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A study of Laser Cutting and Piercing

Kirti[1], Pawan Kumar[2], Sandeep Kumar Khatkar[3], Amit Gupta[4]

[1234]Mechanical Engineering Department, State Institute of Engineering Technology,

Nilokheri Haryana, India

Abstract

The study of laser cutting and piercing is focused on the use of lasers as a tool for material processing in various industries, including automotive, aerospace, and electronics. This study explores the physical principles of laser cutting and piercing, as well as the advantages and limitations of this technology. The laser cutting process involves using a high-powered laser beam to melt, burn, or vaporize a material, resulting in a precise cut. Laser piercing, on the other hand, involves using a focused laser beam to drill a hole in a material. One of the main advantages of laser cutting and piercing is its high precision, allowing for complex shapes and designs to be cut with minimal material waste. Additionally, the non-contact nature of the process reduces the risk of material deformation or damage. , there are also limitations to laser cutting and piercing, including the cost of the equipment and the limited thickness of materials that can be cut. Additionally, laser cutting can produce harmful fumes and requires proper safety measures to be taken.

Keywords : Laser cutting, Laser piercing, Material processing, High precision, Non-contact , Material waste

Introduction

Laser cutting and piercing have become increasingly important in the field of material processing, providing a highly precise and efficient way of cutting and drilling a wide variety of materials. This technology has applications across multiple industries, including automotive, aerospace, and electronics, where precision and accuracy are critical. The process of laser cutting and piercing involves using a high-powered laser beam to melt, burn, or vaporize a material, resulting in a clean and precise cut or hole. This non-contact method of material processing has many advantages over traditional cutting methods, including reduced material waste, increased precision, and improved speed and efficiency. Despite these advantages, there are also limitations to the use of lasers for cutting and piercing, including the cost of equipment and the limitations on the thickness of materials that can be processed. Additionally, laser cutting and piercing can produce harmful fumes, requiring proper safety measures to be taken.

Ongoing research and development in the field of laser cutting and piercing continue to expand its applications in various industries. With advances in technology, this process is becoming more accessible and cost-effective, allowing for increased use in a variety of applications. Recent developments in laser technology have further advanced the field of laser cutting and piercing, allowing for increased precision and control in the cutting process. Additionally, the use of computer numerical control (CNC) technology has made it possible to automate the cutting process, resulting in increased speed and accuracy. Laser cutting and piercing have become especially important in the automotive and aerospace industries, where lightweight materials such as carbon fiber and aluminum are commonly used. Laser cutting and piercing allow for precise and intricate cuts in these materials, resulting in stronger and more durable parts. In the electronics industry, laser cutting and piercing are used in the production of printed circuit boards (PCBs), allowing for precise and efficient drilling of holes for components. The non-contact nature of laser processing also reduces the risk of damage to the delicate components of the PCB. As laser technology continues to advance, the applications for laser cutting and piercing are likely to expand even further. "Researchers are exploring new ways to improve the precision and speed of the cutting process, as well as developing new techniques for cutting and piercing a wider variety of materials.

In addition to the advantages of high precision and reduced material waste, laser cutting and piercing also offer several other benefits over traditional cutting methods. For example, laser cutting and piercing are non-contact processes, meaning that the laser beam does not physically touch the material being processed. This reduces the risk of damage to the material and minimizes the need for additional finishing processes. laser cutting and piercing are versatile processes that can be used on a wide range of materials, including metals, plastics, wood, and ceramics. This versatility makes laser cutting and piercing a valuable tool for many different industries. it is important to note that laser cutting and piercing can also have some disadvantages. For instance, the equipment required for laser processing can be expensive, and the process may not be suitable for all materials or applications. Additionally, laser cutting and piercing can produce harmful fumes and require proper ventilation and safety measures to be taken. Despite these limitations, the use of laser cutting and piercing continues to expand, driven by ongoing technological advances and increasing demand for high-precision manufacturing processes. As a result, laser cutting and piercing are likely to play an increasingly important role in the future of material processing across many different industries.

