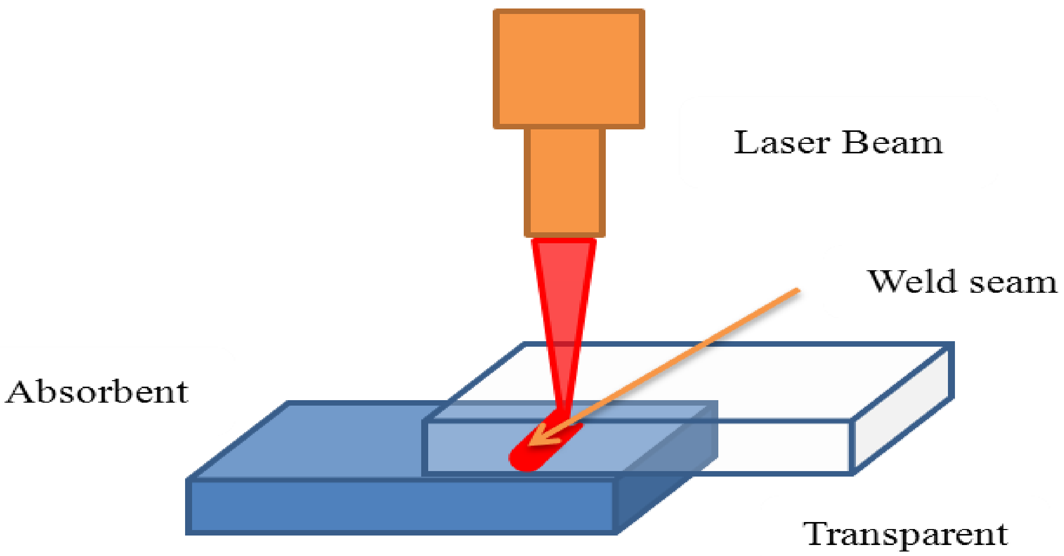


Figure 2.1: Overlap welding with a laser beam (serial welding)

2.3.2 Butt Welding

Polymer welding through papers that were published in the past is not an ideal configuration for butt welding referred respect to this variant.

