Title of the Research Project

<Student Name>

<Student Number>

A report submitted for

300597 Master Project 1

in partial fulfillment of the requirements for the degree of

<For example, Master of Engineering>

Supervisor: <XXX>

<Month Year>

Contents

Executive Summary 3
Introduction 5
Literature Review 13
- Advancement in Welding dissimilar metal for Industry 13
- Dissimilar weldments and welding process 16
- Laser Welding of Magnesium Alloy and stainless steel 17
- Welding of dissimilar metals in different geometries 19
- Spot welding of the dissimilar metals for steel family 20
- Dissimilar metals and friction stir welding practice 21
- YAG pulsed Laser Welding of dissimilar metals 22
- Laser-assisted Friction Stir Welding 23
- Numerical study of heat modes and laser welding 26
- Application of Laser in seam welding process for dissimilar welding 28
- Numerical simulation and laser welding 29
- Distortion of titanium and aluminum weld with the laser beam welding 31
- Advanced High strength steel sheets and dissimilar laser welding 35
- Multiphysical modeling of transport phenomena 36

Methodology 37
Project Development, Data Collection, Data Analysis 40
- Need Analysis 40
- Concept Design 42
- Detail design 44
- Prototyping and Validation 47

Results and Discussion 50
Conclusion and Recommendation 57
References 60

Title: Investigation For Dissimilar Welding Metal

Executive Summary

The area of investigation is based on the welding of two dissimilar metals. The study will investigate the problems and issues present in welding two dissimilar metals. It will also look to analyze the present advanced welding techniques. The first area will be a brief background of the defects and issues present in dissimilar metals welding. The most prominent issues for welding are the formation of porosity and cracks which affect the surface finish had properties of the weld metal. Anotherarea is the microstructure and mechanicalproperties for the weld metal. This study will introduce the cause if research. The research question will be related to the surface defects present in the weld metal. It will also provide information for solubility levels for two dissimilarmetals. This study will also provide information to maximize the properties and weldingprocedures for two dissimilar metals.

The example ofdissimilar metals will be gathered from the serviceindustry. The basic elements will be Aluminum,Steel, and NickelAlloys. Theproxies which are identified for the dissimilar metals are higher corrosion resistance,lightweight, higher fuel efficiency and less energy consumption. Heatinputs and distortion produces defects in the conventional weldingprocessing order to provide innovation friction stir welding, laserwelding and blazing will be discussed in the study. The research methodology in the study will base on the deductive and descriptive approach for the result. The data will be gathered from the primary and secondary sources. Literature survey will be the key element for providing advance knowledgeof welding procedures. Laserwelding technique will be used as the main advance technique.

The main change was proposed in the process parameters.Results showed that laser welding could improve the mechanical properties of two dissimilarmetals. It was also found that phase diagrams provide much information for the dissimilar weldingtechniques. The study will provide information about the simulation of laser welding to achieve optimum mechanical properties. It was recommended that simulation should be performed before welding two dissimilarmetals. This will not only predict the relationship between two dissimilar metals but also help to reduce the surface defects for metals.

Introduction

Dissimilar metals welding is a phenomenon in which two or more metals or elements are joined together with the help of energy. The materials are selected on the base of properties. Two metals which have same properties can be joined with the help of welding techniques like friction stir welding or laser welding. The concept of dissimilar metal is explained as two metals which have different chemical and physical properties(Carlone, et al., 2015). The welding procedure of these two metals will provide a new material which has combine properties related toboth joining materials.

This process is important for areas like construction, automotive and electronics because different office metals are required to be weld together(Carlone, et al., 2015).Thissaves the cost of operations and provides pest properties for both metals. Injoiningdissimilarmetals, the internal processand changes should be reviews as an important part of welding procedures.Two dissimilar metals have different type of properties.

Welding and Solubility

In studying the welding of two dissimilar metals solubility remains the important part of the properties. It is required that two metals tend to fuse at a higher temperature and do notaffect the bond strength.The solubility of the metal is important because it determines which type of welding treatment will be required and how much energy will be consumed for dissolved the base metal in comparison with the joined metal. Ifthe solubility of two metal is not provideda problem, then the welding procedure will fail. In joining two dissimilarmetals,sufficient research is required for the intermetallic compounds(Gupta, et al., 2018.). Crack sensitivity and restraint to corrosion is the main factor which defines the welding od two dissimilar metals. The intermetallic compounds add towards the buffering layer.

The area of weldability also defines the concept of solubility of two dissimilar metals. This will prevent the formation of a crack in weld metal and reduce any consequences for dissimilar metals. Different metals are welded together to maximize the benefits and properties of weld metals. This can be explained clearer by considering the example of Aluminum and steel as the two dissimilar metals(Casalino, et al., 2016). Theproperties of steelinclude the strength and durability.It is also cheaplyavailable compared to Aluminum which has less strength and is not commonly available in the market. The main property of Aluminum is resistant to corrosion. The welding of Aluminum and Steel will provide a combination of higher corrosion resistance and weldability.

Carbon Equivalency and welding

Carbon Equivalency is defined as the element contribution in determining the chemical and mechanical properties.A higher percentage of carbon will be indicated that bond between two metals will face resistance from intermetallic layers. Carbon Equivalency for two metal is also required to be passed before welding two metals. This percentage is calculated on the base of a percentage of Manganese and silicon levels.Chromium is also determined as the significant percentage for corrosionresistant.Most of the welding of materials is made to increase the corrosion resistantto materials.(Gupta, et al., 2018.)

Thermal expansion is also thecentral point for welding of dissimilar metals. Change in temperature also predicts the properties of two weldmetals. One of the commonproblems in welding two dissimilarmetals is present of hydrogen and cracks. When an external pressure or heat has applied the cracks or disowning takes places(Ataya, et al., 2016).This led to the failure of the welding practice. It can also reduce the operating life of weld metal in the service industry as well as application.

Dissimilarmetals welding combinesphysical and chemical properties with the welding technique. Over the latest years, there has been an improvement in conventional weldingtechniques. Welding process has been improved with the application of technology and new welding procedures(Fu, et al., 2015). Now two dissimilar metals can be easily welded without any chances of failures. It is also an example of technological advancement. Welding of two different materials also applies to the fabrication process.

The major problems with the welding techniques of dissimilar metals are the heat input,and distortion produces by conventional methods and designs(Casalino, 2017). Most of the weld material is spattered with the application of heat. Also, light materials like Aluminum lose the strength and durability from the heat affectedzone. Thisreduced the quality of weld material and failures are faced by the construction as well as fabrication industry.

Advanced Welding Process

Six different type of advanced welding process has been developed to reduce the central issues of dissimilarmetals. First is the Magnetic arc welding(Fu, et al., 2015). In this technique, a magnetic field is used for welding two dissimilar metals.If Aluminum and steel are welded with the help of magnetic arc welding hen less clean up time will be required,andit will improve the finish of the weld material.The application for this techniqueisdiverse, the overall welding equipment is expensive,but the applicationis advanced for dissimilar metals.

Friction stir welding technique is the most advanced level mechanism used to weld dissimilar metals. It used friction as a major element for creating heat input. The pieces are joined togated by using the opposite forces of rotation.Friction stir welding is important for good mechanical properties(Carlone, et al., 2015). There are fewer elements of cracks and porosity present in the final weldmetal. The product surface finish is also acceptable,and itis used in the service industry for railroad tracks as well as heavy machinery parts.

A common example is the welding of aluminum with steel,Resistance spot welding and brazing are also the most advanced form for welding two dismalmetal. This has called metals and allowedfor welding regardless of the nature of materials(Gupta, et al., 2018.).For example, stainless steel and shape memory alloys are welding forexcellent application in a biocompatible material.This has provided a great deal of advancement to welding practices and expandedthe scope of material science for fabrication as well as the automotive industry.

Use of conventional Welding

Advancement in welding can only be made by analyzing the old welding process and innovating the welding scheme with the help of available tools. This will look for the dependency in tungsten metal arc welding and shielded metal arc welding as the principal techniques for welding.Most of the Automotive companies have replaced the conventionalTig welding process with the advancementfriction stir welding. This technique not only saves time also buyan asset is casting and forging for the automotiveparts(Jafarlou, et al., 2015).

Anotheradvanced technique which is usedin modern welding is the brute force technique. Explosivesare sued as an element of heat input to weld two dissimilarmetals. Two metals arepressed against each other with the help of explosives. This also reduced the problems for heavystructures(Bandyopadhyay, et al., 2016). The main application of the is technique is for the tube materials and heat exchanges for ships.

Selected Advancement

The most important and center of the discussion is the laser welding process. In this technique, a small and thin beam of light is used for welding two dissimilarmetals. Theconventional process use for weldingwasgas arc welding and ferrous dissimilar metals welding.These were conventional methods of welding(Casalino, 2017). The main difficulties were the hydrogen-inducedabsorption which causes cracking of weldmaterials.

The presence of phosphorus and Sulphur create heat affected zones which decrease the quality of the weld material.The advanced level of welding is the laser welding(Carlone, et al., 2015). Thisincludes laser which isefficient for welding details like steel, Aluminum,andTitanium. Stainless steel is also an important material used in the advancewelding process for the dissimilarweld metals.

Laser welding is a technique favored in the concept of materialscience. It has certain advantages over the conventionalweldingprocess of TIG welding as well as Arc welding. Dissimilar metal weldingis relatedto the application in service and fabrication industry(Jafarlou, et al., 2015). The application is related toelectronics and consumer goods. There are considerable challenges present for welding dissimilar metal. One of the true areas for problems are the properties required for the two metal.

Problems for welding

One of the basicproblemsis related with the size and manufacturing process for the weld materials. The application for the dissimilar metal is distributed in every part of the fabrication industry where the demandfor steel and aluminum is made(Elangovan, 2016). The most common process is related with the melting of two different metals until a strong connection is made for weld materials. The process of making a solid bond between the dissimilarmetal is the main area where advancement has been made. This problem basically forms the attraction of laser welding.

Laser weldingremoves the problems for bond and transition zone because the heat input for the materials is quite higher. The welding is also made in short intervals(Vashishtha, et al., 2017). Thereis less time present for both dissimilarmetals to go in the transition zone and Austenite formation is removed from the laser medium.

Laser welding also helps to provide a thick buffering layer on the weldmaterial. The heat input level is higher for the weldingsource. The most common example of the weld materialis the stainless tell with the additional amount of chromium and carbon alloy with a moderate percentage of Carbon(Casalino, 2017).

Welding of two dissimilar metals

Two dissimilar metal are welded to achieve optimum properties for the work. Forexample, is its required to weld iron with steel for the railway line fatigue resistance and higher toughness will be required. This will be achieved by welding iron with steel. Both of the materials can add towards the strength and stability of bond(Ataya, et al., 2016). Laser technique has solved the complexissues for bond formation and strength of weld metals.

Using the welding concept of two dissimilarmetals, it is also important to analyze the improvement made in the weldingprocedure(Pourali, et al., 2017). One of the commonexamples is the process of welding Aluminum and Steel. Both of the metal has different melting and boiling points. Laserwelding helps to advance the level of welding procedures for both materials.Steel surface requires to have a strong buffering layer which can allow Aluminum to make a strong bond with the base metal. Laser welding helps to meltaluminum and apply a thick coating on steel surface to strengthen the welding procedure.

If aluminum and stainless are examined for dissimilar welding procedure then aluminum coating is applied to stainlesssteel. In the conventional practice, the welding was carried by dipping one of stainless steel into molten aluminum to strengthen the weld bond.The advancedtechnique is the use of laser technique for welding stainless steel and molten aluminum(Yuan, et al., 2017).

Welding Aluminum to copper is also an example which was used by the conventional welding process. The main advancement is the application of new techniques to improve the output of weld material. Friction stir welding can be used as an element to weldaluminum with Copper(Jafarlou, et al., 2015).Copper stands tough as compared to aluminum.The base element will be copper and aluminum will be fused to forma bond.

If the application of the dissimilar welding is studied under the concept of the study, the most advancement made in welding techniquesis related with the industrialapplication(Denlinger, et al., 2017). Theautomotive industry raised the demand for aluminumstructures,and welding was required to select from improved welding procedures.Aerospace industries also dependent on Aluminum and Tungsten as the based metals.The weld of two materials would require excellent strength and lightweightstructures(Yuan, et al., 2017). Automotive and aerospace industryemployed the use of laser welding techniques to forms a pressure resistantstructure for airplaneapplications.

If the laser is divided in a subcategory, then fiber lasers will provide an important advancement for welding dissimilar metals. Thelaser-wielding can be carried out using fit and forget technology. The main application of technology is to createa reliablesolution for the fabricationindustry and reduce the loss of energy for steel structures as well as aluminumproducts(Gupta, et al., 2018.). In the fiber laser technique,three are problems related to the physical or mechanical properties to metals required for the weldingprocess. The lasercontrols the welding process and has a higher range of application for metal including copper, steel,andaluminum.These three metals are the most widely used material for construction as well as fabrication industry(Denlinger, et al., 2017).

