Design and Development from CNC LASER Cutting Machine in Different Sheet Metal

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Abstract — *Nowadays digital control technology is becoming more and more effective to run the machines like laser cutting machines and this is a machine very effective in the big manufacturing industry. This laser machine is used to cut the sheet with different gases like (oxygen and nitrogen and compressed air). The surface roughness of nitrogen gas cutting components is far better as compared to air cutting, this whole process is done by laser cutting in which material removal takes place through melting and vaporization of metal when the laser beam comes in contact with the metal surface. In this paper, the fundamental goal is to design and develop by laser cutting machine in different sheet metal material (like SS 304 and MILD STEEL). This laser cutting machine is controlled by the cypcut software. This software is applicable for both cutting and also small design components. This machine has better surface finishes and is easy to control the whole process plan to any type of intricate or regular shape components. This is very easy to work for the latest manufacturing trend.*

Keywords—Sheet metal cutting , steel sheet material 304 and mild steel, solid works sheet metal module, sheet metal design. LASER BEAM MACHINING, Product process plan.

1. INTRODUCTION

Laser is named as "Light Amplification by Stimulated Emission of Radiation." Lasercutting machines, which are used in a different range of industries for precision cutting and designing projects. Laser cutting is a technology that uses a laser to which material removal takes place through melting and vaporization of metal when the laser beam comes in contact with the metal surface, resulting in a cut edge development. The source of energy is lesser, which forces optical energy on the surface of the workpiece, The highly focused high-density energy melts and evaporates portions of the workpiece in a controlled manner, this process does not require vacuum   is used to machinery a variety of metallic and non-metallic materials, Many different types of laser used in this manufacturing operations (CO_2, N_2 and also by pressurized air).

First, we will create products drawing in sheet metal model in solid works software, and then we will apply the material, in this sheet metal drawing first we will take a plane, the plane on which we will make a drawing that plane with ctrl + 8 We will zoom in on the front screen, after that, we will take a rectangle with a rectangle command and convert it to 1.5 mm sheet. After that this sheet will be ready inside the solid works sheet metal model.

Now we will use the flange command in that sheet, we will apply the flange command on all four sides and we will add the flange of 100 mm and at the same time I will also add 1.5 mm to the corner radius. After this, we will convert this completed drawing into dxf-file formate. This is the file which the cypcut software will read and then cut the sheet metal by applying gas through a CNC laser.

2. RESEARCH METHODOLOGY

In this research, we understand the new products development by customer requirements, new products development is defined as the introduction of the new product into the well-established market in our industrial society.

3. UNDERSTANDING OF PRODUCT DEVELOPMENT:

The development of any product is a very creative and curious approach that guides us to find out the problems and also to improve the present regular, manufacturing process. Human character is to how to explore the new things in the designing and development section. A manufacturing company has the ability how to fulfill the customer requirement when the company fulfills customer needs they will chance to grow up in the manufacturing sector and development sector. Therefore design and development is a very crucial role for the company and also the developing nation. New products are the strategy that allows me to penetrate the existing market with the new products.

In this research proposal customers wants to need a PC CABINET with some different features like as some modular type fitting features with extra cut section provides and many other things as customer purpose, which is the box-type structure of sheet metal in a different material (SS 304 & MILD STEEL), which is optimum cost and also very effective products to fulfill the consumers demanded.
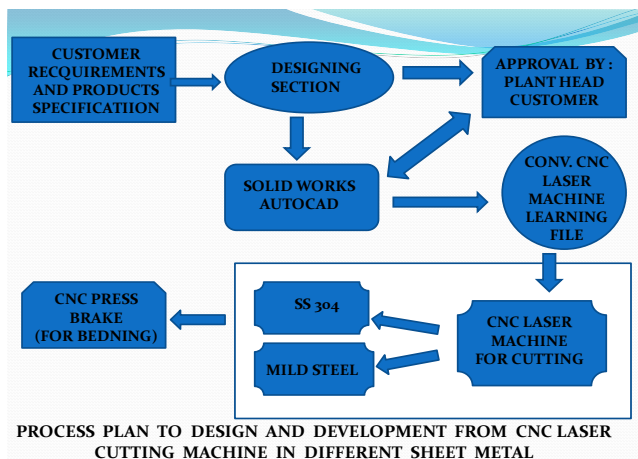
PROCESS PLAN TO DESIGN AND DEVELOPMENT FROM CNC LASER CUTTING MACHINE IN DIFFERENT SHEET METAL

