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AUTOMATED POSITIONER FOR WELDING THE DRIVEAXLE CASE WITH METAL INERT GAS ROBOT

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ABSTRACT

This paper is about the emerging technologies in material handling, that deal with the design and implementation of automatic welding process for a drive axle casing of the truck; an automotive component which aims to achieve better efficiency than the conventional system. The drive axle of the truck is a *Banjo axle* one with a differential and universal joint between the axle shafts which is enclosed in an axle housing structure. Normally, MIG welding is used for joining of the drive axle casing. In this process two layers of gas welding have to be done. First layer consists of joining of the outer spherical cover and the axle shaft housing on one end and second layer consist of joining an axle shaft housing and flange at opposite end. The disadvantages of welding operation in conventional systems are manually operated with more time consuming, poor quality of the job and more wastage of energy. An industrial automation system has to be implemented which consists of several elements that perform a wide range of functions related to Instrumentation, Control, Supervision and Operations Management associated with the industrial process. The new modified system consists of servo control additional axis positioned for the material handling with hydraulic fixture and welding is operated by an industrial robot having multi axis degree of freedom. A sensor and other electronic control systems interface with communication network in the automation process. The advantage of this proposed automatic system reduces cost of production significantly by efficient usage of energy, reduced time in completion of job & manpower. Also product quality is achieved using automated precision machines. Additionally, it increases the quantity produced by several times and has made the plants safer places to work, minimizing the risk of accidents.

KEYWORDS: Welding, Inert, Component, Automation & Robot

INTRODUCTION

In vehicles, the axle is fixed to the wheels with bearings or bushings provided at the mounting points. The axle is a part of the transmission unit through which engine power is transmitted to the wheels via gear box, propeller shaft and differential unit for almost passenger trucks. There are two types of axles in vehicle; called as Live axle and Dead axle. The Live axle is a driver which serves to transmit the torque to the wheel, as well as to maintain the position of the wheels relative to the vehicle body and the dead axle is a driven for support. Many commercial trucks have front dead axle and rear live axle. The driver or live axle is a *Banjo axle, which* consists of differential carrier at the front end and a spherical cover plate at the rear end. Rear axles are positioned and aligned tangentially by torque rods attached with rubber lined bushings which transfer the load to the housing. The joining process of the axle casing in trucks, involves two layers of gas welding operations. First layer consists of joining of the outer spherical cover and the axle shaft housing on one end and second layer consist of joining an axle shaft housing and flange at the opposite end as shown in the Figure [1]. Manual welding of drive axle casing is implemented presently in most of small scale and large firms. Normally, gas shielded metal arc (*GMAW*) also called as Metal Inert Gas welding *(MIG)* method is involved in industries.

Metal Inert Gas Welding of Drive Axle

Metal Gas welding requires the heat of the electric arc to melt the consumable electrode wire and the metal components to be welded. The fusion process is carried out under the shield of an inert gas with a mixture of argon-helium or oxygen-Co_2 in sequence to prevent the harmful contamination of atmospheric gases. A high current is applied to the electrode which causes its tip to melt transferring to the work piece. The electrode is fed at a constant, controlled speed to the arc referred as wire speed rate and is one significant parameter of welding process. The stability of the welding process is very sensitive to the welding parameters such as current, voltage, welding speed, shielding gas, arc length, welding procedures, alignment of component and job handling. The present progression of manual welding effects the possibility changes in

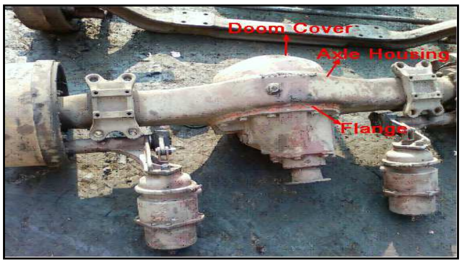

Figure 1: Axle Shaft Housing and Flange **Figure 2: Variation of Welding Parameters**