The majorbenefit for dissimilar welding is the large pool of applications. The weld producing from the laser can be used for automotive as well as the aerospace industry.The laser welding can also use Red energy G4 as the suitable type for welding two dissimilar metal(Elangovan, 2016).The issuesrelatedtohydrogen-induced cracking and disbanding of metalscan also be solved using a laser as a mode of welding.

Another solid justification for selecting laser as the part of the research study is improvement and advancement which can be carried for the laser material. It is a broad area,but laser composition can be modified to required welding for the selected materials. This willadd towards a benefit for the study.The main benefit is to reduce the cost it welding time(Bandyopadhyay, et al., 2016).By increasing the speed of the tool different metals can be welded under the same apparatus. Only the positions and layout of the base metals will change to provide optimum properties.

Research Question

This project will analyze the advanced level of techniques used for welding. The research question is characterized as

- What are the problems present for welding in presentcondition?

- How are the two dissimilar metals joined?
- What is the advanced level of welding techniques present to modify for study?

Literature Review

Dissimilar metal hasbeen joined with numerous techniques present in the welding science. The most advanced techniques are related to spot welding, frictionstirwelding,and laser welding. Of all Laser,welding will be studiedas a main part of the research.

Advancement in Welding dissimilar metal for Industry

Casalino provides a considerable fact related to the welding of similar metal using Laser and a post welding technique as the center of the discussion(Casalino, 2017). Themainrequirement is strong and lightweightstructures which can bear more pressure and remain multi-function.For this requirement, metal is joined for industrial applications. The author states that laser beam and electron welding process help for conventional as well as non-conventionalprocedures. In the study,the authorprovides as a solid demonstration that laser can be used to provide excellent results for welding two dissimilarmetal. Theapplication for the materials will remain for the automotive and aerospace sector. Aerospace and automotive sector will remain the top profile industry where welding application is present(Ding, et al., 2015).

In a study made by Yuce, process parameters for fiber laser welded dissimilar HSLA,and Mart steel joints were investigated for the advancement of the laser welding. The main area was related with the automotive industry where the safety and fuel efficiencywere related with the laser welding techniques(K.Kalaiselvan, et al., 2018).An important description for is the behavior of two dissimilar materials when the welding process is carried out.

Importance in the automotive industry

Welding plays an important part in the joining process used in the automotive industry. Laser welding has been as the most important and advanced method for welding procedure. The authorperformed brief research on the microstructure and process parameters. Themain significance of the study is the welding of high strength and low alloy steel in relation with the martensitic steels. These two metals were welded with the help of fiber laser technique(Yuce, et al., 2016). Themain information was relatedto the microstructure of the final wed materials. Welding speed was the main parameter which affectsthe quality of the weld.When laser power was increased more heat, output was recorded for HSLA and MART steels. Itwas found from the study that laser power is the defining parameter for good weld profiles for two dissimilar metals.

According to the author, the microstructure of HSLA consisted of a ferrite matrix where carbides in the form of dispersed grains were present in the sample cross section. The study proposed valuable information for tensile properties as well asthe microstructure(Hagqvist, 2015). The results of the study show themaximum hardness has been achieved with the help of laser technology. According to author fiber laser technique was successful inproviding strength and corrosion resistantproperties for HSLAS and MART steels.

Space for Modification

The author also reviews the laser welding procedures for the dissimilar metal. In his study, he provided information relatedto the metal and alloys which can be used for the laser welding.The study shows that properties related to heat and corrosion can be modified with the help of laser welding procedures(Harwani & Banker, 2014). It has been accepted that the combination of two dissimilar metal provides challenges regarding physical and chemical properties.

Challenges related to welding

Challenges related tothe joining of two dissimilar metal can be solved with the help of laser welding. This weldingis termed as the higher power source which is quite different from the conventional welding process. According to the author, there are some principal characteristics present for the laser welding process(Gerasimenko, et al., 2017). Thisincludes the low distortion, weld bead and process flexibility for joining two dissimilar metal on the base of properties and design.

Author along with other co-authors have described the useful application of laser welding on an advanced level;thisincludes the application of focused CO_2 laser to provide aid in the conventional joining process. The most distinguished feature of laser welding is the weld quality as well as the components which are used for welding two metals(Harwani & Banker, 2014). This study is connected with the major application on an industrial level.The authorexplores the characteristics and implementation of laser for welding procedures.

Dissimilar metals are joined in various type of application including the components for the power generation where aluminum and steel are the most preferred element in the industry. Petrochemicalindustry will utilize higherstructure and columns(Harwani & Banker, 2014).Stainless steel and Iron are the preferred materials for welding. Weldingincreases the strength of the final product. This product is applied to withstand higher modes of pressure.

Practical Example

The choice of welding two dissimilar metals, for example,Aluminum and Copper have openedpathways for engineeringmaterials(Gupta, et al., 2018.).It has also allowed flexibility in designing of components.According to author laser welding can be used for low welding carbon and high strength. Thecomposition of the metal will remain the main deciding factor for applying the laser welding procedure. Author has also provided some of the common problems present in the laser welding(Fu, et al., 2015). The most prominent is the existence of prosperity level in the weldaffected area which can be prone to cracks and disbanding. Theconceptional fusion weldingprocess in simple terms provided less disbanding.When the laser is applied, a high solidification pattern is observed in the heat affectedzone. Thisled towards the area of porosity. Formation of voids and empty spaces is also an example of the crack formed during the process of welding.

Wang along with co-authors Chen and Qiuhong also provide a solid overview for the welding of dissimilar metals. The specific example was related toaluminumbonding with steel.A basic purpose of reducingweight for aircraft carriers was present behind welding of dissimilar metals. The main advantage was related with the practical problems related to the fuel consumption(Wang, et al., 2016).Laser welding also provides problems related with the physical and chemical properties of weld area and heat affected zones.The laser technique is best,andan advanced form of weldingprocedure which controls the amount of heat required for aluminum as well as the meltingtemperature of steelis also focusedon the welding procedure(Jafarlou, et al., 2015).

The author states some problems present in the Laser welding of Aluminum and Steel. The density and melting temperature of steel and aluminum are different. Laser tends to weld both materials by macroscale segregation is created for both the materials(Harwani & Banker, 2014). This is to the poor mechanical properties of the weld joint who can lead to future of the bond.

Dissimilar weldments and welding process

Himanshu and co-authors also provide solid evidence for welding two dissimilar metals and analyzing the microstructure and mechanical properties of the dissimilar weldments(Vashishtha, et al., 2017).The metals which were studied were the conventional authentic stainless steels. Thecentralimportance for studied the high nitrogen stainless tells was the demand for excellent strength andductility. The weld of austenitic stainless steel has higher ductility and corrosion resistant as compared to the conventional steels used in the service industry. A different in composition and properties are present between stainless steel and those in which nitrogen is added as a supplement to increase the hardness and strength.

The study was an advancedlevel for the welding process because the joining of two dissimilarweld metals was studied for the change in properties and mechanicalstructure.The high nitrogen stainless is classifiedinto four different types(Vashishtha, et al., 2017). One of the categoriesincludes martensitic while the other is the duplex stainless steel. The study proposed that fusion welding process be the best-employedwelding technique for stainless steels. Some of the challenges associated with the conventional technique are porosity and formation of cracks on the subsurface of the materials.

In austeniticsteel, the presence of ferrite elements is the indicator for the formation of cracks.This also reduces the toughness level of the finalweldment(Vashishtha, et al., 2017). In order to deal with the problem of porosity and toughness stainless were modified in chemical composition by adding nitrogen as the centralelement. The author found that the joining of twodissimilar metal was a complex phenomenon.Weld defects were present the forms of small cracks and low quality of the weldmetal. The conventional techniques of welding were to use to provide substantialinformation aboutthe weldingprocess. The study shoes that dissimilar metals can be welding with advanced joining procedures(Vashishtha, et al., 2017).The problems and challenges for fusion also remain animportant part of the study.

Laser Welding of Magnesium Alloy and stainless steel

A study made by Casalino and co-authors provide information for the laser welding tow dissimilar metals. This paper is based on the chances and feasibility of welding stainless steel with magnesium alloy using the advanced welding technique of fiber laser(Casalino, et al., 2016).The joining configuration was related with the butt weld. Thebasic measure of weldability can be definedinform the thermal properties and metallurgical characteristics.

The paper described welding magnesium plate with a stainless-steelsurface. One of the most critical information was related with the offset welding where the laserwas used a targeted medium. The metallurgical properties of weldment shoe that a good quality of fusion zone was developed between two metals(Casalino, 2017). The study also accounted the offset laser welding to be an important part of the bonding and tensile strength.

According to the author, there is a strong justification present for the joining procedures of magnesium alloys with stainless steel(Casalino, 2017).This is because the automotive and aerospace industries have a higherproportion of demand for the magnesium alloys along with the support of stainless-steelstructures. Thebasic area of application is the light metal design used for the construction of light structures.A reliable method of welding is required to weld magnesium with stainless steel.

Focusing on magnesium alloys, maincharacteristics are related with a tendency to oxidize othermetals. This man feature has allowed the used of fiber laser to carry out a strong weldment of magnesium alloy with stainless steel(Casalino, 2017). According to Casalino, magnesium alloys can also be joined with the help of Ultrasonic and friction stir welding. The research on these welding advancementsprovides that some of the defects of weldment metal and porosity were present for the friction aspot welding of magnesium alloys with stainless eel.

In this study,the laser welding technique was proved for feasible welding results. The fusion of two metals was related with the choice of base metals. Itwas found from the study that a thin layer of weldment was formed between magnesium and steel(Casalino, 2017). Laser beam help to prevent the losses of the alloying element and the number of welding defects were avoided with the help of welding technique.

Welding of dissimilar metals in different geometries

Satoh and co-authors Brandal and Naveed provide a new and more advanced approach for the dissimilarmetalsregardinglaserwelding(Satoh, et al., 2017). This procedure was also application specific. Thejoining of two dissimilar metals was required for the biocompatiblematerials. Laser welding was the most optimized technique used for this process.The successful joining of metal will help to revolutionize the implant services in the medical sector.

In this study, the metals were stainless steel and shape memory alloys likenickel and titanium.These metals are best selected for implant services as their bonds have higher strength, and they are resistant to the process of oxidation andcorrosion(Satoh, et al., 2017). The main obstacle is the availability of modern and advanced joining procedures for this metal. Thetraditional methods of joining have faced the issues of brittle intermetallic which often affect the welding nature of the final product. This study based on the advanced application of welds to work in human bodies. The reason for porosity and cracks can producedetrimental for the nature of the weld metal.

The main advancement for the study is the Laser autogenous brazing. These techniquesalloys are joining two dissimilar metals for biocompatible products. The example is selected for stainless steel as well as the Nickel and titanium alloys(Satoh, et al., 2017).The author says that the joining of two dissimilar metals has been a great interest to the field of engineering. This area has allowed the industry to achieve optimum properties in the field of materials as well as in the fabricationindustry. Themain challenge is to join a different type of metal with compassion and properties. The formation of an additional layer of elements and carbon constituent tend to provide a strong barrier to forming a solid bond. Porosity and brittle products are the major reason why dissimilarproducts are welded with conventional techniques of the arch and TIG welding(Satoh, et al., 2017).

Another area which requires advancement is the precision for joining small product for the large-scale application. These applicationsare related with the medical industry where shape memory alloys and Nickel-titanium products are the major elements used for welding purpose. The main objective of this study is to use blazing laserprocess to weldnickel with the stainlesssteel.The main constraints for the approach are the microstructure and thermal properties of both classes of metals. In order to verify the result advantage techniques of research will be used(Satoh, et al., 2017).This will include the scanning electron microscopy and X-raydiffraction as the principal mode of characterization.

Much of the information is present on the background of blazing laserprocess. The diffusion is similarmetal is carried out with the help of ArrheniusRelationship.It is defined as

$D_{ef} = D^{a}_{ofexp}\ (-Q_{ef}/RT$(Satoh, et al., 2017)$)$

According to this relationship, the answer for the welding of dissimilar metals is based on the diffusion level and gradient of two materials(Satoh, et al., 2017). Stainlessless and titanium will have to obey the transport principle. This will allow the process of welding to take place with the help of the laser brazing process. According to the research made by the author, the welding process was a suitable selected for welding stainless steelwithNickel shape memory alloys.

