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# Laser welding of explosive filled components

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## ABSTRACT

**Laser welding technology for high precision fixing is widely used as it provides Long term stability and is preferred method for hermetic sealing of explosives filled components. Furthermore, it provides means for semiautomatic, high speed, high yield production. The mechanism of deep penetration welding is by heat transfer via keyhole which acts as a blackbody. The keyhole is filled with gas or vapours created due to continuous vaporization of wall material by the laser beam. When laser beam moves with respect to the substrate, successful deep penetration weld is only possible when movement of this cavity and molten zone achieve a steady state, minimizes the heat affected zone (HAZ). As welding is carried out, the Heat will be generated which can cause the explosion inside the component, so heat generation is required to be controlled. For this Nd:YAG Laser is an appropriate solution which has a proper concentration of energy and also less Heat Affected Zone (HAZ) instead of other Laser like CO2 laser. Here the use of Laser welding is done since it can be efficiently used to weld very small parts, quality of weld achieved is better than other types of welding processes, takes very less time to cool after welding is stopped, the process is noncontact type hence filler material is not required. The Project has a wide scope in studying and analyzing the 'Heat Affected Zone', the 'Quality of Weld'.**

*Keywords*— ***Laser welding, Nd:YAG Laser, HAZ.***

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## I. INTRODUCTION

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term "laser" originated as an acronym for "light amplification by stimulated emission of radiation". A laser differs from other sources of light because it emits light coherently. Lasers have been used for various applications in Armaments e.g., beam welding for explosive filled devices, machining of explosives, Rapid detection of Explosives, ignition of high explosives, Auto-kinesis free optical Instruments, beam guidance, Designator, Laser Gun as al weapons, rangefinders, Proximity Sensor etc., High power laser welding is ideally suited for hermetic sealing of explosive filled components. In this project, the laser is being used, as welding is to be done to a component having explosive filled in it.

The main purpose behind the use of laser welding and specially Nd:YAG laser welding is that, the rate of cooling is fast in laser welding as compared to other welding process, moreover the object or area to be welded is so small that to get the desired accuracy the only option is laser welding. Even the Quality of the weld, which is obtained, is of high grade then the other methods.

The paper focuses on the study of hermetic sealing of explosive filled components using laser-welding process. The devices are SCD Ignitor, SCD Detonators, Micro Electric Detonators, Fuze, Bombs and Missiles.

Initially these components are sealed using a turn-over process, i.e. turning the edge to seal the component which wasn't an airtight sealing. Moreover, due to turnover the bulging of component takes place, which makes it difficult

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to fit in the desired position. Thus the process of turnover even though easier and cheaper won't fulfill the requirement of the work.

The criticality of not achieving an air tight sealing is that the life of the component is reduced and which also increase the hazards related with machining and actual assembling of the component.

To overcome this problem Laser welding and Electron beam welding can be used, but due the cost involved in electron beam welding this process is not used, instead Laser welding is preferred which gives the same result at a cheaper rate.

## II. LITERATURE REVIEW

Virendra kumar et al. in paper discuss about the Electro Explosives Devices (EED) such as Semiconductor Bridge (SCB) Detonator and Micro Electric Detonator (MED). Here the briefing of different test that are carried out over EED are given, which helps us in knowing the recent EEDs that are manufactured in ARDE and also their properties. The specification given helps in understanding the exact dimension and work zone of the project [1].

Virendra kumar et al. in this paper, the description regarding the initiation of SCB ignitor is studied and the results show that it is safe as per the standards of ARDE. Thus it helps us in understanding the limit to which the output parameters of welding should reach to achieve a safe welding of object without initiating the explosive. As this is the main objective of the work [2].

Virendra kumar et al. the paper deals with different researches in armaments which include beam welding of explosive filled components, machining of explosives, ignition of high explosives and etc. High power laser welding is ideally suited for hermetic sealing of explosive filled components. Due to the advantages that accrue out of using laser-initiated devices, use of laser energy to initiate or ignite energetic materials has been a subject of several analytical and experimental investigations. Here in this paper the principle and Laser system required for each application is described [9].

I Nawi et al., laser welding has been widely used in the manufacturing industry especially in the fabrication of small components for photonics, electronics, aerospace, biomedical, micro-electromechanical systems (MEMS), microelectro-opt mechanical systems (MEOMS) and other applications. Although pulsed Nd:YAG laser welding has been widely used in microelectronics and photonics packaging industry, a full understanding of various phenomena involved is still a matter of trials and speculations. Here an ultra-compact pulsed Nd:YAG laser with wavelength of 1.064 μm has been used to produce a spot weld on stainless steel 304. The paper examines the effect of all the parameter of laser welding for the study of micro welding [10].

