Design and Analysis of Jet Nozzle in Laser Cutting Machine

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Abstract: *Due to the ultra-flexibility of the cutting conditions, high quality end product, quick set up, non- mechanical interaction between the work piece and the tool, and tiny size of the heat affected zone, lasers are frequently utilised in industry for cutting tools. Copper is a common material for nozzle manufacturing. Because copper is a moreexpensive material, the material selection process is done tofind the most cost-effective material for the nozzle. the various materials (Brass and Nickel) based on the temperature and heat flux values obtained from the thermalanalysis The optimal material for jet nozzle is determined based on the thermal analysis results, and the material is advanced through the implementation phase.*

1. INTRODUCTION

In the 1970s, lasers were initially employed for cutting. Laser cutting is more commonly utilised in current industrial manufacturing in sheet metal, plastics, glass, ceramics, semiconductors, and materials such as textiles, wood, and paper. The use of laser cutting in precision machining and micro-machining will expand significantly inthe next years.

The irradiation region warms up quickly as the concentrated laser beam meets the work item, melting or vaporising the material. The cutting process begins when the laser beam penetrates the work item; the laser beam proceeds along the contour and melts the material. A jet stream is typically employed to blow the melt away from the incision, leaving only a small gap between the cutting section and the frame.

2. LASER CUTTING METHOD

2.1 Fusion cutting

The work piece is partially melted during laser fusion cutting, and the molten material is expelled by airflow. Theprocedure is known as laser fusion cutting since the material is only transferred in its liquid condition. The laserbeam is accompanied by a high purity inert cutting gas thatallows the melted material to exit the slot, but the gas doesnot cut. Laser fusion cutting can cut at a faster rate than gasification. Gasification requires more energy than melting. The laser beam is only partially absorbed in laser fusion cutting.

2.2 Vaporization cutting

The surface temperature of the material gets to the boilingpoint so quickly during laser gasification that it avoids melting due to heat conduction. Some of the material vaporises into steam, while others are blasted away by thesupplementary gas flow from the slit's bottom. A very highlaser power is necessary in this instance. The thickness of the material must not exceed the diameter of the laser beam to avoid material vapour from condensing into the slit wall. This method is only appropriate for applications that need the removal of molten material. It is only used ina few places for ferrous alloys.

2.3. Fracture-controlled cutting

Fracture-controlled cutting uses high speed and controllable laser beam heating to cut fragile materials prone to heat damage. The following is the primary element of this cutting procedure: The laser beam warms a small area of fragile material, generating a significant thermal gradient and severe mechanical deformation in the area, leading to material cracking. The laser beam can guide the fractures in any desired direction as long as the balanced heating gradient is maintained.

2.4 Oxidation melting cutting

In most cases, an inert gas is used for melting cutting. Whenemploying oxygen or any reactive gas, the material was lighted by the laser beam and violently reacts chemically with oxygen, producing another source of heat and further heating the material. This is known as oxidation melting cutting. Because of this effect, cutting speed for structural steel of the same thickness is faster than fusion cutting. Cutting incision, on the other hand, may be worse. It will, inreality, result in broader cut seams, visible roughness, greater thermal impact zones, and poor edge quality. Precision models and sharp corners are not suitable for laser flame cutting (risk for burn sharp corners). The pulse mode laser can be utilised to reduce the heat effect, and thecutting speed is determined by the laser's power. The supply of oxygen and the thermal conductivity of the material are the limiting factors for particular laser powers.These are the four most prevalent laser cutting techniques.The cutting plan can be determined by the power of the cutting machine, processing needs, and materialparameters.

3. MATERIAL SELECTION

3.1 Copper Material

Copper is one of the world's oldest metals. The great heat conductivity of copper is one of the key reasons for its use.It is a native metal, which means it may be found naturally in useable form and has excellent metallurgical qualities. Malachite, cuprite, azurite, bornite, and chalcopyrite are allminerals that include it.

3.2 Nickel Material

Nickel is a natural element produced from the core of the planet. It's silver white in colour, with a gleaming foundation and a golden tint. Nickel is claimed to be beneficial due to its ductile and corrosion-resistant qualities. Nickel is recovered from magmatic sulphides andlaterites, two types of ores.

3.3 Brass Material

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3.4 Heat Transfer Calculations

The temperature of a substance will change by a specific amount when heat energy is applied to it. Every material's connection between heat energy and temperature is unique, and the specific heat is a value that indicates how they interact. (mass of substance) (specific heat) = heat energy (change in temperature)

$Q = mc\Delta T$

Q =stands for heat energy (Joules, J)m = a substance's mass (g)

c is the specific heat (in J/g °C).

ΔT = temperature change (Degree Celsius)

For Copper MaterialSpecific heat (c)- 0.385 J/g °C Mass (g)- 29.853

Change in temperature (ΔT)- 2.2

$Q= mc\Delta T$

= 29.853x0.385x2.2

Q_{copper}= 25.285491 JFor Nickel Material

Specific heat (c)- 0.444 J/g °CMass (g)- 29.743

Change in temperature (ΔT) - 9.6

$Q= mc\Delta T$

= 29.743x0.444x9.6Q_{nickel}= 126.7765632 J

For Brass Material

Specific heat (c)- 0.380 J/g °CMass (g)- 28.73

Change in temperature (ΔT)- 7.8

Q= mcΔT

= 28.73x0.380x7.8

Q_{brass}= 85.1557

4. PROBLEM IDENDIFICATION

The nozzle is generally accessible in the market in copper material, although at a high cost. To provide the most cost-effective nozzle with high performance quality in the manufacturing industry. As a result, any other materials must be used to replace the copper.