Obtaining customer information during the new product development (NPD) process is considered to help firms improve business performance in our manufacturing society. Customer demand is a very vital and effective role in a new product-related challenge in product development in a stand-up market-driven society. In this customer is direct contact to our team members to understand the product criteria that are the customer needs, in this, customers give me a model, sketch, and ideas how the purpose of this product. Our company firstly understands all things and also right down each step which customers needs. The customer also gives a handmade sketch to understand the purpose of the things. Customers demand to develop a personal computer cabinet which is developed by SS304 sheet and also a MILD STEEL. our design and development is only the focus of customers needs

And the company team member is easy to understand all the things and they give whole information in our product design section. In this section our design engineers develop the product by SOLID WORKS software, In this software, we will develop pin to airplane all things which your mind think.

4. SOLID WORKS DESIGN MODULE

Solid Works is a CAD software of is a mechanical design automation application that designers easily understand and design very quickly sketch out ideas, with features as well as dimension and produced a very effective model and also a detailed drawing.

In solid works software mainly used three-module which is given below by the table:

S. no.	Title Solidworks programmed	Programmed discussion
1.	Part	This module is used for design methods, tools, and features mainly used to make parts.
2.	Assembly	In this module we assemble all the parts which are developed in the part

		module section, this section also identifies interference, specify mate, and is used for context design purpose
3.	Drawing	This is basically a discussion of a drawing sheet format, dimension views, full annotation, and also the BOQ (BILL OF MATERIAL)

SOLIDWORKS model consists of 3D geometry that gives all its edges, faces, and all surfaces.

The SOLIDWORKS software makes any type of design model very quickly and precisely. A 3D geometry is a model sketch that you want to develop in our different manufacturing processes. Mainly sheet metal fabrication works in sheet metal featured module which is beneath in the part modeling

5. DESIGN PROCESS:

The design process usually involves the following steps:

• Identify the model requirements.

• Check the model based on the identified needs.

• Develop the model based on the concepts.

• Analyze the model by physical and by mechanical.

• Prototype of the model.

• Construct the whole model.

• Edit the model, by the customer demanded.