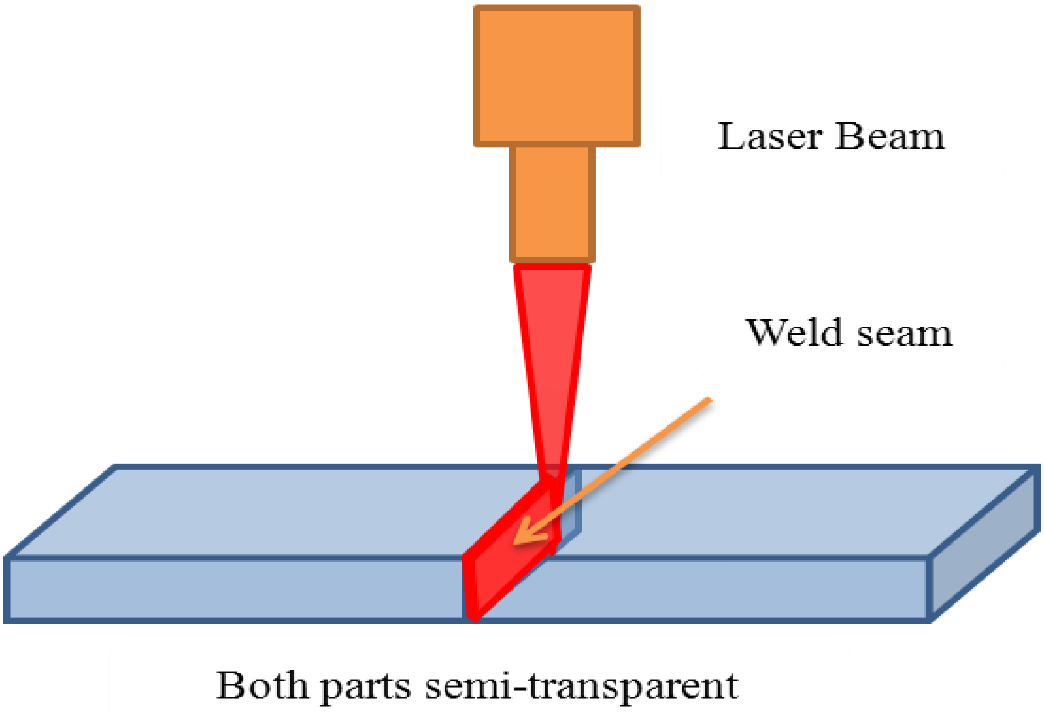


Figure 2.2: Butt-welding with laser beam

Because of low thermal conductivity of polymers (contrary to metals), the only the parts of the workpiece will be melt where the absorption of laser energy. In an effort to reach a stronger weld seam, a melt will be established across the whole joining volume. This places significant barriers on the laser absorption of the two parts, and then on their pigmentations.

In relation to the method by which the laser power is provided to the work pieces, five major variants can be excellent, serial welding, simultaneous welding, quasi-simultaneous welding, line-scan welding and mask welding.

2.3.3 Serial Welding

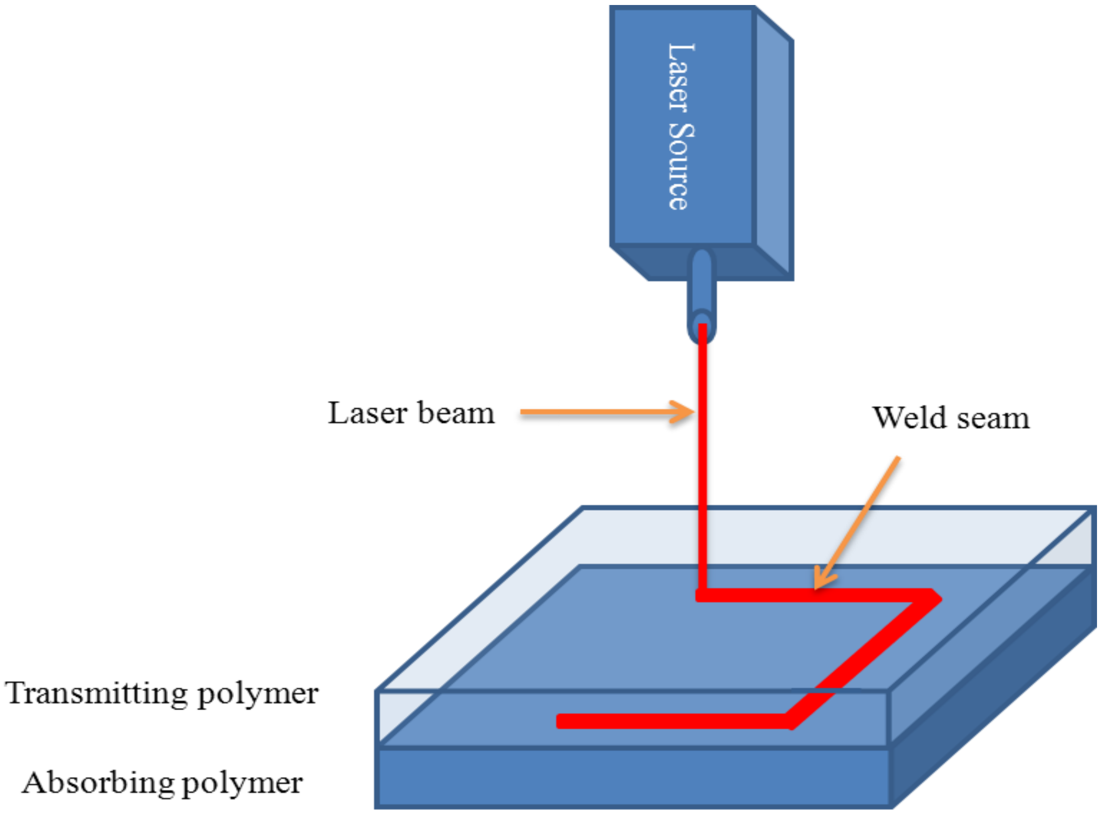


Figure 2.3: Serial welding

With a serial welding, along the welding contour based on laser spot. Thus new weld geometry can be adjusted by simply changing the contour program, establish less arising cost and the welding process provide an unexcelled flexibility and the possibility of participating in a device with 3D contour weld.