Spot welding of the dissimilar metals for steel family

Xinjiang Yuan and co-authors studied an advanced level of welding technique similar to the laser welding.The new element of resistance spot welding was sued to join two dissimilarmetals(Yuan, et al., 2017). The selected material for welding was the advanced highstrength steel where carbon is present at the interstices of the steel product.The industry operatesin the same category(Yuan, et al., 2017). The main aim of joining two different classes of stainless steelwas to reduce the weight of heavystructuresand provide new improvement for the vehicle crash performance. Dualphase steel has also used a combination in welding the AHSS with Aluminum and Nickel.

The author used a resistance spot welding technique for the joiningprocess. Much of the focus for the presentscenario is on the advancedforms of joining techniquesavailable to people.According to author two points are required for the resistance spot welding process(Fu, et al., 2015). The first area is related to the mechanical properties whole second area is the parameters present for designing a strong bond between two base metals.

In this study, the DP steel was welded with the low carbon steel and results were present with the information on SEM and electronbackscatterdiffraction. Characterization of the new element is importantto order to purposechanges for the microstructure and mechanical properties(Fu, et al., 2015). The results show that most of the welding process was carried out successfully and there wherefewer defects and cracks present for in the final weldment of two metals.

Dissimilar metals and friction stir welding practice

The advanced welding techniques for joining dissimilar metal also include friction stir welding.Ahmed Sabbah also made a study to highlight his work related to the welding process.The materials which are used forjoining were alloys of two different categories(Ataya, et al., 2016).These categories include AA7075 and AA 5083.Aluminum alloys havingdifferentchemical and physical properties were welding with friction stir techniques.The main base was on the microstructure and weld properties of both the metals.The author stated that a transformation was observed in the grain size as well as strength and ductility of weld material.

The author states that friction stir welding has been the advance form of welding as compared to shielded metal arc welding where a molten pool is created to dissolve the molten metal tocreate a strong bond between the base and filler metal(Ataya, et al., 2016). Dissimilar alloys of aluminum have been welded to optimize the application for vehicle parts and surfaces. One of the main factors related to the friction stir welding is the speed used for welding two metals.This speed affects the microstructure as wellasthe mechanicalproperties for materials which have to passes through the joining stage.It was found from the study that fine-grainedstructures were formed using the friction stir welding as an advanced welding technique.Welding speed also determines the nature of joints and grains size(Ataya, et al., 2016).This would help to predict the material for application in the service industry.

YAG pulsed Laser Welding of dissimilar metals

Zhang reported a study in which laser welding was used to weld two different metals. One of the metals was titanium alloy and second was stainless steel(Zhang, et al., 2018). According to author pulsed laser welding technique has been used to analyze the microstructure of two different metals using the advanced method of characterization.Mechanical properties of two weld metals were evaluated with the help of a tensile test.The main process was related to welding of a titanium layer with the base of stainless steel. The main area was to study the mechanicalproperties of weld metal with the help pf microstructure evaluation.

The joining of titanium and steel is based on the application for aeronautic and missile industries(Zhang, et al., 2018).The products which are formed from the joining process are lightweight and can be used for the airplanes and airborne vehicles. The main difficulty which arises in joining dissimilar products is the formation of the intermetallic layer if Fe- and Titanium. If the physical metallurgy of two dissimilar metals is studied for the formation of the weldingprocess, then the Iron Titanium Phase diagram will be the best possible evidence to determine that solubility of iron in titanium base is low. This is the reason, therefore, difficulties present in welding and joining process. This study proposes to use laser welding technique to weld titanium and stainless steel. Themain additive is the Niobium which prevents the formation of the intermetallic layer for titanium and iron(Zhang, et al., 2018).

In the laser weldingprocess, two types of weld were made. One was connected with the one pass welding while the second technique was two pass welds acquired to join titanium and stainless steel(Zhang, et al., 2018). The bond strength was studied with the help of analyzing mechanical properties and fracture modes of two dissimilarmetals. The paper studies the feasibility of using a pulsed laser technique to weld Titanium alloy with stainless steel.

Bank studied laser welding with the help of spark electrode. The main important area in this study was modeling of laser welding. Welding of two dissimilar metals depends upon the chemical and physical properties(Zhang, et al., 2018). Modeling help to solve this problem as heating and solidification patterns for the weld metal was studied using the ANSYS software. Nickel was the consistent element used in the study.

Laser-assisted Friction Stir Welding

Xinjiang studied the joining of dissimilar metals where steel and Aluminum were the main subjects of the study. The technique used in the study was the laser-assisted joining of q235 steel with aluminumalloy. The strength of the bond was tested,andmicrostructural examination was carried out. In this study, the major application of welding was to reduce the weight of heavystructures(Fei, et al., 2015).The modification in design structureshelps to manage the oil consumption of airplanes. Aluminum alloys have been extensively used in the automotive industry to reduce the weight of heavystructures.

Aluminum alloys are superior due to their corrosion resistance as well as mechanical properties. In welding aluminum with steel hardness and poor weldability of weld becomes the major problem. The most advanced techniques whichare employed for welding are a laserweld, friction stir welding,andbrazing(Hagqvist, 2015). Laser-assistedfriction stir welding is the studied technique for joining aluminum alloy with magnesium. In this research area, the intermetallic layer formation also possesses a big problem for the welding of two dissimilarmetals. According to the author, the study was influencedby the laser friction scheme. The welding of two dissimilar metals like steel and aluminum were the major part of the study(Fei, et al., 2015). The author also stated that some of the parameters are related with the rotation and traveling speed for jointproperties. A little amount of literature is present for the laser-assistedwelding of Aluminum with steel.

The schematic design of the welding included welding apparatus and tow dissimilarmetals. The welding procedure was performed with the help of underpinning two weld metals. Thisprocedure will not only help to increase the tensile strength by also overcome the formation of intermetallic layers(Yuan, et al., 2017). In this study, a complete metallographic analysis of steel and aluminumjoints were made using the laser-assisted welding procedure. Itis also explained in the fig 1.

(Fei, et al., 2015)

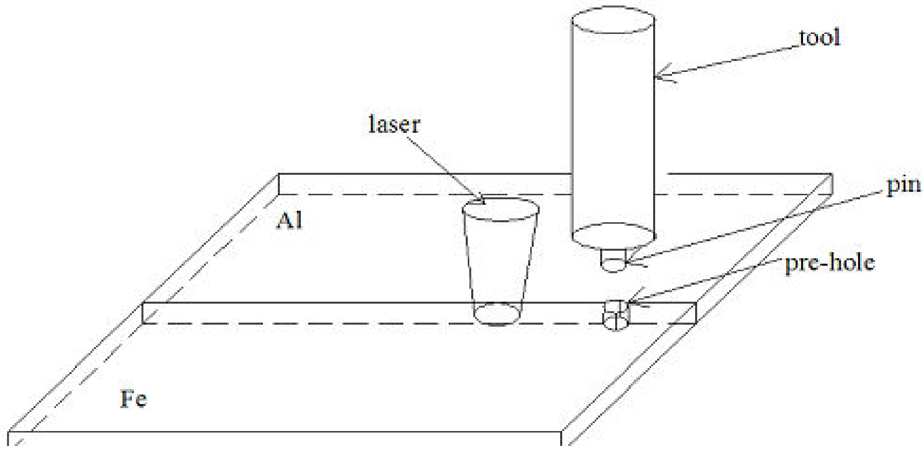


Figure 1 Offset welding of Iron and Aluminum(Fei, et al., 2015)

Figure 2 Laser welding of Aluminum and Iron(Fei, et al., 2015)

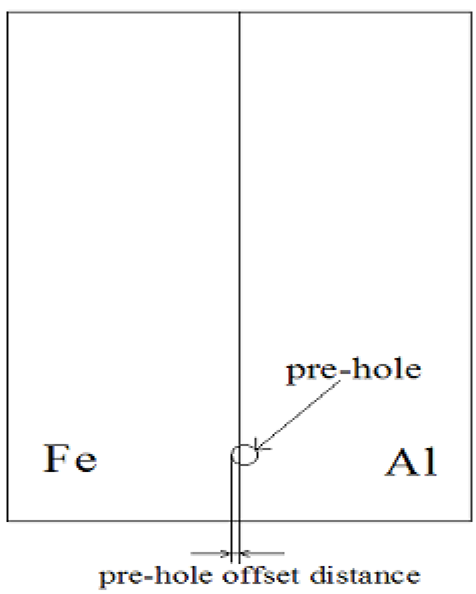
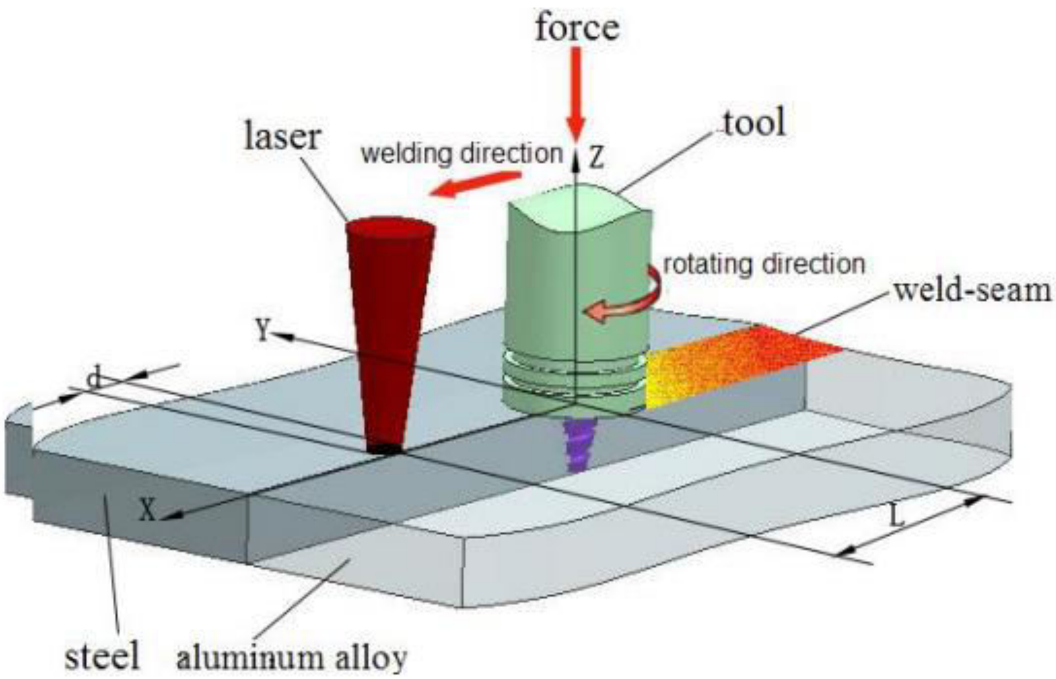


Figure 3 Solid work simulation for Laser welding(Fu, et al., 2015)



It was found from the study that the intermetallic layer affected the formation of the strongjoint. The justification for bond strength was made using the advancedcharacterization methods of scanning electron microscopy and Electron diffraction studies. The author found that tensile strength of the weld metal is present in between good and accepted result for welding steel with aluminum.Due to welding treatment the microstructure and grain size of the crystaldecreaseswhich help to increase the bond strength of stainless steel and aluminum(Fei, et al., 2015).

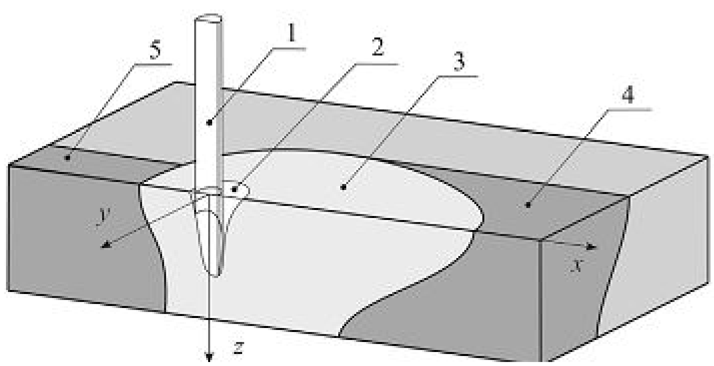
Numerical study of heat modes and laser welding

Isaev studied numerical modes of laser welding. This was an advanced technique used for weldingtwo dissimilar metals(Isaev, et al., 2016). The main conceptual design was the three-dimensional model used for analysis of the laser welding of two dissimilar metal. In this study numerical modes were used to analyze the solidification and melting of the base metals.

Shipbuilding and Power engineering are the two concerned areas where welding has a higher application(Esfahani, et al., 2015). The main issue in this study conforms to the joining of two similarmetals;manyresearch studies have been reported to analyze the welding of two dissimilarmetals. In joining titanium with steel, the main issue is the formation of the austeniticlayer(Isaev, et al., 2016). Researchers have tried to weld titanium directly with steel,but positive results are not achieved with the help of conventional welding procedures.