6. STEPS OF SHEET METAL DRAWING IN SOLID WORKS SOFTWARE, OF MY PC CABINET:

1. Draw a rectangle with 300 * 300 mm, in fig (2)
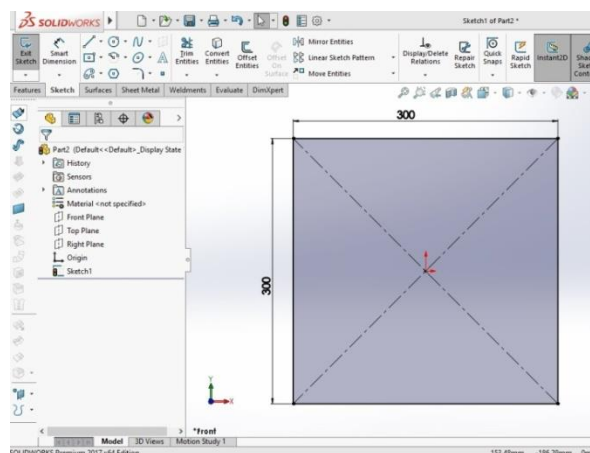

Fig 2.0

2. And convert this rectangle to sheet metal in solid works software from sheet metal module

with 1.5 mm thickness and also apply the K-factor with 0.45. is shown in figure (3.0)
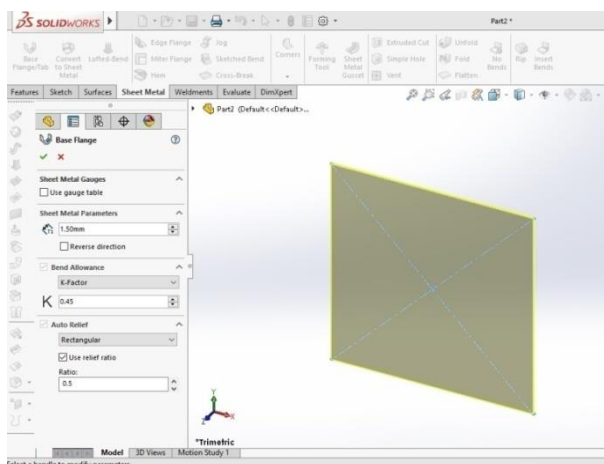

figure (3.0)

3. In this sheet metal module take an edge flange command, with a corner radius of 1.5 mm also and the length of edge flange is 125 mm, is shown in figure (4.0)
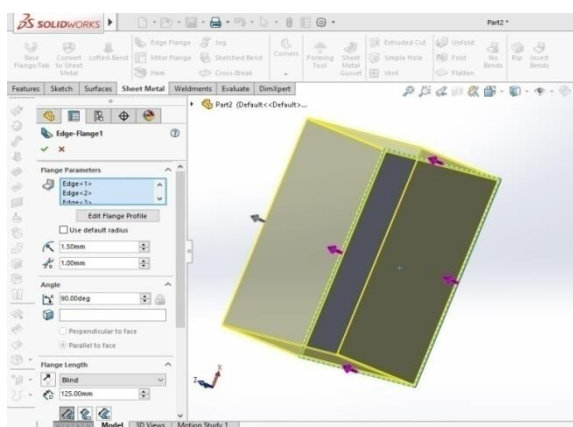

Fig (4.0)

4. Also use the corner command to fill the corner gap with 0.3 mm and this gap is filled by welding after the bending process.
5. Again we use edge flange on the upper side of length 22 mm in three sides of the rectangle and sketch this flange edge flange to draw a versatile and attractive drawing which is shown in figure (5.0).
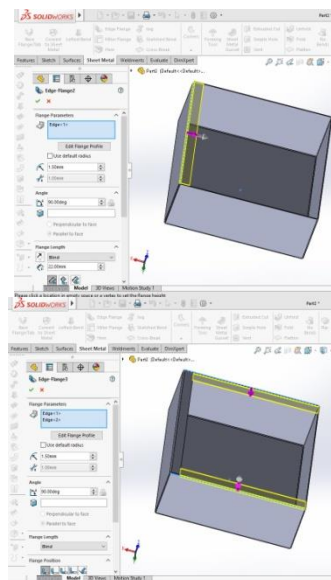

figure (5.0)