2.3.4 Simultaneous Welding

For simultaneous welding (see Figure 2.4), a special consent of the laser-diodes and a suitable, product-specific form of the laser beam optical system in such a way to brighten up the whole contour of the weld simultaneously. There is no relative motion and the laser beam is necessary and very short processing time available.

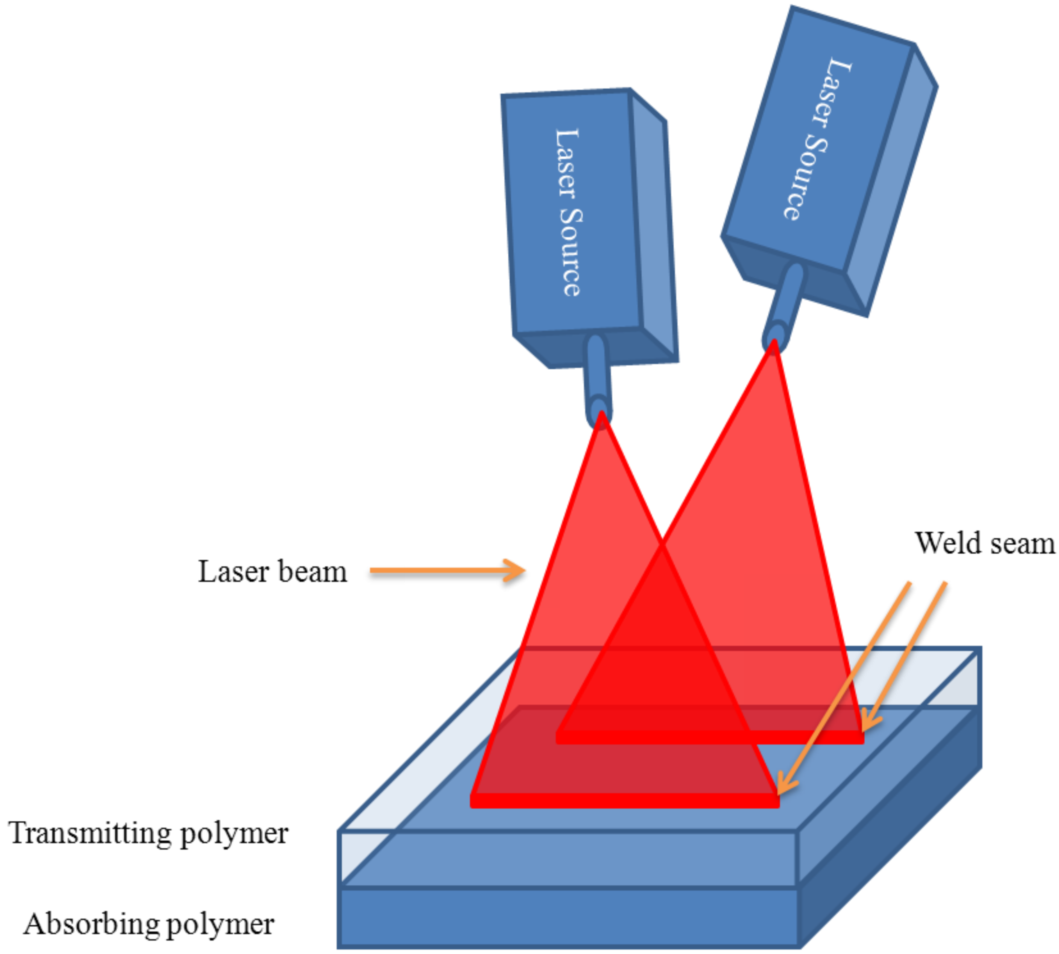


Figure 2.4: Overlap welding with simultaneous energy input

2.3.5 Quasi-simultaneous Welding

Rapidly scanning laser beam weld contours complete. If required the scan is repeated once or more times. Then, the irradiation is serial but the overall contour is in weak condition