Laser welding procures the most advanced form of welding where high temperature and laser radiation helps to form a weld pool. This weld pool is necessary to make a diffusion pattern for titanium to form a strong bond with steel layer(Isaev, et al., 2016). Laser power is also balanced in order to prevent the vaporization of weld metal.Laser environment is difficult to control for the joining of two dissimilarmetals.The author carried out the laser welding in a small area to weld titanium and steel.Numerical simulation is also carried out by computer calculations.

Figure 4A model for laser welding(Isaev, et al., 2016)



According to the author, a mathematical model was used to simulate the welding process. The author used the advanced 3d approach to analyze the laser welding of titanium with steel. The copper insert was used as an additional surface layer to reduce the area for spot welding. The studies also show that the nature of weld also depended upon the point of contact and position of the instrument for steel as well as titanium(Isaev, et al., 2016).

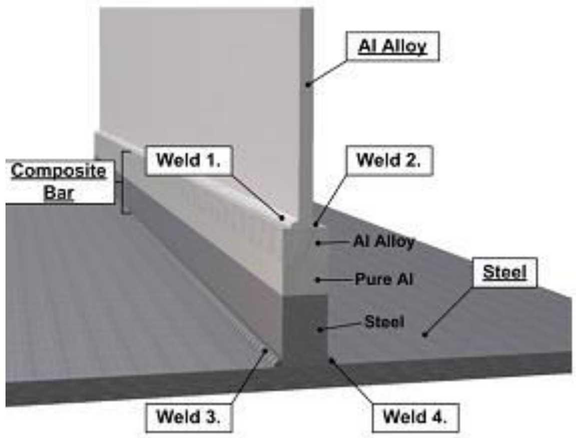
Application of Laser in seam welding process for dissimilar welding

Meco studied the process of seam welding using laser an additional technique to weld two dissimilar metal for structural components. The technique used for welding was the laser welding. Maximum power for the laser was limited to 8000 watts(Meco, et al., 2015). Lap joint configuration was used to in this study. The laser welding of steel surface was carried out with the help of laser radiation. The study was based on the challenges associated with the transportation industry.The weldingprocedures were carried out to reduce the fuel consumption and construct engines which produce less carbon emission. For this purpose, steel and aluminum were the key metal used in the study.

Aluminum is material which is cost effective and has higher corrosion resistance as compared to other metals like Nickel and its alloys(Meco, et al., 2015). The issue which is present in joining the dissimilar metals relatesto the melting temperatures,thermal expansion,andconductivity. The author states that many studies have been carried out in understanding the relation of Iron with Aluminum.The main center of discussion was the formation of a strong bond for a fine layer of composition and growth.The physical state of alloys basically determines the feasibility of weld.

Some of the solid-state joining processesare friction stir welding and brazing. Laser welding technique is used to form a solid bond of steel and aluminum.The research was based on analyzing weldment of steel with aluminumplates(Meco, et al., 2015). The study involved analysis of Iron and Aluminum in terms of the mechanical strength as well as metallurgical properties of the sample.

Figure 5Numerical simulation of Al and Steel welding(Meco, et al., 2015)



In this study, some of the advanced features for weldingwere used to join aluminum and iron. Theparameters like laser power and interactionparameters were used to make the welding process much efficient(Casalino, et al., 2016). The power density of laser was measured with the help of

Power Density=Laser Power/Area----- Equation 1

The interaction time for laser and the weld metal was measured with the help of

Interrelation Time=Diameter/Travel speed……Equation 2

According to the author, laser welding is the most promising technique used to weld two dissimilarmetals. Ithelps to reduce the formation of the intermetalliclayer(Meco, et al., 2015). It was found that Iron solubility in less in Aluminum as compared to steel.The mechanical strength of the final weld bond was increased by using the laser welding treatment with fixed parameters.

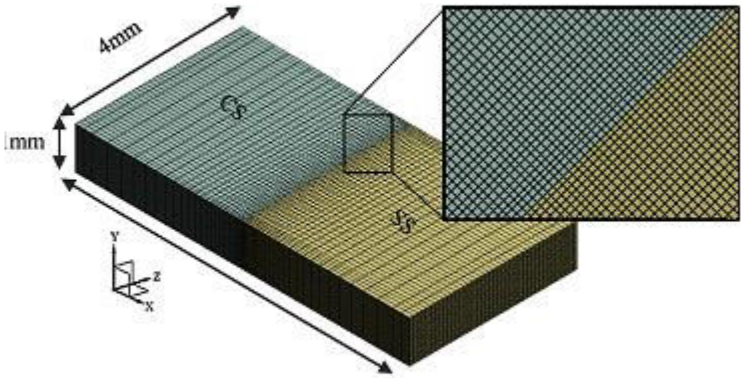
Numerical simulation and laser welding

According to Nekouie a study was carried out related to the numerical simulation of advice laser welding. The model which was developed to answer the research objective was the related with the alloy composition and fluid dynamics of low carbon steel(Esfahani, et al., 2015). The authoruses the modeling technique to make predictions for lasingwelding. Italso helps to analyze a range of parameters for the study. The study stated that, in using laser welding as an optimumtool, a wide number of dissimilarweldingcould be carried for industrial applications.

Laser weldingcannot be denied for its importance in the manufacturingindustry. This is because most of the fabrication process have found relevance with the laser welding process.Laser welding has numerous advantages present over the conventional forms of welding. It helps to control the energy level for the weldment and reduce the formation of intermetallic layers(Esfahani, et al., 2015). It is also shielded with the help of laser beam welding technique. Forexample, the welding joints made by low carbon steel and stainless steel are used in the power generation industries. It thus provides that dissimilar metals have found various application in the major commercial sectors of the fabrication industry.

According to the author, there have been studies carried out on numericalinvestigations of the dissimilarweldment. This work is basically related with the computationaldynamics which can alloy the feasibility of welding carbon steel with the stainless(Esfahani, et al., 2015). Process parameters will be used for calculating the alloy concentration as well as the energy required for the dilution zone.

Figure 6 Cross section view of carbon steel and stainless steel (Esfahani, et al., 2015)



The research was intended to develop a CFD Mode for predicting the effects of laser welding of two dissimilarmetals. In the case, the metals selected for the research were stainless steel and carbon steel. There was a difference in properties and chemical composition present for both of the material.Laser helped to make a solid bond with the interfaces where heat transfer process was carried out in a planned way(Esfahani, et al., 2015).

Distortion of titanium and aluminumweldwith the laser beam welding

Kalaiselvan provided brief information for the laser beam welding. In this study,adifferentapproach was relatedto the welding of dissimilarmetals. Laser beam welding was used to produce lightweight and cost-efficientstructuresforairplanes.The materials which were used for the welding purpose were Titanium and aluminumalloys(K.Kalaiselvan, et al., 2018). Thewelding configuration involved Yag laser as the welding technique. Titanium and aluminum have remained the most common based elements for laser welding.The change I carried out in composition and series of metals. The previous technique used for welding aluminum and titanium was the friction stir welding. Inadvancing the role of two dissimilarmetal, laser welding has been added to impact on the fusion and solidification of the weld metal. The main area for laser welding is related to the pressures and mechanical properties.

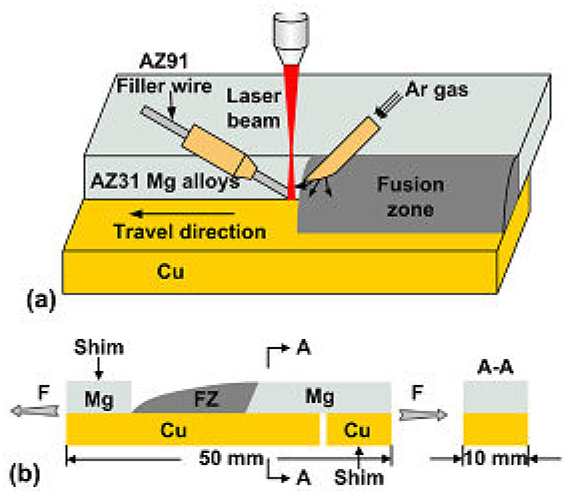
It was found that laser welding reduced the distortion and contractions of the weld area. There changes in residual stress actually impact the weldstructure(K.Kalaiselvan, et al., 2018).The author mentioned a new treatment procedure to improve the quality of weld results. It involved post heat treatment to remove the level of distortion for the dissimilar weld metals.

Zhao studied fiber laser welding process to join two dissimilarmetals. The metals which were used in the study are Magnesium and Copper. Two samples of different thickness were welded by fiber laser welding technique(Zhao, et al., 2018). The main point of the study was the heat input. Welding of two metals was achieved with the help of increasing the radiation levels. From the study, a eutectic structure was observed for magnesium and copper intermetallicstructure.The final weld was achieved with a smooth surface.

Hybrid structures which are formed from dissimilar metals have been targeted for research due to improved application and properties in the industry.Magnesium and all the alloys present in the family have been the suitable elements for joining.Copper, on the other hand, has higher strength, and it is preferred for ductility and conductivity(Jafarlou, et al., 2015).The main challenge present for the joining of copper and magnesium is the difference in physical and mechanical properties. One of the researches has provided importantevidence of welding copper with magnesium with the help of tungsten inter gas welding technique. The main issue recorded in welding of magnesium and copper was the formation of intermetallic and oxides(Zhao, et al., 2018). This increases the consumption of energy and made the conventional welding process more expensive.

Laser welding and brazing were selected on the bases of previous research(Zhao, et al., 2018). This technique was considered to be more important for the welding copper and magnesium because it helps to reduce the formation of the intermetallic layer and allows the molten metal to form a protective layer over the copper surface.

Figure 7Model of Coper and Magnesium alloy(Zhao, et al., 2018)



The major information was gathered from the result section of the study. Author stats that effective joining of magnesium with copper was made with the help of the laser welding method(Zhao, et al., 2018). The welding process used a large amount of energy to form suitablejoints with the laser and base metals. Much of the information can be gathered from the phase diagrams for copper and aluminum.

Figure 8Phase diagram for copper ((Zhao, et al., 2018)

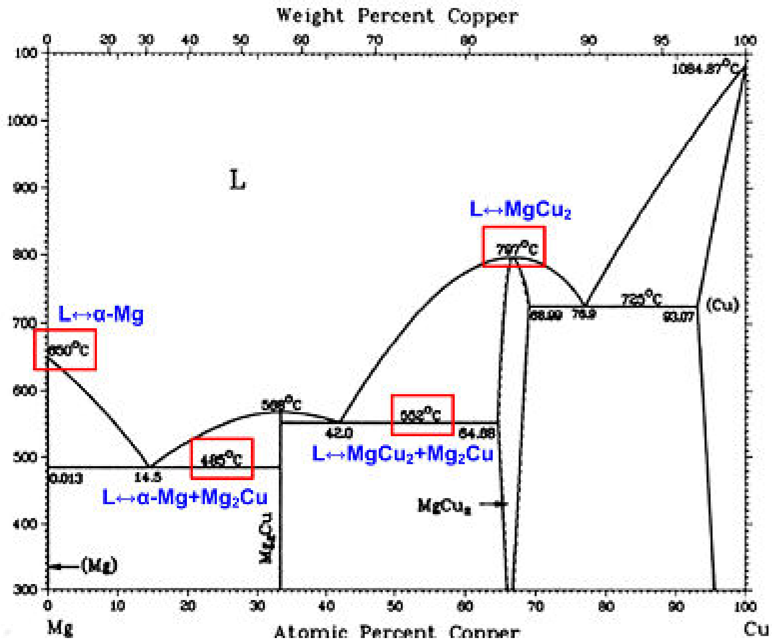
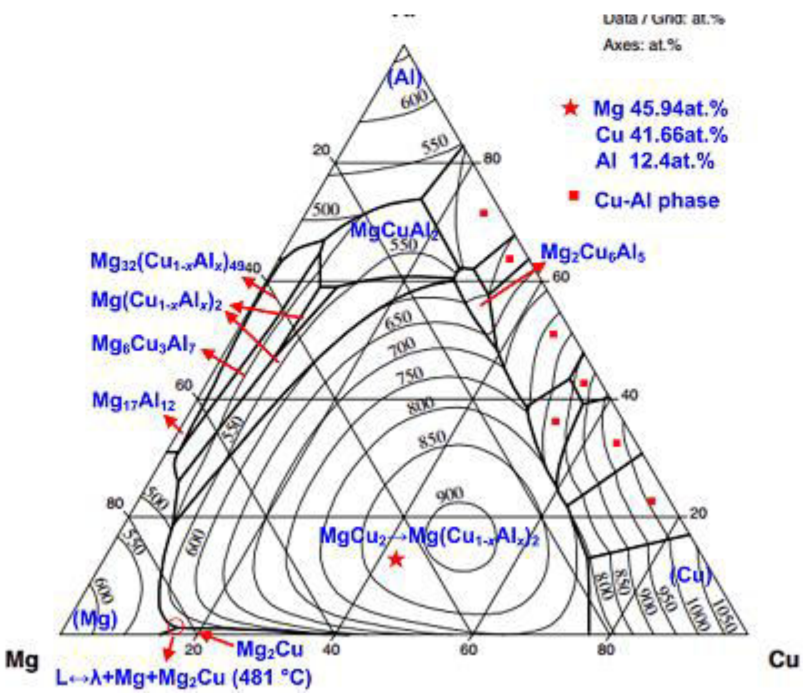


Figure 9Phase diagram of Magnesium (Zhao, et al., 2018)



It was found from the study that laser welding was an accepted and advanced technique for joining magnesium and copper. Theappearance of weld surface and mechanical properties also justified that welding was carried out without any addition of the oxidelayer. Diverse morphology was obtained from the welding practice. Laser welding can be used to join materials which are difficult to fuse with the help of conventional welding practices(Zhao, et al., 2018).