Another advantage of laser cutting and piercing is the speed and efficiency of the process. Traditional cutting methods can be slow and labour-intensive, especially when working with complex shapes or designs. Laser cutting and piercing can be automated and controlled through computer programming, allowing for faster and more precise cutting and drilling. In addition, laser cutting and piercing can offer environmental benefits. Because the process generates little waste and does not require the use of cutting fluids or other consumables, it can be a more sustainable and eco-friendly option compared to traditional cutting methods. laser cutting and piercing can be used in combination with other material processing techniques, such as welding or etching, to create complex parts and structures. This versatility makes laser cutting and piercing a valuable tool for many different applications, from industrial manufacturing to artistic and design work. As laser technology continues to evolve, the cost of equipment and the limitations of the process are likely to decrease, making laser cutting and piercing more accessible to a wider range of industries and applications. Ongoing research and development are focused on improving the speed, precision, and safety of the process, as well as expanding the range of materials that can be processed using laser cutting and piercing.

- Laser cutting and piercing offer high precision and reduced material waste.
- Laser cutting and piercing are versatile and can be used on a wide range of materials.
- Laser cutting and piercing are faster and more efficient than traditional cutting methods.
- Laser cutting and piercing can offer environmental benefits.
- Laser cutting and piercing can be used in combination with other material processing techniques.
- Ongoing research and development are focused on improving the process and expanding its applications.
- Laser cutting and piercing are non-contact processes, reducing the risk of material damage.
- The use of computer numerical control (CNC) technology allows for automated and precise cutting and drilling.
- Laser cutting and piercing are especially important in the automotive, aerospace, and electronics industries.
- The equipment required for laser cutting and piercing can be expensive.
- Laser cutting and piercing can produce harmful fumes, requiring proper safety measures.

- Laser cutting and piercing have potential applications in many different industries and fields.
- Laser cutting and piercing can be a more sustainable and eco-friendly option compared to traditional cutting methods.
- The range of materials that can be processed using laser cutting and piercing is likely to expand as technology advances.

Review of literature

(Gunes 2018) studied Effects of Laser-Cutting and Spark Erosion Techniques and Heat Treatment on the Magnetic Properties of Grain-Oriented Transformer Steels discovered that Spark erosion and laser cutting procedures were investigated in terms of the influence that they have on the magnetic characteristics of grain-oriented electrical steels while operating at working frequencies. The maximum permeability value in each scenario was used as a reference point for determining the quantitative impact of cutting and eroding processes, as well as the effects of heat treatment. This was done so that the results could be compared. The specimens were treated to heat treatment at the temperature that was determined to be optimal in order to reduce the amount of degradation that occurs as a result of carrying out the piercing procedure. Through the use of magneto-optical Kerr microscopy, it was possible to detect, during the whole of the domain refinement on the surface, the impact of stress-relief annealing. The domain contrast at the cut edge of the spark-eroded sample was clearly found to be more uniform than that which was supplied" by laser cutting when a high AC-field amplitude was applied. This was seen to be the case when comparing the two methods.
(Guo et al. 2018) studied An effective method of edge deburring for laser surface texturing of Co-Cr-Mo alloy discovered this and It was shown how an efficient approach of edge deburring in laser surface texturing may be achieved. Due to the fact that they are able to store wear debris, micro-dimples that are appropriately oriented on a Co-Cr-Mo alloy may effectively minimise the amount of interfacial friction that occurs. On the other hand, burrs that form around the dimple rim as a result of laser ir ration have a tendency to produce ploughing wear because of the piercing and cutting action they have. The purpose of this research was to assess a strategy for increasing the quality of laser-irradiated textures by applying a layer of frozen water to cover the surface of the texturing substrate. This approach was implemented in order to cover the surface of the texturing substrate. The presence of a layer of frozen water around the periphery of the laser-ablated patterns caused a reduction in both the Young's modulus and the hardness of the substrate material. The integration of the laser texturing technology with the frozen water layer successfully restricted the deburring, and its beneficial mechanism in increasing the quality of textures was also proposed based on the results of the experiments. Irradiation was used as a method, and it was successful in lowering both the friction coefficient and the amount of wear.
(Li et al. 2018) studied A Universal Theoretical Model for Thermal Accumulation in Materials During Repetitive Pulsed Laser Processing discovered this and The goal of this work is to develop a universal theoretical model that can be used to investigate the process of thermal integration that is caused by recurrent pulsed lasers in materials. "Pulsed laser heating is widely used in high-tech industries such as surface processing, thin solid films, laser machining, and three-dimensional (3-D) printing in recent years. As a result, thermal integration in materials induced by laser pulses has become a very important issue. This is due to the fact that thermal integration in materials has become a very important issue. In these laser-based techniques, an understanding of the temperature distribution in the material serves as the foundation for the optimization of process parameters and the control of product quality. In this piece of work, the analytical solution formula for temperature field in materials caused by repeated