6. Draw a sketch in the left side flange and make a triangular cut sector for the demand of the customer
7. (Figure 6.0), Sketch one flange with two-hole of diameter 8 mm and center to center distance 200 mm. and this completed sketch mirrored in the opposite side of the flange and then cut these holes with the extrude cut command in sheet metal.
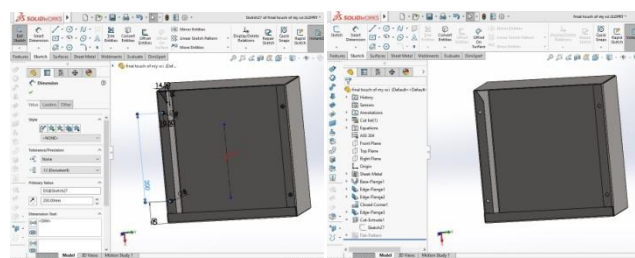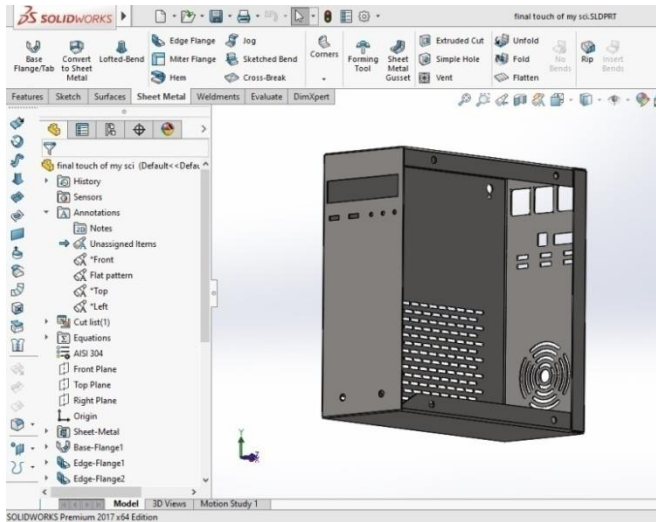

Figure (6.0)

8. After this, Select the one side flange of length 125 mm and sketch all the required things in (fig 7.0) which customers need like fan lovers, cut section wire socket USB socket, on /off switch button socket, and many more things related to our market demand.

(fig 7.0) This is the final touch of my PC cabinet drawing IN 3D MODEL

After completing the drawing our design section give me the final approval from the senior officers and also one copy to send the customers side to approval, which we made a drawing file in pdf. Formate in figure (8.0) and then further proceed with the manufacturing.
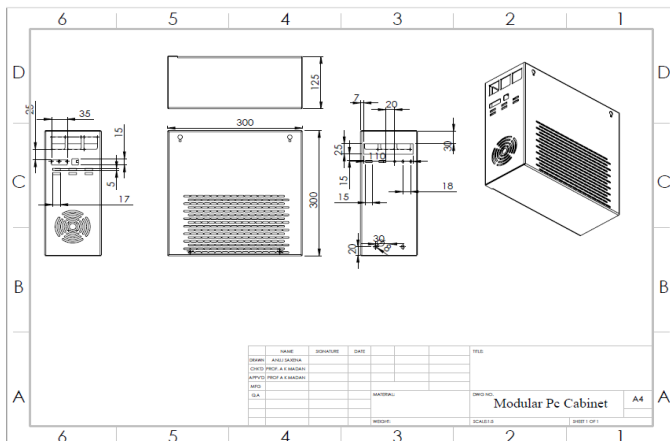

Figure (8.0)

Convert the whole design in which formate by which CNC machine software read. We use CYPCUT software which is used in the HSG LASER CUTTING machine, this laser machined manufacturing unit in china, they are a very accurate and precise machine.

7. EXPERIMENTAL SET-UP

Working Material:

7.1 Stainless steel

Stainless steel Grade 304 is the standard stainless; it is the most common, versatile and most widely used stainless steel, available in the market, It has excellent forming and welding in different materials.

Chemical composition of SS- 304

Grade 304	% Max	%Min
C	0.00 -0.08	
Mn	0.00 - 2	
Si	0.00 – 1.00	
P	0.0 0.0456	
S	0.00 - 0.0301	
Cr	17.00 - 20.0	18.0
Ni	8.00 - 10.5	
N	0.00 - 0.11	

Mechanical properties of SS 304

Tensile Strength (MPa) min	515
Yield Strength proof 0.2%(MPa) min	205
Elongation (% in 50 mm) min	40
Rockwell B (HRB) max	92
Rockwell Brinell (HB) max	201

Characteristics of the SS 304 are given below:

- Corrosion and oxidation resistance due to the chromium content in SS.
- Deep drawing quality is very versatile.
- Excellent Toughness.
- Ease to fabrication is the main characteristic of this stainless steel sheet.