Advanced High strength steel sheets and dissimilar laser welding

Rossini and Co-authors also investigated the effect of laser welding for the high strength steel sheet. The area of application was the car structures and fabrication with the help of joining and welding steel sheets(Rossini, et al., 2014). Thewelding procedure was applied for dual phase steel as well as transformation induced steels. The examination of results was made with the help of metallography. In order to study the mechanical behavior of joints, the characterization tools were used as an element of examination. Welded samples were also subjected to factor graphic studieswhere the microstructure and nature of the intermetallic layer were studied for the laser welding technique.

The main area behind the study is the need for the automotive industry to control the pollution issues related tofuelconsumption(Gerasimenko, et al., 2017).The welding tow dissimilar metal was supposed to provide an answer for reducing the weight of heavy structures as well economics of the service industry.Most of the fabrication industry uses dual phasesteel with some of the number of TRIP steels. The sheet of TRIP and Dual phase steels are welded to form blanks of airplanes.

According to the author, fusion and heat affected zones of the laser welds provide information about the microstructure as well as mechanicalproperties.In the study, fractography was also carried out to analyze the weld surface of the dual phase and TRIP induced steels. The subject of study was TWIP and dual phasesteels. The analysis was made by welding steel sheet using Yag Laser(Rossini, et al., 2014). It was found that phase transformationoccurs for the sample steel sheets. Thedissimilar joints formed from the laser welding have less mechanicalstrength. A small force was required to fracture of the weld zone.

Some of weld cross section provideacceptable results. This was due to less deformation of steel in the heat affectedzone(Carter, 2015). Laser welding technique can be used to weld dual phase as well as TRIP steel sheets. This technique can allowthe formation of lightweightstructures without the hassle of pollution or higher fuel consumption.

Multiphysical modeling of transport phenomena

Metals and coauthors also researched the dissimilar metal welding using a laser as the preferredtechnique. This was due to the fact that high strength steel was preferred for the weight reduction(A.Metais, et al., 2016).The main purpose ofjoining and welding different couples of steel sheet was to control the process of joining. Laser welding has allowed answering the question related with the welding of blanks for car and aircraft structures.Most of the alloying elements predict the strength and properties of weld metal.

According to the author, the new approach adopted in the study is the use of the numerical model to deal and predict the properties of steel sheet using a laser as the prominent source of joining(Satoh, et al., 2017).In order to provide optimum result, a 3d model was used for heat transfer as well as the turbulent flow for properties and element distributions.The model involved the application of keyholeapproximation to validate the weld metal on the base of properties and mechanical structure.

Laser welded blanks have been used in most car vehicle design.The conventional welding procedureshave provided more issues and difficulties for welding two dissimilar steel plates. The essence of the study is relatedto the transportmechanism involved in welding two metals(Isaev, et al., 2016).Thisanalyzes twodissimilarmetals where properties and composition do not fit for the base as well as the filler materials.

Methodology

The methodology for the study will depend upon the need of the dissimilar metal welding and area in the service industry.

1. Three major parts of the industries were targeted in the study.
2. These were Automotive, Aerospace,andmanufacturing(Pang, et al., 2015).The methodology was based on the base ofprimary and secondary sources for welding to research and portray the finding for advanced welding methods. The basic technique was surveying and analysis of previous research carried out in the field of dissimilarmetals. Theprincipal technique was the use of laserwelding.

In research methodology, the first step was the collection of journal articlesand manuscript to the literature review.All these articles contain essentialinformation for the previous research. Secondary sources will be included in manuscripts and published journal articles(Ragavendran, et al., 2017).The research in welding procedures will help in explaining the advanced welding methods used for laser welding.It is also important to highlight the problems in dissimilar welding's.

The main problems for dissimilar welding are the intermetallic layers which can result in porosity and crack formation. Thechoice of laser materials and the medium is also a concerning factor for research. In order to suggest a solution to the intermetalliclayer, the experimental procedures from journal articles were analyzed(Bandyopadhyay, et al., 2016).The method was based on theoretical concepts,and google scholar was preferred as the search engine for assessing the journal articles. The literature suggested that laser-assistedwelding is a possible solution and advanced technique for joining two dissimilarmetals weld. Enough timewas spent on research. The first week of the projectprioritized the literature review for assessing scholarly information about welding.

The advancement in welding process was made by investigating the trends in the automotiveindustry. Thefabrication, as well as the automotive industry,showed great demandforstructures which are lightweight and reduce the elements of pollution(Petković, 2017). A research survey in the form of the literature review was carried out to analyze the problems and challenges present in joining two dissimilar metals.

The first challenge was to deal with the power density and orientation of metals.The methodology carried out was based on facts and experimental evidence from the industry(Plaine, et al., 2016).After reading the research papers and journals, the challenge of geometry was resolved using a modification in the design of experiment assembly.

In order to deal with the physical and chemical properties,the methodology based on analyzing the metallurgical properties of common weld metals. The categories for weld metal included steel, aluminum, titanium,and Nickel.

The methodology of the research project was descriptive and deductive. In the descriptive part of the methodology, all the main procedures and welding techniques were analyzed in the based-on phase diagram(Pang, et al., Pang, S., Chen, W., Zhou, J. and Liao, D., 2015). The metallurgical characteristic was described from the common phase diagrams of Iron, copper,andnickel. Phase and ternary diagrams were the key sources of evidence in judging the welding behavior of two metal.

The first part of the research methodology concerned with the melting point of two dissimilarmetals. Porosity and intermetallic layers were the main drawbacks of conventional welding techniques(Denlinger, et al., 2017). Laserwelding removed the difficulty by reducing the diffusion time and increasing the temperature for the weld metal to form a strong weld bond.

The deductive approach was based on facts and results from the literaturereview. This research project was concerned with the advancement of welding procedures for two dissimilarmetals. The major part was based on a critical analysis of research papers(Yan, et al., 2017). The conclusive evidence for the study was carried out from dozens of research papers. This showed that laser weldingcould be used to join steel with aluminum or copper with nickel.The milestone was to achieve structures which have less weight and fuel consumption.

The methodology also involved a professional strategy to deal with the physical properties and parameters for welding.The first part of the procedure was to determine the condition and requirement of the serviceindustry(Wei, et al., 2015). Fabrication industry tends to focus on the joining of stainless steels with copper alloys. Copper and Steel was analyzed on the base of different phases and eutectic transformation.

Diffusional patterns were studied on the based-onFick’s diffusion laws. The distance and time were calculated from the theoretical literature. This approach was instrumental in providing effectiveresults. It also deduced the preferred laser technique for the dissimilar weld metals.

Yag lasers were the most advanced form of welding.The information about the laser and welding procedures was carried out byliteraturesamples. It helped to provide conclusive evidence for justifying the welding of two dissimilarmetals. This research project was based on the examining the process of welding two dissimilar weld metals(Wang, et al., 2016). The choice of methodology was based on primary and secondary sources because it will help toincrease the knowledge for the project and will provide the necessaryevidence for results.

The challenges of cracks and porosity level in welding process also tailored the methodology to a professional note where samples for dissimilar metals were analyzed in order to strengthen the base of this study.Intermetallic layer often develops in conventional welding techniques wile tungsten arc welding or gas metal arc welding.Friction stir welding was used as the method to analyze the level of surface defects. Laser welding was a new and advanced form of welding. Much of the data was available on the technique,and several studies have been reported in favor of this technique. Themethodology of the research project was efficient and based on solid literature background to propose the effects on the research area.

Project Development, DataCollection, Data Analysis

Need Analysis

In analyzing the condition and requirement for laser welding, the first part is the removal of porosity and oxide layers during the welding process. Another element is the intermetallic layers formed during the process of welding. Laserweldinganswers the challenges in dissimilar welding. Conventionalwelding'sprocedures have increased the issues for the fabrication as well as automotive industry.The weight of vehicles deduces the need for welding procedures. The application for laser welding can be connected with the dynamic balancing systems for automobiles.Interior and Fuel pipe for automobiles also deepened on the efficiency of welding technique. Ifthe surfaceoxide layer or intermetallic are formed on the automobileequipment, it will tend to reduce the efficiency of the system(Elangovan, 2016). The car body is also accounted for the need forperfection.

All the equipment required in service and automotive industry dependent upon welding procedures and results.Joining of two dissimilar metal is an effective technique used to achieveoptimumproperties which cannot be covered using the single metal. Forexample, steel is understood to have higher corrosion resistance.Stainlessis the advanced form of steel which hashigher nickel content and tends to resistcorrosion and an oxide layer on the surface of the material. Aluminum, on the other hand, islightweightandit ispreferred materials for airplanes and structures which are lightweight and efficient energy consumption(Carlone, et al., 2015).

In combining stainless steel and aluminum, major barriers are the intermetallic layer and fusion temperature.Tungsten Arc welding and Shielded metal arch welding form a higher oxide layer which resists the welding of stains less steel with aluminum.A need is present for advanced welding treatment which can reduce the intermetallic layer and provide optimum weld structure which will have higher corrosion resistant(Casalino, 2017).It will also be lightweight for automotive industry applications.

Laser welding tends to provide an answer to welding limitations for the dissimilarmetals. Difference and physical and mechanicalproperties are analyzed with the help of phase diagrams. The important parameters like weldability and hardness of the material can only be achievedsuitablematerials are used for melting dissimilar metals.

If laser technique is examined with the assistance of advancedweldingprocedures like friction stir welding bad brazing, it will reduce the formation of the intermetallic layer and tend to provide excellent mechanical properties for the service industry.It will help to save materials in fabrication industry which are either damaged by the hot temperatures or tend to fatigue in the application of a cyclic load or high pressures(Casalino, 2017). Thedissimilar metals were required to be welded with advanced welding procedures. Fabrication industry cannot rely on conventional metal and alloys to full fill most of the applications.The automotive industry cannot use stainless for aircraft structurebecauseit will require more fuel for propelling and absorba higher level of heat to affect the performance of the wholestructure.