or melting at the same time, if the time-interval between successive scans is short enough (this may be due to low thermal conductivity of the polymer).

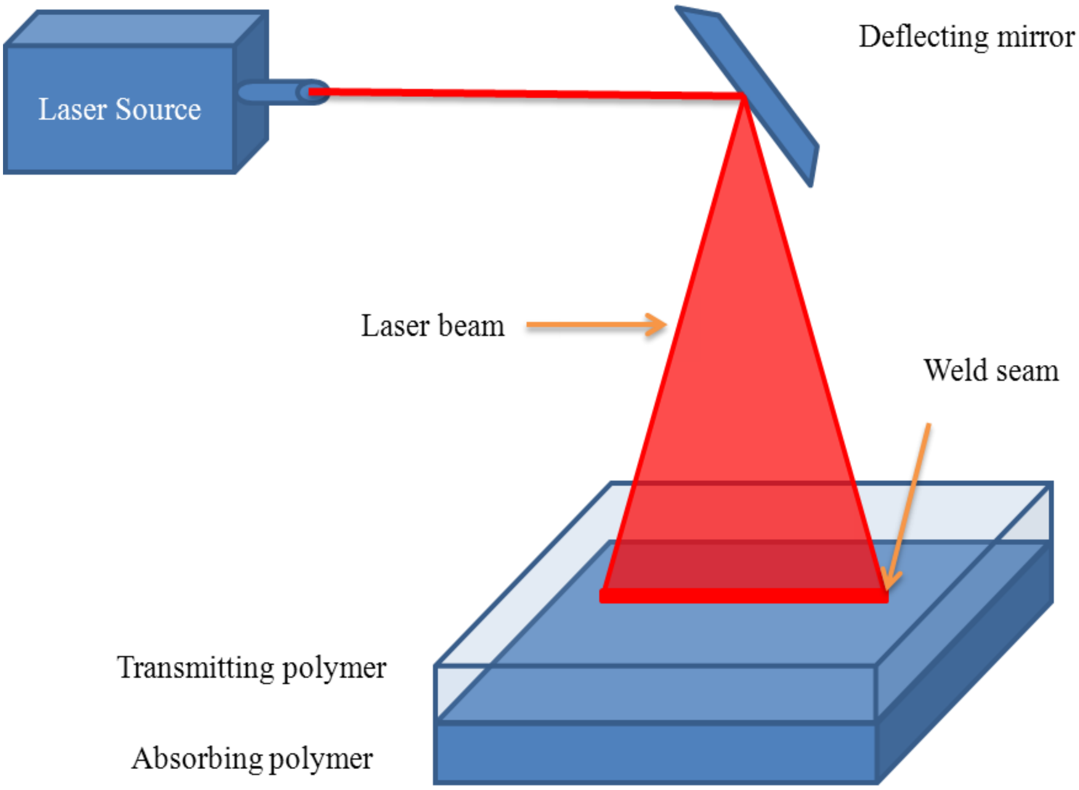


Figure 2.5: Quasi-simultaneous Welding

2.3.6 Line Scan Welding

A surface is irradiating when the laser is moving and making perpendicular line to its length.

2.3.7 Mask welding

By a contact perforation mask, the shaping of the laser beam is done here. It will produce a weld line is very smooth and elaborate. In principle, any of the four above mentioned method can be combined for mask welding. The Figure 2.6 is shown that the combination of the line scan welding.