Objective:

The major goal of this research is to design and analyse several types of jet nozzles (copper, nickel and brass). Temperature and total heat flow values from the thermal study are used to compare and determine the optimal material for the nozzle using Ansys software.

5. INTRODUCTION OF FEM

5.1 Introduction of FEM

The FEM is a mathematical model for predicting close experimental solutions in a variety of computing fields. FEM-based numerical analysis is generally referred to as finite element analysis (FEA).

5.2 FEA Works

As a machine tool for performance arts engineering analysis, FEA could be valuable in engineering. It entails theuse of mesh construction techniques to break down a complex problem into little pieces, as well as the usage of a software package programme that follows the FEM rule.

5.3 Advantages of FEA Software

1. It reduces the number of prototype tests, saving both money and time.
2. It shows a graphical depiction of the analysis' results.
3. The finite element modelling and analysis are done in the pre-processor and solution phases, which would take a long time and, in some situations, be impossible to execute manually.
4. It aids in the optimization of a design.

6. THERMAL ANALYSIS

Thermal analysis is a discipline of materials science that studies how materials' properties vary as temperature changes. Several techniques are regularly employed. The property that is measured distinguishes them from one another. The temperature and heat movement within and between components in your design, as well as between them and their environment, are calculated using thermal analysis. Because many goods and materials have temperature-dependent qualities, this is a significant design concern. Product safety is also a factor to consider. You may need to design a guard over a product or component that becomes too hot. The heat flow through the components can be either constant (where the flow does not fluctuate over time) or transient (where the flow changes over time).

7. PROCEDURE ANALYSIS

ANSYS is a finite component modelling software system that may be used to solve a wide range of mechanical problems numerically. It will do structural (linear and non- linear), thermal, magnetic attraction, and fluid analysis, among other things.

The user interface technique makes it simple to do analysis. A graphical interface is created, making the software system simple to use.

The answer of a finite element analysis can be separated into three stages:

1. Pre-processing stages
2. Solution
3. Post processing

7.1 Pre-processing stage

The following major steps are engaged in the pre- processing stage:

1. Import or Create geometry
2. Define element type & real constants
3. Define material properities
4. The meshing of lines/areas/volumes

7.2 Post processing

1. One of the most important phases is to examine theanalysis results to see how the applied loads effectour design.
2. We can see temperature distribution and heat flux,among other things, with this post-processor.

7.3 Results

Overall comparison of Nozzle Results

Description	Units	Copper	Nickel	Brass
Temperature distribution	°C	2724.7	2717.3	2719.1
al HeatFlux	W/mm²	0.19289	0.19241	0.19253

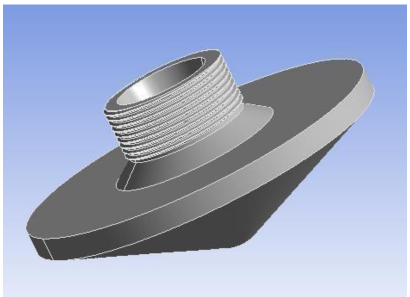

Fig-: 3D Nozzle design

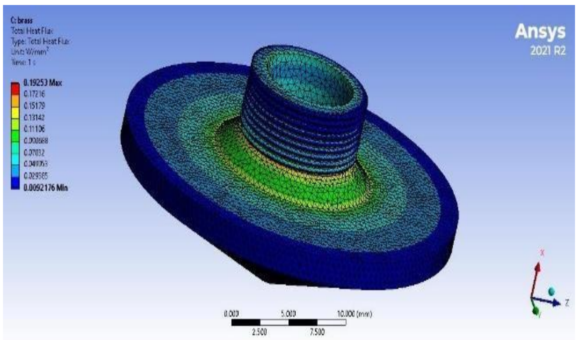

FIG-2: Total heat flux of nozzle with brass

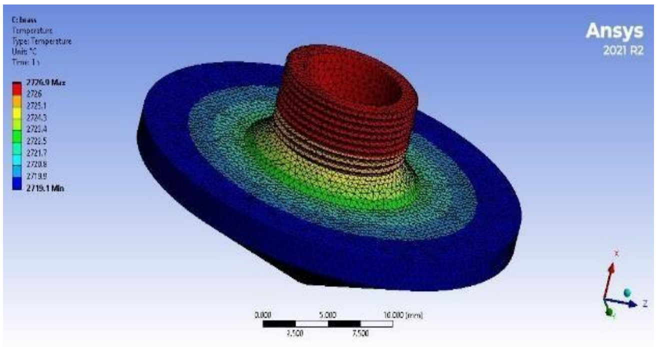

Fig-3: Temperature distribution of nozzle withbrass material

8.CONCLUSIONS

Laser cutting is a crucial aspect of the manufacturing process. This research presents an effective nozzle configuration estimation for high-pressure laser jetting. Solidworks software was used to model the jet nozzle, while ANSYS workbench software was used to do the thermal analysis. All aspects of the boundary conditions can be addressed using steady state thermal analysis. A nozzle made of nickel was chosen as the best thermal performance and economically acceptable material based on the temperature distribution and total heat flux data. Based on the heat transfer on the nozzle with various materials, it appears that nickel has a substantially higher heat transfer (126.7765632 J) than other materials (25.285491 J and85.15572 J respectively for copper and brass).

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