In analyzing the materialscategory, laserwelding gives an answer to the processof alloy formation.Alloys are also formed to increase the properties of the final product. Dissimilar metals welding help to combine two different metals to portray a combined effect on single weld metals. This is important for the service industry(Ataya, et al., 2016). There is always a gap presents in joining two dissimilarlymetals. Laser metal welding is the advanced technique selected for the study. It helps to improve the welding speed and reduced the wear of welding tool for excessiveapplications.(Esfahani, et al., 2015)

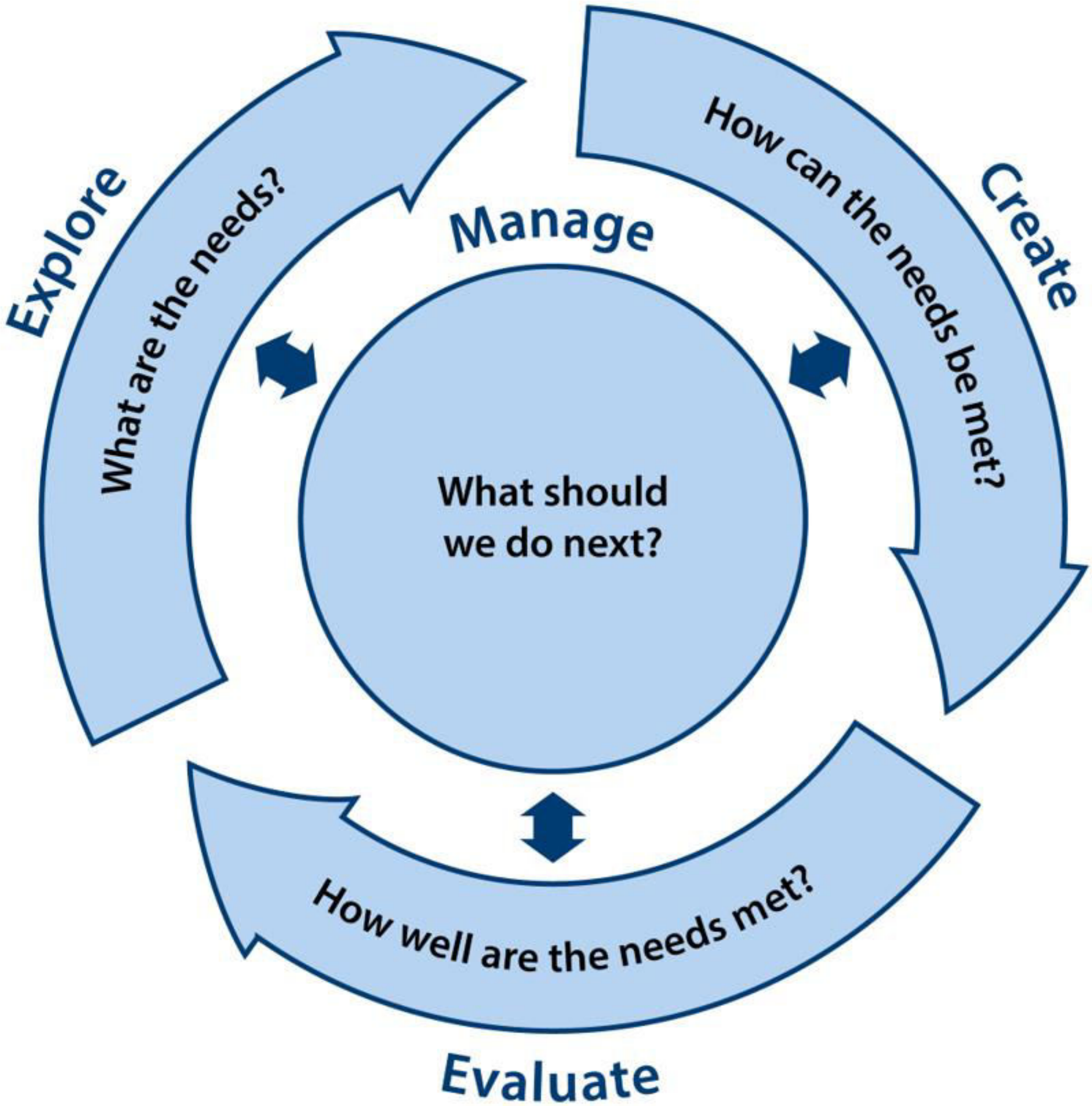
Concept Design

The new and advanced concept in welding to simulate the comparison of metal which can help in welding of two dissimilar metals. This concept is based on the approach used by Esfahan and co-authors in simulating the laser weldingprocures with the help of advanced technology(Esfahani, et al., 2015). Thiswill not only provide a soft image of the welding but will help to reduce the difficulties and challenges present in the technique. The concept will base on a three-dimensional model. This model will investigate the physical and mechanical properties of metals. Theapplication of this concept will be applied to stainless steel and carbon steel. It will be open to weld any dissimilarmetals. The main requirement will be higher properties for corrosion resistance and a smaller numberof porosityand cracks present on the surface of themetal. The concept behind welding will be based on Laser welding schematic as an attribute in the diagram

The concept is rested upon stages. The first stage is the selection of materials.In materials family and characteristics, the selection of materials will be a mostcrucial stage; second is the application of Numericalsimulation to project the properties of materials. The main assumption is to weld two dissimilar metals. Laserwelding technique will provide the answer to all the welding requirement's because it is resistance to remove the formation of intermetallic layers. Oxides will be removed from the surface layer(Wang, et al., 2016). The final mechanical and physical properties will be improved for materials.The material will become corrosion resistance and will be used for application in the automotive sector as well as service industry. The concept is based on dissimilar metal welding using a laser as the preferred technique to introduce the strength of the bond and get desired results from the study. This helps to answer the research question because the main basis is on the problems and challenges present for the two dissimilarmetals. Similarmetal cannot be welded with each other.

The defects present in conventional welding were analyzed as the first part of theresearch. These defects basically affect the research industry.Many of the vehicle's parts are distorted or misconfigured due to the presence of surface cracks on the weldsmetal. The power sector also relies onaluminum and steel structures.In order to analyze the maintenance and fabrication industry laserwelding is the best approach for joining two dissimilar metals.The concept is based on the physical and mechanical properties of both metals used in the practical case.

Figure 10 Concept Desing for study



Detail design

The main stages of the concept design are presented in the diagram. The first part is related win determining the needs of welding procedures.The service, automotive andmaterials industry requires achievement of properties by modifying the element structure andjoining steel and aluminum for increasing corrosion resistance was reducing the fuel consumption. The investigation and exploration for will be done in the first part of the study where literaturereviewwill provide the information about the laser welding techniques and their application on different materials.The first conclusive technique for welding two dialermetals is the YAG laser. It is followed by the Fiber laser in which the tool focusses all the laser radiation on the boundaries of two dissimilarmetals. The molten metal allows the second metals to make a stronger bond irrelevant to the difference in properties(Zhang, et al., 2018). Whena bond is formed its surface finishwill improve as compared to conventional welding recess where oxides layers tend to affect the heat affected and fusion zone.

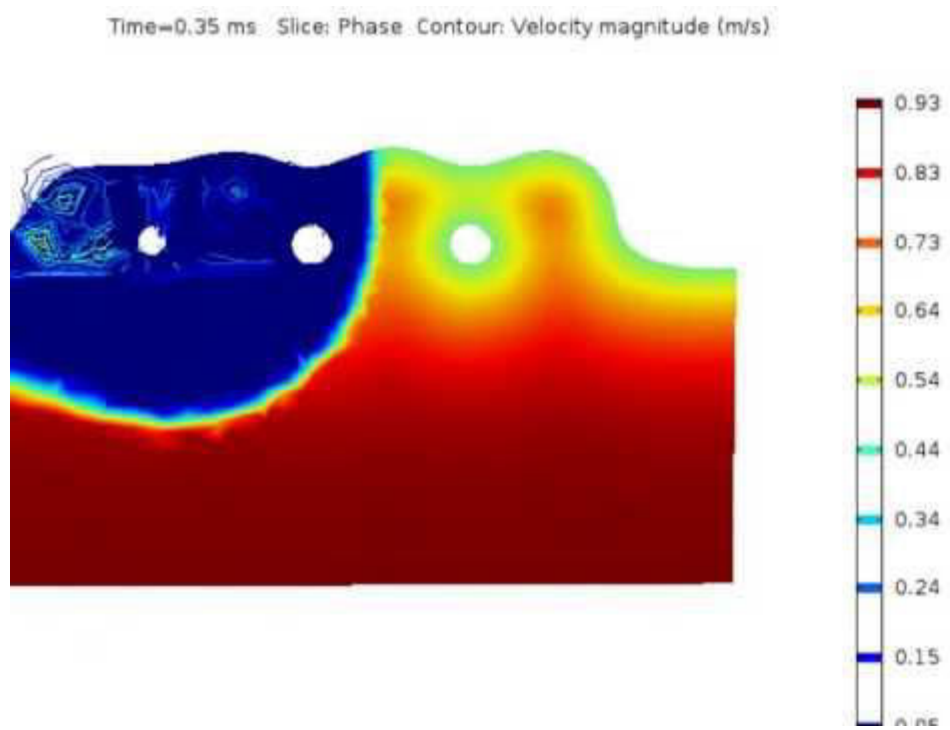
The aim of investigating the dissimilar metals welding to create an improvement in the laser welding process. This can be done eitherby changing the assembly of the process of adding a newparameter and sensors to the conceptional schematic system of welding(Yan, et al., 2017).If the laserwelding tool is coded with a heat and light sensors, then it will help to record the heat pattern. Simulation of laser welding will also be an advancement to improve the welding procedures.

The portion of creating a new scheme or modifying the present schematic will also depend upon the requirement of industry and flexibility present for combining metals. This will be studied from the phase diagrams of metals. Forexample, if steel and aluminum are connected with the concernedconcept, then its laser welding will be carried out by analyzing the melting points and phase transformation temperature(Pourali, et al., 2017). Phase diagrams help to predict the changes in properties and structure.The process parameter and assembly design will be made with the help of phase diagrams. Now in order to create or define advancement in the laser process, cracks, porosity and surface defectsit will require that two dissimilar metals should be prepared for welding procures.

This will be a new approach towards the welding mechanism. The major objective of the concept design is formulating the early stages of development for laser welding technique. It is beneficial to have a great advantage inexploring advanced knowledge for laser welding. The last stage of the conceptual design will impact on how needs of service and fabrication industry aremet.The justification will be from the practical example of similar metalwelding.The first area is achieved required mechanical properties(Wang, et al., 2016).The weld materials will also be tested for corrosion resistance.If the final weld metal is not able to withstand corrosion effects, then it will provide a loss towards the modification of the laserwelding process.

Model through Solid work

Figure 11 Solid work design for simulation model



The model for welding two dissimilar metals through laser weldingwill base onsimulation software.The main idea was to use the help of numerical simulation for laser welding.The pictures clearly show the energy zones in relevance to the temperature colors.The high-intensityshoes that temperature present around the weld and heat affected zone is higher. Metals can be allowed to diffuse into each other at high temperature. This will ease the welding process between two metals and also allow to remove the porosity and chances of cracks and to debond.The model for welding two dissimilarmetals is based on analyzing properties with the application. This will help to categorize metals with importance properties for their application in the industry.

Prototyping and Validation

The main concept of the study is to introduce laser welding as an advanced form of technique to the fabrication and automotive sector. The changes in the concept designare properties and schematic used for welding.The change can be observed in accordance with the addition of new equipment.(Denlinger, et al., 2017) If a high-resolution microscope is introduced with thermal optics, then this technique will reduce the need of scanning electron microscopes to study the microstructures and properties. A suitable prototype for the product provides variable options for welding two metals. Thisnewconcept will allow two different metals welding done without a major change in process parameters.

Table 1Model for study

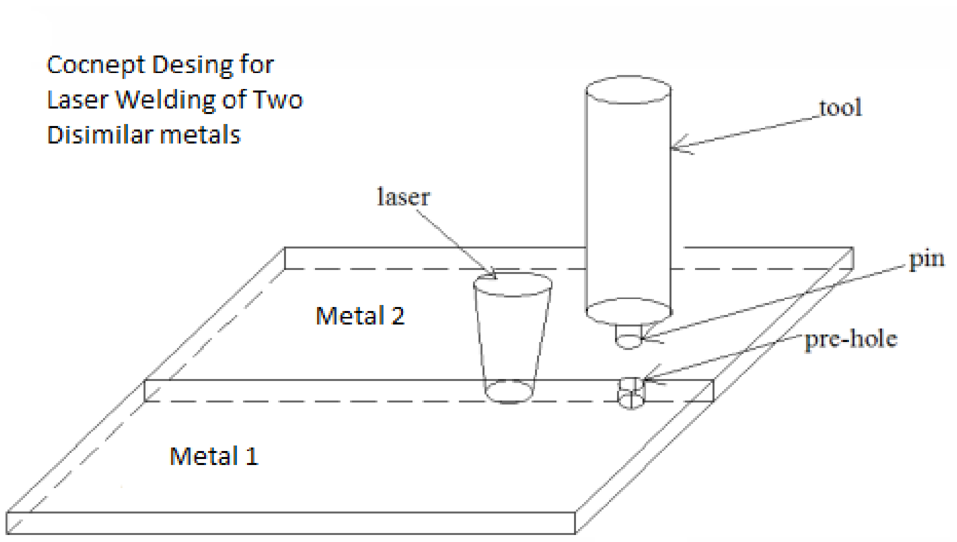
The prototype for the advanced form of laser welding is related to industry needs. The idea is to introduce laser welding for all the dissimilarmetals. Aprototype will be based on numerical simulation. Ifan industry or domestic need is to be fulfilled by laser welding the first stage will the simulation of two alloys(Carter, 2015). This will make suitable process parameters for laser welding.

The prototype will laser welding technique and sample metals A and B as the part for the two dissimilarmetals. It is required that the first prototype should be applied on a small scale. This is a new design. Therefore, the application for small butt joints will be a feasible mode for the product. The main purpose of prototyping wasto provide a new concept of laser welding. This will be introduced in the form of a product to the fabrication as well as the automotive sector.

For the sake of simplicity improvement in the laserwelding will be assumed as the new product. The first and foremost area for prototyping is the production facility required for the clients and customer. Forweldingapplication, there is no restriction for the facilities.This technique is utilized in almost all service industries where stainless steel,copper, aluminum,and nickel are utilized as the primary working metals. Another advantage of prototyping is to introduce designimprovement(Ding, et al., 2015).. The evidence for this improvement will be gathered from case studies and service industries.