7.2 Mild Steel

Mild steel is ferrous material that is made from iron and carbon content. It is a very cheap price material that has suitable properties for the engineering sheet operation. Low carbon mild steel has good magnetic properties due to its very high iron content. In mild steel carbon content of between 0.16% to 0.29% as well as very high melting point approximate to $(1450 – 1520)^0$ C

Chemical composition of mild steel

ELEMENT	CONTENT
CARBON	0.14 – 0.20 %
IRON	98.81 – 99.26 %
MANGANESE	0.60 – 0.90 %
PHOSPHOROUS	<0.040 %
SULFUR	<0.050 %

Mechanical properties of mild steel

Tensile Strength ultimate (MPa) min	440 Mpa
Elongation (% in 50 mm) min	15
Rockwell B (HRB) max	24
Yield Strength	250 Mpa
Density	7860 kg/m³

Steel is higher carbon contains than mild steel, which has a lower melting temperature. Mild steel is a more ductile material and it is also suitable for forging, cutting, drilling welding, and also easy to fabrication. Mild steel is not suitable for hardening purposes.

8. HSG CNC LASER CUTTING MACHINE 1KW (X – 3000, Y – 1500, Z-400 MM)

LASER is named as for Light Amplification with Stimulated Emission of Radiation. The lasers were first introduced in the 1960s and since then these are widely used in the manufacturing and fabrication industry for fine machining of sheets and parts. The distinctive feature of this process is that it can machine conducting as well as non-conducting materials without any problem, including metals, non-metals, composites, plastics, rubbers, etc. In the engineering field, the laser process is used widely. For example, the laser cutting machine cutting process used a laser as the cutting tool by the different gases for the different thicknesses of the material.

Figure (9.0), laser beam machining (LBM), cutting occurs due to the melting of a given metal by vaporization. Laser cutting is a non-contact and highly automated process suitable for various manufacturing and construction industries to produce a large number of components with high accuracy and surface finish. The high flammable oxidized gas from the gas cylinder enters the nozzle where it is ignited by amplified light and generates a high-intensity flame which gives on the material and thereby causes a cutting action on the material. This high-intensity flame can be of various gases, the mainly used gases are CO_2, O_2, N_2, etc. Depend on the cutting parameters different gases are adjusted to different thicknesses of sheet metal which generate flame with pressure. The molten metal is ejected from a high-pressure gas that assists the beam.

The main purpose of these flames is sublimation, thawing, and evaporation. The cutting process is started by moving a focused laser beam at a constant distance along the surface of the workpiece, producing a narrow and very thin cut kerf. Thin kerf design perfectly penetrates the material along the desired cut contour of the shape.

This process is successful only when the melt zone has completely penetrated the sheet of the workpiece. Laser metal cutting is usually limited to thin sections. The process is more commonly and routinely used on metal sheets 6 mm or less in thickness.
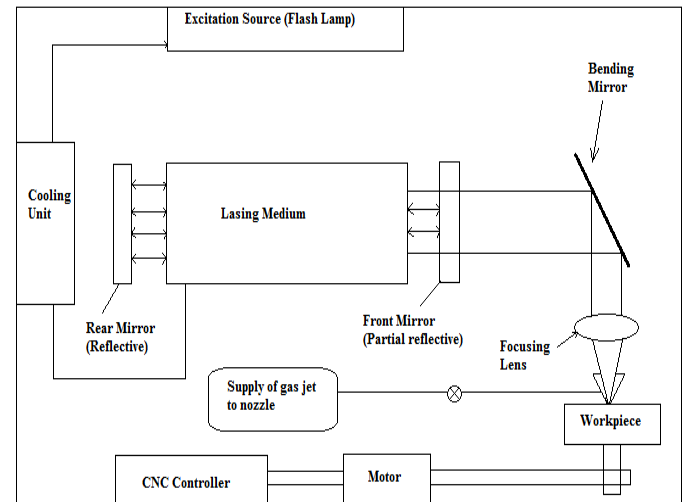

Figure (9.0), Systematic sketch diagram of laser cutting machine.