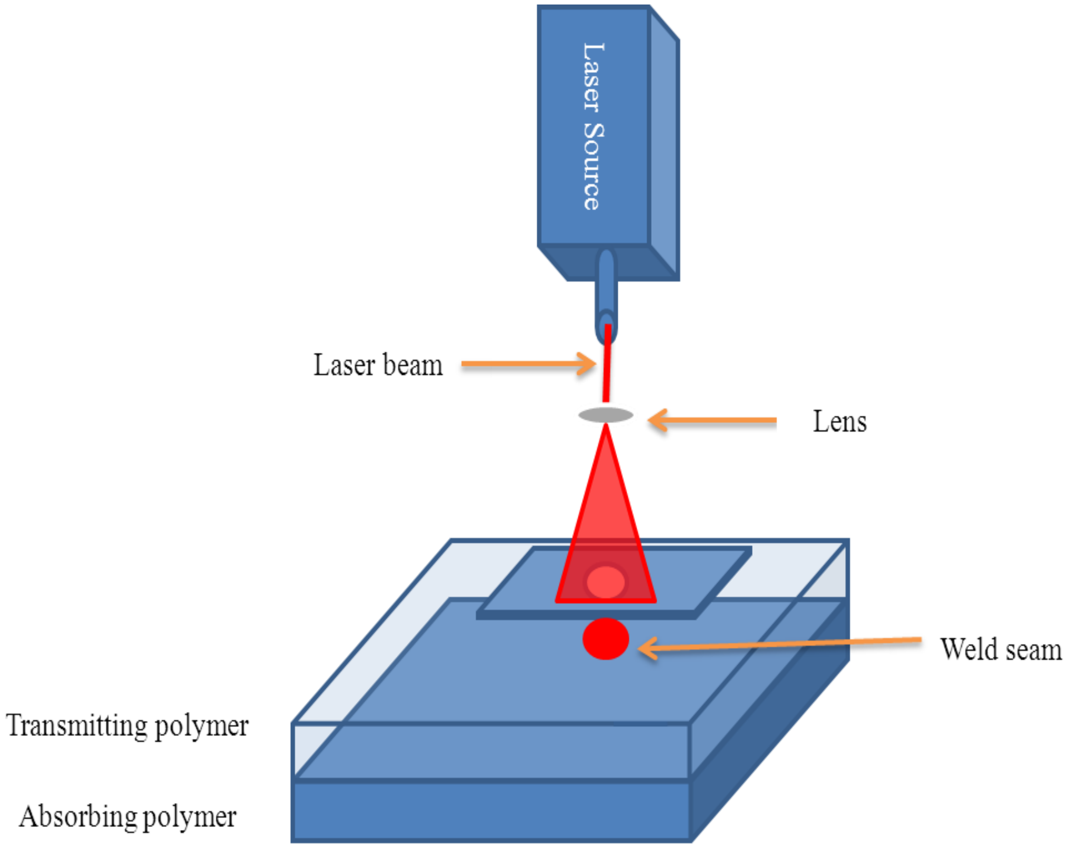


Figure 2.6: Line-scan welding with a mask-shaped laser beam

2.4 TYPES OF LASER TECHNOLOGIES

2.4.1 CO_2 Laser

The surface layers of plastics absorb the CO_2 laser radiation (10.6 μm) rapidly. If the laser attractive a resonant frequency in the molecule, the plastics will heat up. So, the absorption coefficient for the CO_2 laser is very high with most of the plastics. Consequently, very high processing a thin plastic film may be even in the laser power is low or moderate (100-1000 W).