I Naim et al., laser welding is a vital jointing technique for various materials with their increasing implementation across a wide range of manufacturing environments ranging from medical, automotive, aerospace, defence and photonics. Here the authors did the research work and the recent progress in pulsed neodymium-doped yttrium aluminium garnet (Nd:YAG) laser welding technique, which are critically reviewed. The various parameters of the (Nd:YAG) laser welding of numerous material has been studied.The paper is a review of previous study on Nd:YAG laser welding, which gives the base for future studies [3].

## III. DESIGN METHODOLOGY

The miniature design is EED is made, in which the dimensions are reduced. The new design is completed with two pin and single pin EED. The parts consist of Header assembly in which the pin is fitted a slot of 1 mm *1 mm is made where the explosive will be filled, and to close the cup is made. The parts of SCB igntor or Detonator are as follows:

1. Cup
2. Header
3. Pin 1
4. Pin 2
5. Disc
6. Bush

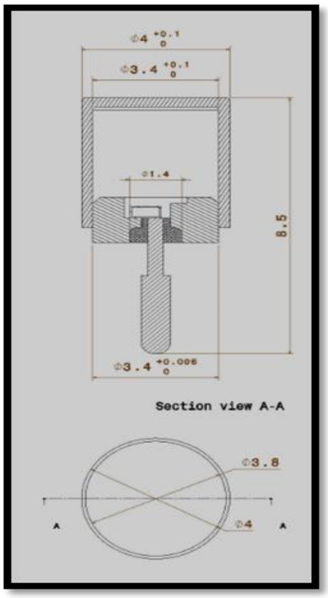


Figure No. 1: Assembly of Micro Electric Detonator

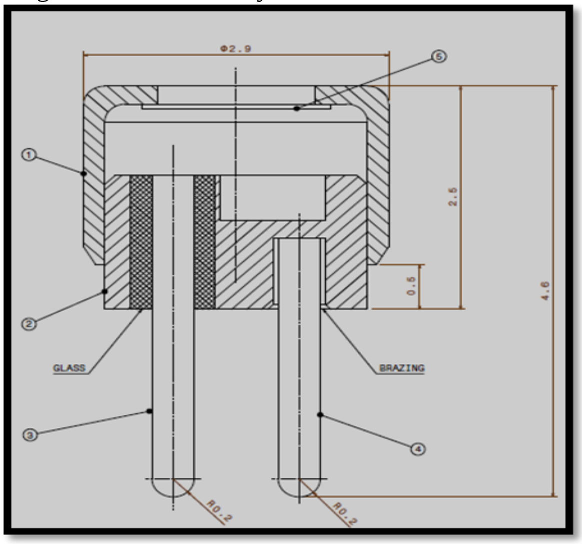


Figure No. 2: Assembly of Miniature SCB Ignitor.

### A. *Experimental Setup:*

Advances in manufacturing technology and the trends for smaller part geometry have opened the door for new metal-joining applications where traditional TIG and resistance welding methods no longer meet precision, quality, or productivity requirements. Pulsed Nd:YAG laser spot welding technology is now being used to replace these processes, often with increased productivity and lower overall cost.

Nd:YAG laser spot welding eliminates problems associated with resistance welding. Spot welding is the simplest form of laser welding. There are two types of spot welding modes: conduction and penetration. The conduction welding mode is employed for micro-joining purposes. Penetration welding permits aspect ratios (ratio of depth to width) much higher than unity. Related to the process are parameters such as the welding speed, the focal length of the beam, focusing lens, the work-piece position relative to the beam focal point and the shielding gas type and flow characteristics. The above are the requirements of the laser welding in this project thus the machine of standard specification available in the market is used, the machine in the figure is the one over which the welding is done to the specimen.

The machine is assembled with a roller conveyor which will provide the raw specimen to the machine and will remove the finished product. This will help in achieving the aim of mass production, and the gradually the price of finishing the Ignitor or Detonator will reduce drastically. This makes the process quality, quantity and cost effective.