For the information, advanced machining is adopted rapidly in materials focus areas and manufacturing disciplines. In this project, laser cutting CNC machines are considered as the advanced machining system to their precision work or operate effectively. This kind of advanced machining is not only high-speed operation, it also easy to control due to advancements in laser technology and computational powers. For any type of laser cutting CNC machine, the axis of motion is typically the X and Y-axis. For the machine to operate included with Z-axis motion, the cutting head may be controlled by the software named cypcut which is used in this research journal. Laser cutting machines are very different from traditional mechanical cutters. The laser cutter never makes physical contact with sheet metal material. Eventually, there is less probability for the material damaged and the surface finish of material cuts is high performance.

9. LASER CUTTING PROCESS

Laser cutting is the process used by a laser as the main agent to cut the material on specific or certain values of parameters given. This process becomes significant in the industry due to material uses for automotive, aerospace, and manufacturing field that need high-quality products from the cutting material. In order to get the best cut quality and high efficiency in cutting performances, laser processing parameters that give the important role of the cut quality are literature below:

- Power and intensity of the laser

- Cutting speed of the laser machine

- Focal length of the lens (concave and convex)

9.1 Power and intensity:

Lasers are mainly described in terms of power. Laser power is defined as the total energy emitted in the form of laser light per second. The intensity of a laser beam is equal to its power divided by the area to which the power is concentrated. The high intensity makes the material heat up very fastly to that minimum time is available for heat to be dissipated into the surrounding material of the sheet which I want to cut easily and also accurately. This produces very high cutting rates and very perfect quality of the cutting.

By the way, the laser intensity also can determine the thickness that should be cut. Higher laser intensities can be formed by increasing the laser power and another parameter with shorter focal lengths. If we want to cut the higher thickness materials, the intensity must be higher as compared to low thickness material. However, focusing the beam on a smaller spot also reduces the depth of focus and is therefore unsuitable for cutting thick materials. High intensity can be achieved both in pulsed and continuous beams of the laser. but either the peak pulse power in pulsed cutting or the average power in continuous cutting determines the penetration.

Intensity = power / area (watt/m^2)

9.2 Cutting speed:

The next parameter is that cutting speed plays an effective role in the laser cutting process. The speed of the cutting can give a great significant role even changes in speed values are small.

A speed In which is too fast or too slow leads to an increase in the surface roughness, burr formation, and too large dragline in the cutting process. The energy for the laser cutting process is such that the energy supplied to the cutting zone is divided into two sections namely: energy used in generating cut and the energy losses from the cut zone. It is given that the energy which used in cutting is independent of the time taken to carry out the cut contour but the energy losses from the cut zone are proportion to the time taken. Therefore, the energy lost from the cut zone decreases with increasing cutting speed resulting in an increase in the efficiency of the cutting process. The cutting speed must be adjusted with the gas flow rate and the intensity of power. When oxygen gas is applied in mild steel cutting, too low cutting speed results in excessive burning of the cut edge, but we cut with high thickness material excessive power gives an excessive heat and also increase the heat-affected zone into the sheet.

9.3 Focal length

Figure (10.0), Focal length also gives a significant effect when has a change of values of focal length. By the way, the focal length is the distance between the centers of the concave or convex lens to the point where the parallel rays of the light meet. As you can see below show the mechanism of focal length occurs at concave and convex lenses.
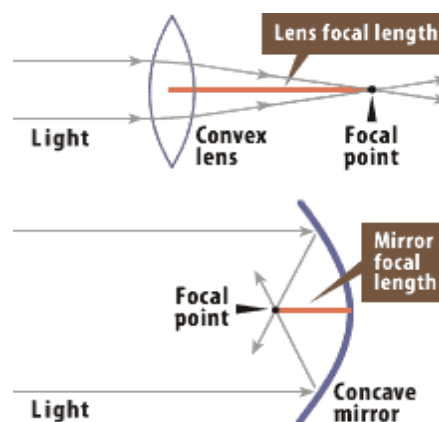

Figure (10.0), Focal length diagram

However, in order to get good performances on the cutting process, the suitable focal length should take serious action. How to choose the right lens focal length for the cutting process? By the way, the first consideration to take any action when choosing lens focal length for the cutting process is the depth of focus required of the material to cut. Then, two factors more must be considered due to more accurate machining which are the thickness of the material want to cut and the distance between lens and material.