2.4.2 Transmission Laser Welding - Nd:YAG Laser

The Nd:YAG laser is for substance processing. The development has led to an increase in the power of the 6 kW and also can reduce the physical size of the laser. The beam quality and the energy efficiency (from 3 % using flash lamps to 10 % using diode laser) is improved by the development of diode pumped Nd:YAG lasers. Generally, the light from Nd:YAG lasers are much less easily absorbed in the non-pigmented plastic compared with CO_2 laser light. The level of energy absorption in Nd:YAG laser wavelength (1.064 μm) mostly depends on the presence additional materials in plastics. The laser will penetrate into the material if there are no fillers or pigments in the plastics. The additives such as pigments of fillers can be used to increase the absorption coefficient. To enable easy operation or manipulation of the flexible gantry robot, the Nd:YAG laser beam could be emitted through a silica optical fiber.

2.4.3 Transmission laser welding - Diode laser

The important joining process for thermoplastic is also from diode or Nd:YAG lasers. For overlap welding, the upper plastic is transparent to the laser and the lower plastic is absorbing to the laser and it is also known as transmission laser welding. At the interface, the heat is coming from absorbing radiation and the heat conduction will causes the joint of the lower plastic with upper plastic. The carbon black is good additive absorbing material for use in the plastic material in the industry. But, the transparent plastic is becoming darker color when using the carbon black.

2.5 ADVANTAGES OF LASER WELDING

For welding plastics, the laser provides many advantages over conventional welding technique. The advantages of the laser welding are:

a) Minimal thermal and mechanical power output is required.
b) Weld quality is consistent.
c) There is no melt injection.
d) It has excellent reject rate.
e) Very short processing time is possible.
f) The heat-affected zone is very small.
g) Precise focusing allows accurate joint formation.
h) A perfect surface is attainable.
i) Welding seam contours are flexible.

2.6 THE TAGUCHI METHOD FOR OPTIMIZATION OF PROCESS PARAMETERS

Taguchi method is a well-known technique that provides a systematic and efficient methodology for process optimization (S. Kamaruddin et al., 2004). It has been used for product design and process optimization worldwide because its design includes simplification of experimental plan and feasibility of study on interaction between different parameters.

The key step in the Taguchi method to achieve high quality without increasing costs is to optimize the process parameters. This step is effective for optimization of process parameters can enhance the quality parameters and optimum process gathered from the Taguchi method is not sensitive to changes in environmental situation and other noise factors. Generally, the classic process of design parameters is elaborate and difficult to use (Wiley, 1991).

The Taguchi method emphasizes performance characteristics of the mean value of the target and not nearly the value of the specified limits, thus improving the quality of the product. Taguchi method has another advantage of the design of experiments is simple and convenient to apply to more engineering situations, making it a powerful but easy. It can be applied very quickly close the scope of the research project or to identify problems in the production process of existing data (S. Fraley et al., 2006).

The Taguchi method has disadvantages where the results are only relative and do not accurately indicate what parameters have an effect on the performance characteristics of the highest value. This rule must not be used with all relations between all variables because orthogonal array does not test all combinations of variable. In addition, the interaction between parameters is making difficulty in accounting and because of that, the Taguchi method was criticized in the literature for the accounting. Among other disadvantages of the Taguchi method is not suitable for the dynamic process that varies as a simulation study. In addition, past years the Taguchi method to control the quality of design and not correct for low quality, they are used most efficiently in the initial stages of process progress (Unitek Miyachi Group, 1999).

2.6.1 The Taguchi Technique

The Taguchi proposes plans in a variety of orthogonal array experiment that provides a combination of different parameters and their levels for each experiment. Pursuant to this technique, the whole parameter area examined only the minimum number of experiments necessary. According to the average output value of the quality features at each parameter level, major impact analysis performed.

The complete procedure in Taguchi methods of design distributable into three levels which is system design, parameter design, and tolerance design as shown in Figure 2.7. The second level (design parameters) is the most significant level. It has been used extensively in the United States and Japan successfully for the optimization of industrial processes and manufacturing process. Taguchi parameter design stage need that the factors which influence the quality features in the production process were determined.