pulsed laser heating is mathematically determined using the Green function approach. The Fourier heat transfer theory serves as the foundation for this mathematical derivation. After obtaining the temperature field formula, one must next deduce it into its dimensionless version in order to arrive at an analytical solution that is not reliant on the characteristics of the material. Both the pulse spacing to pulse width (tc/th) ratio and the laser inten- sity ratio are extensively analysed using the dimensionless analytical solution formula in order to evaluate the influence of two major parameters of the laser pulse on the thermal integration process. According to the findings, both the tc/th ratio and the laser intensity ratio have a significant and direct impact on the thermal integration procedure. The thermal integration is primarily controlled by the tc/th ratio for a given setting value of the laser intensity ratio, and the peak temperature difference decreases exponentially as the tc/th ratio (25) increases linearly. There is a certain laser intensity ratio that, in turn, results in a constant temperature distribution. The connection between the peak temperature difference and the laser intensity ratio is linearly, and there is a certain laser intensity ratio that results in a specified cooling duration. In addition to this, the analytical formula is utilised to analyse the temperature distribution in the materials of SiGe thin solid films and fused silica substrates, which was induced by the use of a pulsed laser. Numerous laser-based technologies may stand to benefit from the analytical formula of temperature field if it were applied to thermal integration in materials caused by pulsed lasers.

(Badoniya 2018) studied CO2 Laser Cutting of Different Materials – A Review discovered that, and in laser cutting of a variety of technical materials, cut quality analysis was an issue. The most prevalent process parameters and cut quality attributes were the focus of this investigation, as well as the question of whether or not a DOE design was used and, if so, which one. There is a significant amount of research work being done in the field of laser cutting in order to improve the cut quality. According to the review, the quality of the cut is contingent upon a wide variety of control factors or parameters. These include laser beam parameters (laser power, pulse width, pulse frequency, modes of operation, pulse energy, wavelength, and focal position); material parameters (type, optical and thermal properties, and thickness); assist gas parameters (type and pressure); and processing parameters (such as temperature and pressure) (cutting speed). The influence of these process parameters on a variety of quality characteristics, including material removal rate (MRR), kerf quality characteristics (kerf width, kerf deviation, and kerf taper), surface quality (cut edge surface roughness, surface morphology), metallurgical quality characteristics (recast layer, heat affected zone, oxide layer, and dross inclusions), and mechanical properties, has been investigated by a large number of researchers (hardness, strength). In order to accomplish this goal, the majority of the experimental research have been carried out without making use of the DOE technique. Surprisingly, only a small number of researchers have used the Taguchi experimental approach. Roughly half of the articles that were looked at came to the conclusion that the best cutting parameter settings for the material in question could be found.

(Pocorni et al. 2018) studied Dynamic laser piercing of thick section metals discovered that, and with regards to cut quality analysis in laser cutting of a variety of technical materials. The goal was to determine the most frequent process parameters that were studied, cut quality attributes, and to determine whether or not a DOE design was used and, if so, which one. In the realm of laser cutting, there is a significant amount of research effort being done to improve cut quality. According to the review, the quality of the cut is dependent on a wide variety of control factors or parameters. These include laser beam parameters (laser power, pulse width, pulse frequency, modes of operation, pulse energy, wavelength, and focal position); material parameters (type, optical and thermal properties, and thickness); assist gas parameters (type and pressure); and processing parameters (cutting speed). The influence of these process parameters on a variety of quality characteristics, including material removal

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rate (MRR), kerf quality characteristics (kerf width, kerf deviation, and kerf taper), surface quality (cut edge surface roughness, surface morphology), metallurgical quality characteristics (recast layer, heat affected zone, oxide layer, and dross inclusions), and mechanical properties, has been the subject of investigation by a large number of researchers (hardness, strength). In order to achieve this goal, the majority of the experimental research that have been conducted have been done so without employing the DOE technique. Surprisingly few researchers choose to use the Taguchi experimental design. A little less than half of the papers was being used.