The optimal cutting will occur at the focus point. The depth of focus will function as a guide to see how far from the focus point can perform the cutting process. we can assume that when the focal length increase, the depth of focus is automatic increases.

10. CUTTING PERFORMANCES

Figure (11.0), The cut quality can be geometrically characterized by the mean width of the cut opening which is kerf width, the cutting edge surface roughness, and the size of the heat-affected zone. By the way, both operating parameters which are laser power and cutting speed play an important role that affects the quality characteristic especially on the kerf width, heat-affected zone, and surface roughness that what mentioned earlier. The diagram shows the formation of kerf width and heat-affected zone. The kerf width gives the accurate size of the cut and the amount of material wasted, therefore a small diameter of laser is required for less wastage of material. The width of the cut kerf corresponds to the circular beam best size which is determined mainly by the laser beam quality and focus optics parameter.
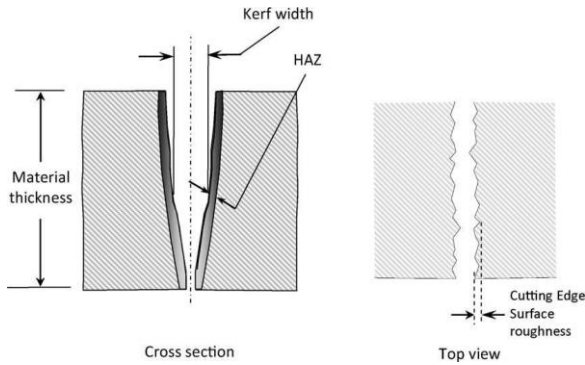
Figure (11.0), Diagram for kerf width, heat-affected zone and surface roughness

The combination of the operating parameters by combining cutting speed with laser power will result in the formation of kerf width and heat-affected zone. The lower the laser power and the higher the cutting speed will positively result due to lower kerf width and heat-affected zone. For the surface roughness, the laser power and cutting speed also become the influencing parameters due to laser cutting. Lower the value of frequency will result in the decreasing of the laser spot overlaps and finally increasing the undulations and ripples at the cutting edge.

Process Characteristics of laser cutting machine are given below:

1. Very fastest cutting process.
2. The workpiece does not need clamping but work holding is advisable to avoid shifting with the table acceleration and for locating when using a CNC program.
3. Zero tool wear since the process is non contacting cutting process
4. Zero noise level
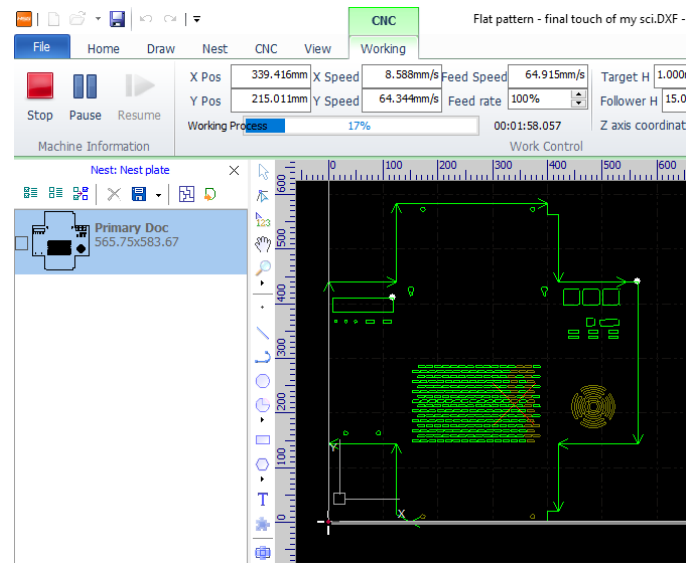5. Easily automated process and easy reliable software programmed.