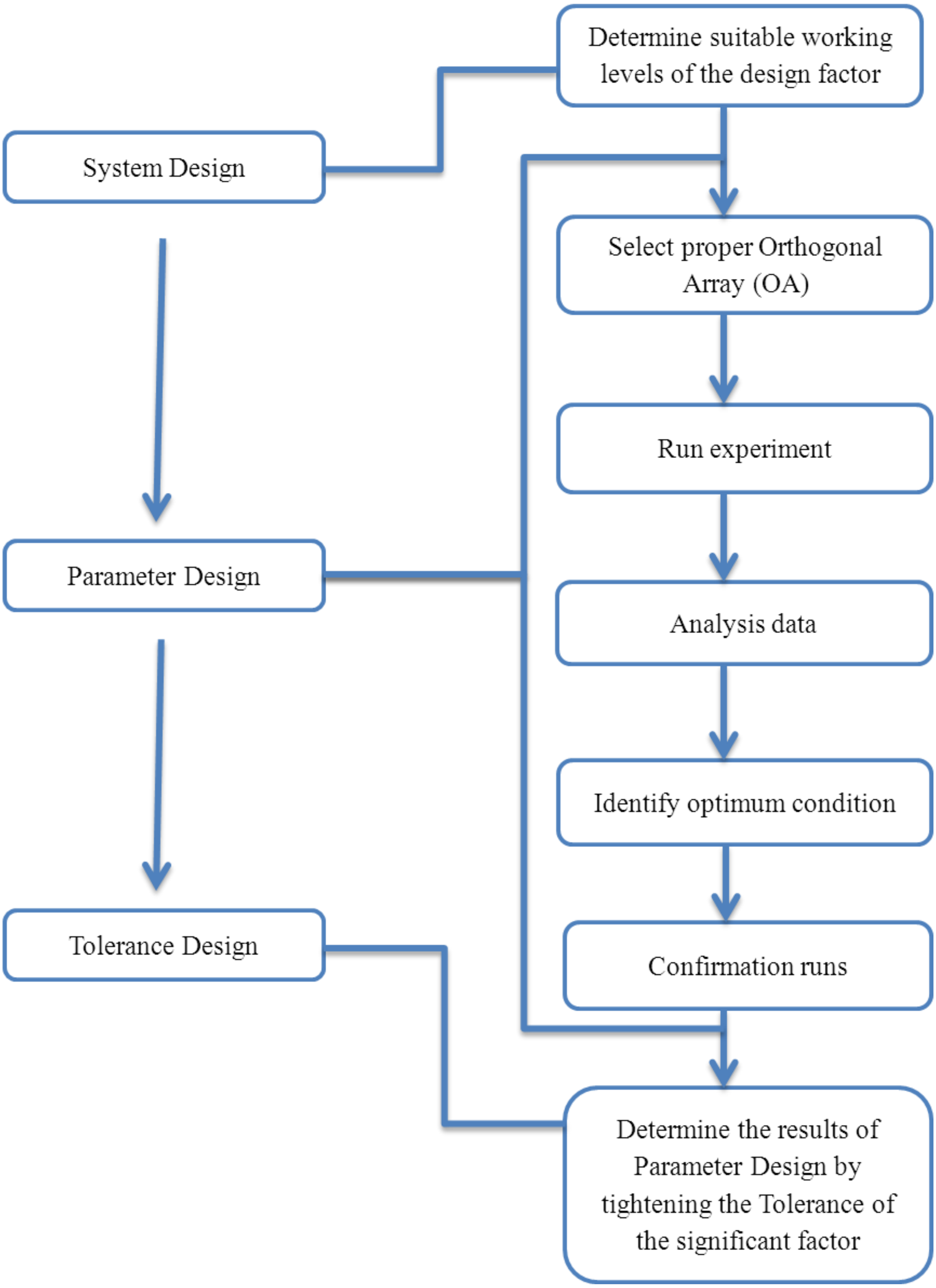


Figure 2.7: Taguchi design procedure

Source: C.Y. Nian, W.H. Yang, and Y.S. Tarng (1999)