The distance between the welding torch and the component being welded which may produce a substantial variation in the current,voltage and shielding gas influence transfer mode of melted filler metal to the component being welded, affecting the weld quality. In case of the electric arc is unstable, defects like awful penetration profile, undercut or excessive spatter may happen as exposed in Figure [2]. During welding, extremely high temperatures of the components are concentrated in welding zones. Physically, that affects the material by localized thermal expansion, contraction cycles and mechanical behavior along with plastic deformations. Consequently, it requires skilled manual welder in the positioning of the welding torch, arc stability, alignment of job, controlling the welding parameters, welding procedures along with shielding gas and wires. The good quality of weld relies on the welder experience and skill in a way to respond to customer needs in time with precision and good quality. As a result, to overcome the disadvantages as mentioned above, automating the welding process is a very challenging area of research in the fields of robotics, sensor technology, control systems and artificial intelligence. It includes the observation of the ongoing process and adjust the controlling parameters, with automatic material handling system and welding process parameters, in accordance to the desired results.

Industrial Automation Challenges

The demand for the use of robots from the potential for flexible, intelligent machines that can perform multi tasks in a repetitive manner at a reasonable cost of welding operations and material handling. Automation is a set of control technologies that results in operation of machines and systems with or without signs of human interference and achieves high performance better than the manual operations integrated with control network. However, it may have much more functionality, such as monitoring performance of system, output flow progress through set points, plant startup or shutdown, job scheduling, etc. Based on all aspects there are various levels of automation in an industry which can be explained by the automation pyramid shown below in Figure [3]. Sensors and actuators layer relates to the processes and machines which is used to convert the signals from processes for analysis & decisions and hence forms the base of the pyramid called as ‘level 0’ layer. Automatic control layer consists of advanced control and monitoring systems which drives the actuator using the process information from sensors and called as ‘level 1’ layer. Supervisory control layer drives the automatic control system by setting a goal of the controller, which consists of control and feedback signal loops and called as ‘level 2’ layer. Production control layer solves the decision problems like production targets, resource allocation, task allocation to machines, maintenance management, etc and called as ‘level 3’ layer. Enterprise control layer concern with less technical and more commercial activities like supply, demand, cash flow, product marketing, etc and called as the ‘level 4’ layer. All the four levels of layers are interfaced by various types computer network standards like CAN bus, field bus, etc. For communication with the convergence of technologies working in synchronization. The research idea is to acquire an automatic procedure for welding and online data rectification accomplishing better quality welding.

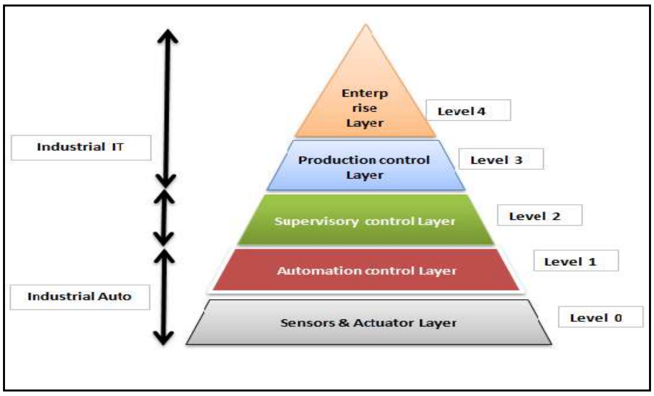

Figure 3: Industrial Automation Pyramid

Consequently, the application of the new modified automated material handling, welding system with robot manipulators is unique, flexible and multitask performers, with comparable good quality of job for long periods of time. In addition, it also bridges the best rate between production cost and production volume for small and medium batches. In fact on considering actual market scenarios like very high competition, customers defined products with low life cycles, increasing demand for better quality at lower prices, companies operate based on orders and risk factors which always keep production on small and medium scale in reasonable scale of market value. The advanced system can be adopted easily with manufacturing setups requiring frequent task changes, which respond to market changes or new trends for the products.