Figure (12.0), CNC CYPCUT SOFTWARE SCREEN OF CUTTING COPONENTS

Figure (12.0), this is the cypcut software screen, this cypcut software only read the dxf-file formate. Cutting file, solid works 3d drawing is converted into dxf-file formate. File after finalized our senior goes to the laser cutting process starts which is shown above on the screen.

After cutting the whole sheet a cutting part is taken outside and the rest part is only a scrap portion of the sheet. After that, the cutting part goes to the CNC bending machine. This CNC bending machine bends the sheet with each bend portion which is created on the design of the solid work. This bending operation is different in SS 304 and also mild steel because the tensile strength of both the material is different. v- type die is used to bend cutting sheet we will also calculate the bending force in two different sheets by the bending force formula which is given below :

$$P = \frac{K.L. \, t^2 .Ts}{d} \quad (\, KgF \,)$$

P   - Bending Force (Kgf)

K   - Coefficient (1.33 for V die)

L   -   Length of the bend in (mm)
t   -   Plate thickness 1.5 (mm)
Ts - Tensile strength（Kgf/mm²）

d   - 8 times the material plate thickness.

Material	Tensile strength
STAINLESS STEEL 304	515 MPa = 52.5154 kgf/mm²
MILD STEEL	440 MPa = 44.8521 kgf/mm²

In this product, there are 7 bends in which 4 bends are equal in length of 125 mm and the other three bends are equal to 22mm. we can calculate all forces in these bends.

- *For SS 304 Material, Bending force Calculation*

1. L = 125 mm

$$P = \frac{1.33 * 125 * 1.5^2 * 52.5154}{8 * 1.5}$$

P = 1637.003 kgf or 16059.004 Mpa

2. L = 22 mm

$$P = \frac{1.33 * 22 * 1.5^2 * 52.5154}{8 * 1.5}$$

P = 288.112 kgf or 2826.38 Mpa

- *For Mild Steel Material, Bending force Calculation*

1. L = 125 mm

$$P = \frac{1.33 * 125 * 1.5^2 * 44.8521}{8 * 1.5}$$

P = 1398.124. kgf or 13715.59 Mpa

2. L = 22 mm

$$P = \frac{1.33 * 22 * 1.5^2 * 52.5154}{8 * 1.5}$$

P = 246.069 kgf or 2413.94 Mpa

The bending force of the press bending machine in SS304 is high as compared to mild steel. It is also a given that when the tensile strength, the thickness of the material and bend length of the material will increase the bending force also increase,

After calculation of force, my blanks sheet is bend by the CNC Press brake.

11. SUMMARY CONCLUSION:

A combined process of experiments and theoretical investigation of laser cutting machine in two different sheet metal (SS 304 AND MILD STEEL). The experimental work was intended to identify the most versatile role of the comfortable factors to achieve the design and development of any product of the sheet metal fabrication industry. This clarifies the designing purpose of new product development to achieve a goal of the industrial sector. This also works for reverse engineering, in this reverse engineering a physical part discovering the material design, the dimension which is measured by CNC mechanical measuring instruments named as a vernier caliper, micrometer, height gauge inches tape, depth gauge, and also a different mechanical measuring instruments. It gives the manufacturing proposal of new products in the existing market demanded by the customer. Designing solid works, I have used only the sheet metal module we can work on different solid works modules like part modeling and assembly module. it's a very easy and interesting software to design and developed any type of product. a new products process plan is also given in this paper to identify the basic characteristics of any customer's demanded products. It is finally concluded that the design of every product in the manufacturing company, which is done by the customer's demand is a very effective way to analyze the whole process of the products plan.

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