In order to validate the efforts of initial prototypingpractices will be carried out for the laser welding categories of the dissimilar metals will be weldingthrough laser welding(Laureto, et al., 2016).A numerical simulation of two metals will be made in order to predict the results for

Figure 12 Design of Welding model



welding. For validating the results for prototyping, it is required that a base platform and monitoringis carried for the process.

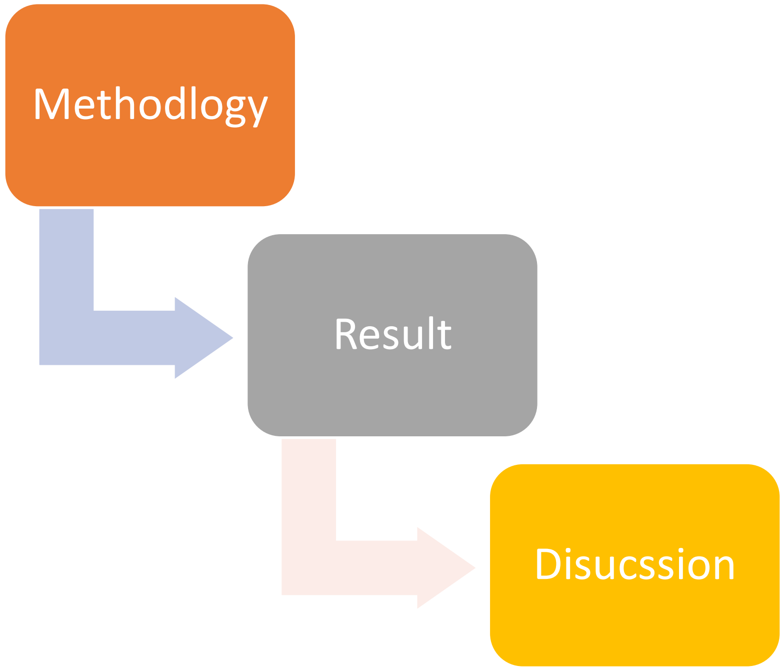
In prototyping automotive and service industry will be the main preferred area of expansion. This is because welding is carried in high number and there is a required present to deal with welding defects and porosity(Schüttler, 2018).Prototyping will not only solve the problemsrelatedtohigher energy consumption but will provide a solution for alloys and metal categories to form a solid bond. Yag and fiber laser will be the selected options for validating the prototyping process.

Using laser welding technique and modification in design and control parameters,it will offer a unique contribution to the process of welding. Some of the practices from friction stir welding will also be incorporated from the case studies to improve the result of the prototyping method.The need analysis of the laserwelding technique was an important direction which helped to design and modify the conceptto laser welding. Expansion has been carried out in the welding stage (Monsheimer, 2015).This study will use prototyping as a tool for adding changes in the welding practices and techniques.

Results and Discussion

This research project was based on an investigation of two dissimilarmetals. Some of the advancement was made in the modeling and design of laserwelding. The primary area of the research was to investigate the present problems present for Australian fabrication and automotive sector in joining two dissimilar metals. The first area was the energy consumptionand the second was the financial loses of poorly welded structures(Kalpakjian, et al., 2014).The methodology based on using the primary and secondary sources for research analysis.

Figure 13 Stages for welding



It was found that Australian Industries faced welding issues in joining two dissimilarmetals. The first area was the formation of an intermetallic layer on the surface of the weld metal (Gerasimenko, et al., 2017). This affected the efficiency of the mechanical process and resulted in energy loses for the service industry.

There was also a rising issue present in the form of pollution. Australian automotive industry depends upon aluminum for making lightweightstructures.For this reason, the preferred combinationexists with the stainless steel and aluminumalloy. If the eutectic diagram of steel and aluminum is analyzed, it isinferred that joining of two metals will require a high amount of energy(Hagqvist, 2015).Conventional welding techniques were unable to weld two dissimilarmetals. It was found from the research and case studies that new and advanced welding techniques can be used to join two dissimilar metals.

Laser welding was the selected technique. This was the primary objective of the study. The secondary objective was the type of welding present in Australian fabrication industry.Laser welding was the selected type.The results of the study show that laser has been used to weld dual steels and HSLAs with improved mechanicalproperties (Williams, 2016). The main element was the weldability and fusion temperature of two metals.

The result of the research shows that Laser welding can be modifying under numerical simulation to achieve the desired properties of welding.This can be done with the help of prototyping and validation. The past cases from Australian fabrication industry show that laserwelding(along with the frictions stir welding) has been used to weld metals, where fusion temperature and melting points are higher. The laser welding reduces the formation of the intermetalliclayer. Fewer oxides are formed during the welding process,and it helps to improve the strength of the final weld metal(Wu, et al., 2014).

In some of the researchstudy, an example of MARTsteels with HSLAS was used under the laser weldingdescription. It was inferred from the case study that laser welding is an advanced level of technology used in the present weldingconditions.Service industries can employ this technique to improve the mechanical properties of the final weld metal(You & Katayama, 2014).

The study revolved around the descriptive and deductive methodology.It was found from the secondary sources that phase diagrams were instrumental in predicting the weldingproperties of two dissimilarmetals. This is because the microstructure and diffusionalpropertiespredict the feasibility of one metal in joining with the other metals. Theprototyping technique also helped to provide significant results related to the research project.

The main part of the research is related with the incorporation of the research question in methodology.The research question was to investigate the problems present for welding two dissimilarmetals. Thechemicalproperties, porosity,andresponse of cracks were the information revealed for the research studies. A major focus on service and automotive industry has to remain ed on building lightweightstructures which are efficient and consume less fuel. The main issue was the unavailability of advanced weldingtechniques.The incorporation of the laser weldingalso with the solidification of Yag and Fiber laser help to provide the answer for the research.

Discussion related to results

Design and production area for Australian fabrication and automotive sector dependents of the use of different metals and joining procedures.In welding two dissimilar metals, properties like heat, corrosionresistance are analyzed for production economies.Welding two dissimilar metals are often considered a challenging task because in most of the cases favorable environment is requiredfor the welding procedures.Laser welding was the selected procedure used to join metals having different properties.Laser welding uses high power energy sources to melt and fuse two dissimilar metals.

The study revolved around the concept design and prototyping of laser welding. The new model approach for laser technique was to employ a numericalsimulation of two welddissimilarmetals. It is different from the conventionaldesign of welding because the tungsten metal arc welding relies on the strong arc to diffuse metals. Forexample,stainlesssteel and aluminum were joined with the help of arc welding the result was poor weldability and a high number of cracks of the surface of final weld metal. The product was unable to bear the higher load and resulted in failure. Stainless steel is provided enough time to forman intermetallic layer of oxides on surface metal. This oxide layer restricts the penetration of heat to the aluminum metal.It acts as a protectivesheetand results in a weak bond between aluminum.Some of the problems are related todistortion of aluminum metal helps to make the welding process much less favorable.

Laser weldingtechnique proposes to answer for the automotive industry. It was prototyped on the base do higher power zone and preferred welding results. The area for laser welding helps to cover a higher range of industrial sector including the power generation and chemical sector.Theliterature provides enough evidence for this advanced form of welding. This is because productivity depends on weld quality and manufacturing process.

The main study focus was the primary research area. This was the literature review carried out for the laser weldingpractice. It was required to propose a mode which is comfortable for the dissimilarmetals. The welding requirement is based on properties and application of dissimilarmetals. It is a challenge to welddissimilar metals.Presence ofhydrogen and cracks appear as the drawback to joiningprocess. Highercorrosionresistance is also required for metals. Now in analyzing the reason of cracks the most common phenomenon observed in weldingdissimilar metals is deboningprocess. When two different metals are joined together, disbanding takes places.Disbanding effects the weld properties and final product do not fit towards the requirement of the fabrication industry.

Some of the principals of laser welding were also studied in proposing a comfortable model for the laser. This was based on the equation of Fick’s law.Diffusional transport is also important to predict the microstructure and machinal properties of the laser weld.The modification in the laser method was a method on the position of the welding tool as well as the size of joint required for the two metals.

The concept design of the technique was innovative and advanced because it helps to target the need of automotive and fabrication industry. The most obvious requirement for the industry was higher corrosion resistance in comparison with the excellent surface finish.The final weld materials should be able to withstand load and bear fatigue in the form of cyclic stress.Laser-assisted welding has an advantage as a focused beam is used to weld.There are fewer fusion effects on the heat affected zone.

The area of welding two dissimilar metals is a wide context present in the field of materials science. Theconventional welding practices have been affectedby the debonding mechanism.A large amount of money has been spent on corrosion of materials. Fabrication industries prefer to use materials which have the higher mechanical strength and withstand loads at elevated temperatures. Some of the parts of literature studies have focused on the increasing case for fatiguefailure's major reason for fatigue is the presence of porosity and cracks in weld metals. These cracks act as stress raisers.When weld metals are used in the serviceindustry, the different number of cyclic loads increased the chances of failures.

Welding practices are accounted for the negligence in the serviceindustry. Theconventionaltechniques tend to ignore the phase transformation of the of two dissimilar metals. In discussing the principals for laser welding friction stir welding was also used to analyze the surface level defects for dissimilarmetals. This practical approach was unique in the sense as the new model was proposed for the comfort level of similar metals. Inthisstudyprototyping and validation was carried on the base of need analysis for the laser welding. The most common need for the fabrication and automotive industry is the lightweightstructure.For this purpose,aluminum is the strong category for welding.Alloys of copper and nickel are the preferred source of welding medium becausenickeltends to provideconductivity and strength to the material.

It was alsorequired to perform the numerical simulation for the weld metals. This idea was the part of the concept design because simulating a practice a case can identify the advantages and limitations present for the laser welding technique.It can also dictate that which metals are feasible for welding. In material sciencecategory, numerous combinationsof metals and alloys are present for the automotive industry.Phase diagrams help to provide the answer to professional

In the fabricationindustry, theadvancedmethods for welding steel withaluminum or iron with copper will requiredcomposition test.The second will be the surface inspection of the materials in order to investigate the nature of weld metals. The final step performedfor an advancedlevel of weldment is the inspection of the fusion zone and weld zone.Laser technique is the most preferred form used in welding. It helps to reduce the contact of two different metals. With the help of a focused ion beam, much of the problems can be reduced for material.

This study was based on the descriptive and deductive mode of research.It is necessary to explain the deductive results for laser welding technique.As from literature, it was found that by changing the alignment of metals different type of joints can be made without any extra cost of energy. Laser help to create a weld pool. This melts the molten layer,andsmoothcovering on base metal is carried for the second metal.

Overall it was deduced that Laser welding could be modified with ease to provide a solution for welding two dissimilar metals. Process parameters and nature of the laser materials will require modification. In order to provide an advance, deform of welding the needs of industry should be targeted first. The automotive industry is the highest industry which commonly utilizes welding as an advanced procedure. The second industry is the power sector where heavy structures are welded by offset welding procedure.

Laser welding and Simplified model

The main reason for selecting laser welding of all the advanced joining techniques present in material science was the redesigning and modeling of the welding to suit for joining two dissimilar metals. The model is based on application. The logic is gathered from the literature and case studies where laser welding has been incorporated with the help of friction stir welding and blazing. The types of laser welding include Yag laser and fiberlaser. These two techniques reduce the number of defects present in the final weld metal. The automotive and power sector of Australia depends on the innovation of welding procedures to simplify the technical failures in the industry.

Conclusion and Recommendation

The welding of dissimilar metals is marred with many challenges such as the development of cracks and accumulation of chromium layer over the joints. The properties of the metals in the dissimilar welding determines the strength and properties of the weld metal. It is challenging to prevent the cracks and corrosion at the welded joint as it is exposed to the extreme weather conditions. The conventional welding techniques make the weld metal prone to the corrosion and eventually reduces the durability of welded joints. Sometimes, the application of external pressure or exposure of joint to the heat reduces the strength of joint. The laser welding of dissimilar metals has reduced the challenges of traditional welding techniques. The latest methods of laser welding made the dissimilar joints relatively more resistant to the corrosion. This technique has reduced the probability of the failure during the process of welding.

The chances of development of heat affected zone in the weld metal can be reduced by using laser welding. This technique facilitates the automotive, aerospace and manufacturing industries which demand a cost-effective and reliable method to produce the high quality welded joints of dissimilar metals. The high accuracy and welding speed of the laser welding highly differentiates it from conventional welding techniques. The laser welding prevents the crack and pore formation by controlling the amount of heat transfer to the weld metals. The laser welding facilitates the welding of metals which are more susceptible to the oxidation and subjected to the threat of material loss during welding. The avoidance of such losses and defects are made possible with laser welding.