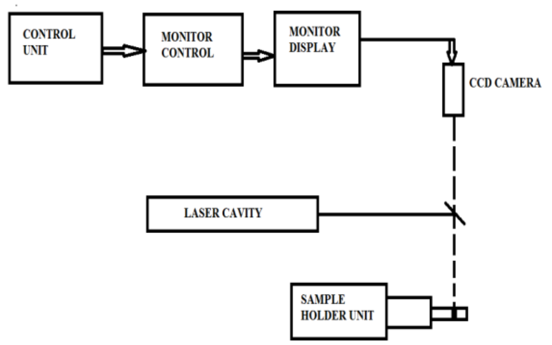


Figure No. 3: Schematic view of Laser Welding Machine

Figure No. 4: Actual Nd:YAG Laser welding Machine.

***B. Calculation of Depth Of Penetration:***

The object to be tested is very small in size thus there is a need to first check the depth of penetration that will take place in the process as the object contain explosive material inside. This is also important as we have to weld the object for hermetic sealing.

A model of Penetration Depth is as follows:

$(l_p) = ((1-R) * P_P * \tau) / (\pi * r^2 * \rho *(L_m + c * (T_m - T_o)))$ (1)

Where, R is the reflectivity, $P_p$ is the power, $L_m$ is the latent heat of the material, $T_m$ is the melting temperature, $T_o$ is the ambient temperature, c is the specific heat, ρ is the material density, r is the laser spot radius and τ is the heat absorption duration.

Depth of Penetration $(l_p)$= 0.56 mm.

***C. Temperature Model:***

The testing done is on the cylindrical surface of radius 'a' at uniform temperature 'Tv'moving with constant speed of 'v' along x-direction in a sample the initial temperature is 'T0'. The thermal gradient in z-direction is smaller than in x and y direction. In the Cartesian coordinate system x denotes the welding direction, z the coordinate in the beam direction and y the perpendicular to both the geometry of keyhole is calculated in the x-z plane.

$T_{(x,y,z)} - T0 = (Q/2*\Pi*\alpha) * \exp(-v*x/2*\alpha) * \exp(-v*r/2*\alpha) / r$ (2)

Where, $T_0$ is the initial temperature and

$T_v$ is the vaporization temperature

$T_{(x,y,z)}$is the temperature of sample at xyz

α is a thermal diffusivity

With the help of this equation we can calculate inside temperature at different location.

This helps in getting approximate temperature inside the sample.

Table 1: Theoretical calculation of Temperature.

| Sr.No. | Power 'q' in Watt (W) | Temperature 'T' ($^0$C) |
|---|---|---|
| 1. | 25 | 89.07 |
| 2. | 26 | 91.24 |
| 3. | 27 | 93.4 |
| 4. | 28 | 95.56 |
| 5. | 29 | 97.73 |
| 6. | 30 | 99.9 |

## IV. EXPERIMENTAL RESULTS

The laser system available was Nd:YAG with the varying Power, the Pulse width can also be varied. The beam energy used for the laser welding is set and then the final result is checked. The spot size of the laser beam after focusing is 0.3 mm. The energy of the laser can be varied by varying the electrical supply.

Total five samples were tested and the results were follows.

Table 2. Experimental Results.

| SAMPLE | POWER (W) | PULSED DURATION (mS) | FREQUENCY (Hz) | TEMPERATURE (T) | REMARKS |
|---|---|---|---|---|---|
| 1. | 31 | 4.7 | 4.8 | 102 | Good |
| 2. | 31 | 4.6 | 4.8 | 101 | Good |
| 3. | 30 | 4.7 | 4.8 | 100 | Good |
| 4. | 22 | 3.2 | 2.9 | 83 | Good |

 

| | | | | | |
|---|---|---|---|---|---|
| 5. | 23 | 3.2 | 2.9 | 85 | Good |

Figure No. 5: Semiconductor Bridge (SCB) Ignitor.

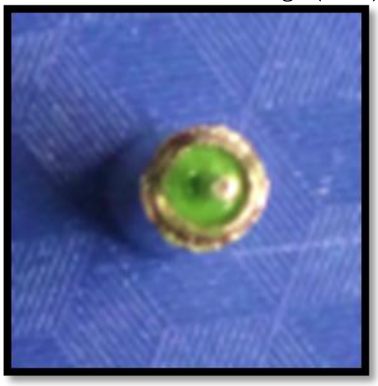

Figure No. 6: Micro Electric Detonator (MED)