(Hayakawa et al. 2018) studied Study on material removal mechanism in EDM process through observation of discovered that, and material removal from molten metal was observed in order to understand the material removal mechanism that occurs during the electrical discharge machining (EDM) process. Since material removal occurs intermittently not only during the discharge duration but also just after the discharge duration, we hypothesise that one of the possible mechanisms of material removal is the degassing of the solution gas in the molten metal, which will occur when the molten metal resolidifies. This is so because material removal occurs intermittently not only during the discharge duration but also just after the discharge duration. A colour high-speed video camera was used to examine the process of material removal as it occurred during the cooling of a thin steel plate that had been melted by the Joule heating caused by the plate itself. The ratio of the brightness of the three colours shown in the video footage was used to determine the temperature distribution throughout the surface of the plate. It was discovered that material removal took place in air at atmospheric pressure, but that it did not take place in a vacuum environment. In addition, it was discovered that the material was taken away from a certain area during a time when the local temperature was lower than the substance's melting point. Degassing of the solution gas in the molten metal was thus thought to be the process behind the observed loss of material.

(Hajad et al. 2019) studied Laser cutting path optimization with minimum heat accumulation discovered this and In this research, a novel strategy for reducing the length of the cutting path as well as the amount of heat accumulated during the laser cutting process is provided. The suggested approach was derived from a memetic algorithm, which combines a potent genetic algorithm with an adaptable big neighbourhood search. This memetic algorithm provided the basis for the proposed algorithm. The issue of the cutting route was modelled after the generalised travelling salesman problem, and then it was solved using that model. The optimization of the cutting route was done with the use of a heat conduction model, and a critical radius of the heat-affected zone was used as a constraint in the process. In order to reduce the amount of heat that was accumulated in the workpiece, a penalty was applied to the cutting routes that overlapped the heat-affected zone. Along with the optimal cutting route, which was given in order to visualise the degree of heat buildup, a heat map was also presented that indicated the temperature gradient surrounding the laser piercing locations. In contrast to the strategy that did not take into account the heat constraint, the algorithm that took into account the heat effect was able to determine the laser cutting route that accumulated the least amount of heat in the workpiece while still maintaining the shortest possible journey distance. The method that has been presented can also be used for other thermally-related processes, such as surface hardening, welding, and additive manufacturing. These processes, whose processing distance and heat issue need to be optimised in order to gain their productivity and final product quality, are examples of the types of procedures that could use this method.

(Mezera and Römer 2019) studied Model based optimization of process parameters to produce large homogeneous areas of laser-induced periodic surface structures located that, and In this research, a novel strategy for reducing the amount of heat accumulated during the laser cutting process along with the cutting route is provided. A memetic algorithm was used as the foundation for the suggested approach. This technique combines a robust genetic algorithm with an adaptive large neighbourhood search". The issue of the cutting route was based after the travelling salesman problem, and its solution adhered to its parameters. In order to optimise the cutting route, a heat conduction model was introduced into the process by using a critical radius of heat-affected zone as a restriction. In order to reduce the amount of heat that was accumulated in the workpiece, cutting routes that overlapped the heat-affected zone were assessed a penalty. Together with the optimal cutting route, a heat map that shows the temperature gradient surrounding the laser piercing locations was also shown in order to see the amount of heat that has been accumulated. The algorithm that took into account the heat effect was able to determine the laser cutting path that accumulated the least amount of heat in the workpiece and had the shortest possible travel distance. This was determined by comparing it to an approach that did not take into account the heat constraint. The method that has been presented can also be used for other thermally-related processes, such as surface hardening, welding, and additive manufacturing, all of which require the processing distance and heat issue to be optimised in order to achieve the highest possible levels of productivity and quality in the final product.

Conclusion

laser cutting and piercing are highly precise and efficient methods of material processing that offer a wide range of benefits over traditional cutting methods. These benefits include reduced material waste, increased speed and efficiency, and the ability to process a wide variety of materials with high precision. Laser cutting and piercing are especially important in industries such as automotive, aerospace, and electronics, where precision and accuracy are critical. The non-contact nature of the process reduces the risk of material damage, and the use of CNC technology allows for precise and automated cutting and drilling. Despite the limitations of the process, including the cost of equipment and the need for proper safety measures, the potential applications for laser cutting and piercing are vast and expanding. Ongoing research and development are focused on improving the speed, precision, and safety of the process, as well as expanding the range of materials that can be processed. As laser technology continues to advance and become more accessible, it is likely that laser cutting and piercing will play an increasingly important role in the future of material processing across many different industries. The potential benefits of this technology are significant, offering a more efficient and sustainable way of processing materials with greater precision and control.

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