The pulse laser techniques are the major method of laser welding and used for welding of dissimilar alloys to achieve the desired level of tensile strength. The conventional welding methods are prone to the risk of formation of the intermetallic layer which reduces the bond strength of welded joints. The weld pool in the laser welding facilitates the optimized transfer of heat and have minimum risk of metal vaporization from the weld pool. The laser welding allows the transfer of heat according to the properties of metals and size of the welded joint. The preciseness of interrelation time allows the formation of the strong and fine bond. Different parameters of laser welding help in the delivery of power level which is essential to achieve the desired dilution zone during the welding process.

The optimized heat transfer process of the laser welding reduces the development of residual stress in the joint eventually, reducing the risk of porosity and crack during the post heat treatment of weld metal. The variations in the radiation level of the laser beam facilitate the use of laser welding in the fabrication industry. The laser-assisted welding also addresses the challenges related to the geometry or configuration of weld metals. The results of this study could be used for further analyzing the efficiency of laser welding for different combinations of dissimilar metals which are commonly used in the aerospace and automotive industries.

It was concluded that most of the research had provided benefit for the laser welding procedure. Literature review suggests that laser welding has provided better mechanical properties as compared to the conventional welding techniques used in the industry. The process of prototypingand validation was also addressed with the help of need analysis of the industry. It was found that most of the resistance present in welding two dissimilar metals was due to the formation of the intermetalliclayer. Oxides of the base metal cover the weld surface which effects the welding procedure and efficiency.

It was also analyzed that most of the past researchers have focused on laser welding for a short duration of time. The laserfocuses on the contact of two dissimilarmetals. This helps to form a weld pool in which base metal is dissolved,anda strong bond between two metals is formed.

Recommendation

It is recommended that in order to achieve for advance level of welding,metals should be simulated on the base of properties as well as chemical reaction. This will not only predict the weld relationship of two dissimilar metals but also provide enough information to design the process parameters for welding.

Another recommendation is to expand the scope of welding to the nextlevel. A practical number of applications for dissimilar metal should be targeted as the research question. This will not only provide practical insight for the welding but also extend the report for critical appraisal. The research area can be improved with the help of adding interaction from welding reports and incorporating the welding standards for the study. It is alsorecommended that numerous challenges are present for joining two dissimilar metals.The challenges should be answered with the help of special attention to weldability and mechanical properties. Welding is a technique which helps to join two type of materials. The final end product has combined application of joined metal.This can serve as a purpose for the cost reduction because when optimum properties are achieved with the help of welding then need for alloy formation can be reduced.

I would also like to recommend that study for two dissimilarmetals should provide a complete overviewof the subject. It is recommended that standard and professionalapproach should be used in targeting the welding procures of two metals. The challenge is based in different properties of the material.Another recommendation is for the future work.This study can be explored in the context of welding procedures.If the SOPis adopted for each of the welding practice, then the resultsof the study will improve.Another important benefit of using the standard operating procedures is to reduce the wear of the weld metals.It will also be conclusive evidence to design structure’s which are lightweight and can serve the industry for various applications.

References

A.Metais, S.Matter & S.Gaied, 2016. Multiphyiscal modeling of transport phenomenon during laser welding of disimilar steels. *Physics Procedia,* 83(1), pp. 1387-1396.

Ataya, A. S., El-Sayed & Ahmed, A. E., 2016. Friction stir welding of similar and dissimilar AA7075 and AA5083. *Journal of Materials Processing Technology,* 1(1), pp. 1-40.

Bandyopadhyay, K., Panda, S. & Saha, P., 2016. . Optimization of fiber laser welding of dp980 steels using rsm to improve weld properties for formability.. *Journal of Materials Engineering and Performance,* 25(6), pp. 2462-2477.

Carlone, P. et al., 2015. Microstructural aspects in Al–Cu dissimilar joining by FSW. *The International Journal of Advanced Manufacturing Technology,* 79(5-8), pp. 1109-1116.

Carter, L. N. E. K. &. A. M. M., 2015. Optimisation of selective laser melting for a high temperature Ni-superalloy.. *Rapid Prototyping Journal,,* Volume 21(4), pp. 423-432..

Casalino, G., 2017. Advances in Welding Metal Alloys, Dissimilar Metals and Additively Manufactured Parts. *Metallurgy Journa,* 1(1), pp. 1-6.

Casalino, G., Guglielmi, P., Lorusso, V. & Mortello, M., 2016. LASER OFFSET WELDING OF AZ31B MAGNESIUM ALLOY TO 316 STAINLESS STEEL. *Journal of Materials Processing Technology,* 1(1), pp. 1-29.

Denlinger, E. R., Gouge, M., Irwin, J. & Michaleris, P., 2017. Thermomechanical model development and in situ experimental validation of the Laser Powder-Bed Fusion process.. *Additive Manufacturing,* 16(1), pp. 73-80.

Ding, D., Pan, Z., Cuiuri, D. & Li, H., 2015. Wire-feed additive manufacturing of metal components: technologies, developments and future interests.. *The International Journal of Advanced Manufacturing Technology,,* 81(1-4), pp. 465-481.

Elangovan, K., 2016. Communication to the editor: Friction stir welding (FSW)-accelerating automobile industries.. *International Journal on Design and Manufacturing Technologies,* 10(2), pp. 15-20.

Esfahani, M. N., Coupland, J. & Marimuthu, S., 2015. Numerical simulation of alloy composition in dissimilar laser welding. *Journal of Materials Processing Technology,* 1(1), pp. 135-142.

Fei, X., Jin, X. & Yi, Y., 2015. Effect of Pre hole offset on the property of joint during lasser assisted friction stir welding of disimilar metals and alumunium alloys. *Materials science and engineering,* 1(1), pp. 10-20.

Fu, B. et al., 2015. Friction stir welding process of dissimilar metals of 6061-T6 aluminum alloy to AZ31B magnesium alloy. *Journal of Materials Processing Technology,* 218(1), pp. 38-47.

Gerasimenko, A. Y., Ichkitidze, L. P., Piyankov, E. S. & Pyanov, I. V., 2017. Use of Indocyanine Green in Nanocomposite Solders to Increase Strength and Homogeneity in Laser Welding of Tendons.. *Biomedical Engineering,* 50(5), pp. 310-313.

Gupta, V. et al., 2018.. Linking process and structure in the friction stir scribe joining of dissimilar materials: A computational approach with experimental support.. *Journal of Manufacturing Processes,* 32(1), pp. 615-624.

Hagqvist, P. C. A. K. &. H. A., 2015. Automation of a laser welding system for additive manufacturing.. *In Automation Science and Engineering (CASE),,* 1(1), pp. 900-905.

Harwani, M. D. & Banker, M. K., 2014. Welding Of Dissimilar Metal Alloys by Laser Beam. *Journal of Engineering Research and Applications,* 4(12), pp. 64-70.

Isaev, V., Cherepanov, A. & Shapeev, V., 2016. Numerical study of Heat Modes of laser welding of dissimilar metals. *International Journal of Heat and Mass Transfe,* 1(1), pp. 711-720.

Jafarlou, D. et al., 2015. The application of equal channel angular pressing to join dissimilar metals, aluminium alloy and steel, using an Ag–Cu–Sn interlayer.. *Materials & Design,* 87(1), pp. 553-566.

K.Kalaiselvan, A.Elango & NM.Nagarajan, 2018. Experimental investigation on mechanical and distortion characteristics. *Journal of Advanced Manufacturing Systems,* 1(1), pp. 10-20.

Kalpakjian, S., Vijai Sekar, K. S. & Schmid, S. R., 2014. *Manufacturing engineering and technology.* 1 ed. Newyork: Pearson.

Laureto, J. J., Dessiatoun, S. V., Ohadi, M. M. & Pearce, J. M., 2016. Open source laser polymer welding system: design and characterization of linear low-density polyethylene multilayer welds.. *Machines,* 4(3), p. 14.

Meco, S., Pardal, G. & Ganguly, S., 2015. Application of laser in seam welding of dissimilar steel to aluminium joints for thick structural components. *Optics and Lasers in Engineering,* 67(1), pp. 22-30.

Pang, S., Chen, W., Zhou, J. & Liao, D., Pang, S., Chen, W., Zhou, J. and Liao, D., 2015. Self-consistent modeling of keyhole and weld pool dynamics in tandem dual beam laser welding of aluminum alloy.. *Journal of Materials Processing Technology,* 217(1), pp. 131-143.

Pang, S., Hirano, K., Fabbro, R. & Jiang, T., 2015. Explanation of penetration depth variation during laser welding under variable ambient pressure.. *Journal of Laser Applications,* 27(2), pp. 10-15.

Petković, D., 2017. Prediction of laser welding quality by computational intelligence approaches.. *Optik-International Journal for Light and Electron Optics,* 140(1), pp. 597-600.

Plaine, A. et al., 2016. Process parameter optimization in friction spot welding of AA5754 and Ti6Al4V dissimilar joints using response surface methodology.. *The International Journal of Advanced Manufacturing Technology,* 1(1), pp. 10-15.

Pourali, M., Abdollah-Zadeh, A., Saeid, T. & Kargar, F., 2017. Influence of welding parameters on intermetallic compounds formation in dissimilar steel/aluminum friction stir welds.. *Journal of Alloys and Compounds,* 715(1), pp. 1-8.

Ragavendran, M. et al., 2017. Optimization of hybrid laser–TIG welding of 316LN steel using response surface methodology (RSM).. *Optics and Lasers in Engineering,* 94(1), pp. 27-36.

Rossini, M., Spena, P. R., Cortese, L. & Matteis, 2014. Investigation on dissimilar laser welding ofadvanced High strength steel sheets for the autmotive industry. *Material science and engineering,* 1(1), pp. 10-15.

Satoh, G., Brandal, G., Naveed, S. & Yao, Y. L., 2017. Laser Autogenous Brazing of Biocompatible, Dissimilar Metals in Tubular Geometries. *Journal of Manufacturing Science and Engineering,* 1(1), pp. 1-14.

Schüttler, J., 2018. Virtual Prototyping of High-Power Fiber Lasers: How lifetime tests in the computer improve reliability of industrial laser sources.. *Optik & Photonik,* Volume 13(2), pp. 28-31.

Vashishtha, H., Ravindra V, T. a. & Patil, A., 2017. Effect of welding processes on microstructural and mechanical properties of dissimilar weldments between conventional austenitic and high nitrogen. *Journal of Manufacturing Processes,* 1(1), pp. 1-12.

Wang, P., Chen, X., Pan, Q. & Madigan, B., 2016. Laser welding dissimilar materials of aluminum. *International Journal of Advance Manufacturing Technology,* 1(1), pp. 3081-3090.

Wang, W., Xiao, Y., Wu, X. & Zhang, J., 2016. Optimization of laser-assisted glass frit bonding process by response surface methodology.. *Optics & Laser Technology,,* 77(1), pp. 111-115.

Wei, H., Zhang, Y., Tan, L. & Zhong, Z., 2015. Energy efficiency evaluation of hot-wire laser welding based on process characteristic and power consumption.. *Journal of Cleaner Production,* 87(1), pp. 255-262.

Wu, C. S., Wang, L., Ren, W. J. & Zhang, X. Y., 2014. Plasma arc welding: Process, sensing, control and modeling.. *Journal of manufacturing processes,,* 16(1), pp. 74-85.

Yan, F. et al., 2017. Liquation cracking behavior and control in the heat affected zone of GH909 alloy during Nd: YAG laser welding.. *Journal of Materials Processing Technology,* 244(1), pp. 44-50.

You, D. G. X. & Katayama, S., 2014. Multisensor Fusion System for Monitoring High-Power Disk Laser Welding Using Support Vector Machine. IEEE Trans. *Industrial Informatics,* 10(2), pp. 1285-1295.

Yuan, X., Chen, J., Li, X. & Liang, X., 2017. Resistance spot welding of dissimilar DP600 and DC54D steels. *Journal of Materials Processing Technology ,* 1(1), pp. 31-41.

Yuce, C., Tutar, M., Karpat, F. & Yavuz, N., 2016. The Optimization of Process Parameters and Microstructural Characterization of Fiber Laser Welded Dissimilar HSLA and MART Steel Joints. *Metals,* 1(1), pp. 10-15.

Zhang, Y., Sun, D. Q., Gu, X. Y. & Li, H. M., 2018. Nd:YAG pulsed laser welding of dissimilar metals of titaniumalloy to stainless steel. *Int J Adv Manuf Technology,* 94(1), pp. 1073-1085.

Zhao, X., Tan, C., Meng, S. & Song, X., 2018. Fiber Laser Welding–Brazing Characteristics of Dissimilar Metals AZ31B Mg Alloys to Copper with Mg-Based Filler. *JMEPEG,* 1(1), pp. 1427-1439.