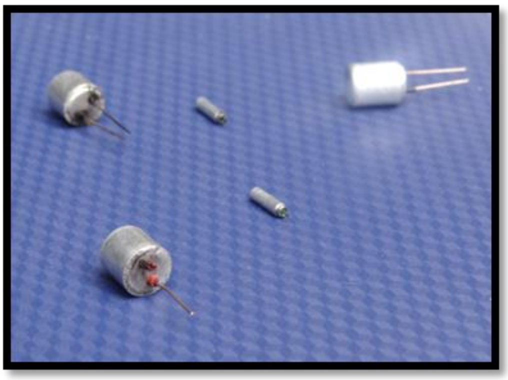

Figure No. 7: All Tested Samples

## V. CONCLUSION

The total sample welded are five in number (three SCB Ignitor and two MED), the result shows that the welding is ok and acceptable, more-over if less brittle material can be used the surface finish will be even better and more uniform welding can be achieved. Even the Hermetic sealing (Air-tight sealing) is possible using the laser welding process.

The arrangement of conveyor makes the process cost effective. The conveyor helps in getting the mass production of the SCB Ignitor's and MED's.

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## REFERENCES

[1] Virendra Kumar, Semiconductor Bridge (SCB) based highly reliable,safe and ultra-fast initiator forfighter aircrafts and advanced armaments. Presented at 65th AGM & conference Hyderabad 2014.

[2] Virendra Kumar, Semiconductor Bridge (SCB) based miniature explosive devices. Presented in 3th international conference " Nanocon014.

[3] Naim I., An Investigation of a Pulsed Nd:YAG Laser Welding Technique. (IEEE-RSM Proc. 2009, Kota Bharu, Malaysia)

[4] MalekGhaini F., Weld metal microstructural characteristics in pulsed Nd: YAG laser welding.(Published by Elsevier Ltd., ScriptaMaterialia 56 (2007) 955–958)

[5] Naeem Mohammed Microwelding Performance Comparison Between A Low Power (125w) Pulsed Nd: YAG Laser And a Low Power (100-200w) Single Mode Fiber Laser.(Proceedings of the 3rd Pacific International Conference

[6] Olsson R., Pulsed laser weld quality monitoring by the statistical analysis of reflected light.(Luleå University of Technology, SE-971 87 Luleå, Sweden).

[7] Nd:YAG Laser Welding Guide by UnitekMiyachi Corporation.

[8] Kompitsas M., Laser Induced Plasma Spectroscopy (Lips) as an Efficient Method For Elemental Analysis of Environmental Samples.(Proceedings of EARSeL-SIG-Workshop LIDAR, June 16 – 17, 2000).

[9] VirendraKumar,Laser Applications in Armaments.(Armament Research and Development Establishment, PUNE High Energy Materials Research Laboratory, PUNE).

[10] Nawi I.N., Nd:YAG Laser Welding of Stainless Steel 304 for Photonics Device Packaging. (2nd International Science, Social Science, Engineering and Energy Conference 2010:8 (2011)374–379).

[11] Sokolov Mikhail, Methods for improving laser beam welding efficiency. (8th International Conference on Photonic Technologies 2014, 56 ( 2014 ) 450 – 457)

[12] Tadamalle A. P., Evaluation of Nd: YAG Laser Welding Efficiencies for 304L Stainless Steel. (3rd International Conference on Materials Processing and Characterization 6 ( 2014 ) 1731 – 1739).

[13] Fuerschbach Phillip W., Understanding Metal Vaporization from Laser Welding. (Prepared by Sandia National Laboratories Albuquerque, Issued by Sandia National Laboratories, operated for the United States Department of Energy bySandia Corporation.).

[14] 14. Norris Jerome T., Evaluation of Weld Porosity in Laser Beam Seam Welds: Optimizing Continuous Wave and Square Wave Modulated processes.(Prepared by Sandia National Laboratories Albuquerque, Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.).

[15 Norris J. T., Pulse Shaping Effects on Weld Porosity

 

] in Laser Beam Spot Welds: Contrast of Long & Short Pulse Welds. (Prepared by Sandia National Laboratories Albuquerque, Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.).

[16] Madison Jonathan D., Porosity in Millimeter-Scale Welds of Stainless Steel: Three-Dimensional Characterization. (Prepared by Sandia National Laboratories Albuquerque, Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.).

[17] J DuttaMajumdar, Laser Processing of Material. (Sadhana Volume 28, Part 3 & 4, June/ August 2003).

[18] Axel Lundberg, Temperature profiles and hardness of laser weld HAZ. Published in June 2014.

 