RESEARCH METHOD

For the elaboration of this report at complete survey of the existing and available automation process has been analyses related to the way factories and distribution centers work. Many companies have contributed by sharing their conveniences and their concerns to the authors. An Indian firm is a consultant and manufactures many customized automated welding solutions for Gas Tungsten Arc Welding, Plasma Tungsten Arc Welding, Submerged Arc Welding and Gas Metal Arc Welding processes. It has also executed the complete welding automation solutions from simple mechanizations to turn key plant automations with sophisticated computer controls and data logging systems. A new project for welding automation of drive axle casing of the truck has to be designed and implemented as per the expectations and needs of clients.

Prof. S. Sen and Prof. S. Mukhopadhya (2011) [1] presented an article which describes the various elements of an industrial automation systems and hierarchical levels related to their functions to control technologies and product life cycle related to the various phases. J. Norberto Pires, *et al*, (2006) [2] published a book which gives a detailed overview of robotic welding, evolution of robotic welding, welding technologies and requirements for automation using robot manipulators with hardware and software interfaces. H.L. Saunders (1997) [3] published a book which contains the basic guidelines specific to gas metal arc welding process and its types with basic fundamentals. J. Norberto Pires, *et al*, (2001) [4] discussed about technological problems of robots, welding process and human machine interfaces related to industrial automation. F. Noberto pries, *et al,* (2004) [5] proposed a methodology for extracting the robot information from CAD data in automatic robot welding application by understanding the detailed data of working pieces in computer aided design files. R.G. Baggerly (2003) [6] explained about the failure of steel castings weld in heavy truck axles with real time examples. P.K. Palani, N. Murugan (2006) [7] discussed about the selection parameters in various aspects of the pulsed gas metal arc welding process and its effects. Sinhe Hernandez (2010) [8] presented a work on Laser welding of hardenable steel based on nucleation and growth applied to an induction heat treatment of a laser welded component of rear axle. Bernd Scholz-Reiter, *et al*, (2008) [9] developed a new model towards automation of low standardized logistic processes of cyber physical robotic systems by the concept of robotics and mobile technologies using bar codes or RFID tags and sensors. Ho Choi, Muammer Koc (2006) [10] proposed a new system for design and feasibility tests on a flexible gripper based on the use of compliant materials with pneumatic inflation and sensor based control system.

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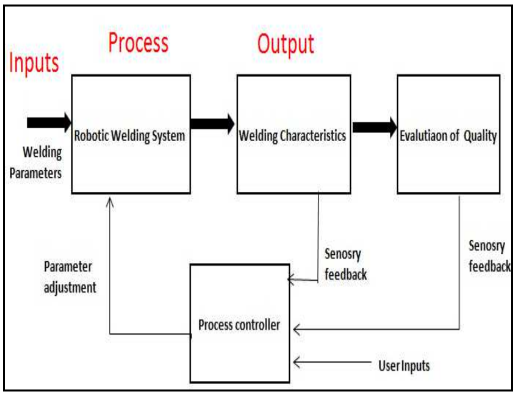
Summary of Literature Survey

The different elements of an industrial automation hierarchically level are described. An overview of robotic welding, evolution of robotic welding, guidelines, welding parameters such as current, voltage, welding speed, shielding gas, arc length, welding procedures and job handling techniques, etc. are elaborated. Sensors are used for welding robots, measuring weld seam tracking, quality control and supervision. The limitations and design strategies of a flexible gripper with pneumatic inflation and sensor based control system are reviewed. A new automatize material handling system using programmable logic controllers, data acquisition, Matlab, multiagent holonic control and embedded systems integrated with communication network are projected. The different characteristics, features are conversing on the short circuiting, pulse current parameters, controlled metal transfer, effects of shielding gas for the arc welding process. The manufacturing complexity and emerging technologies of intelligent Mechatronic approach control system are explained. Development of a web based association for product manufacturing, process design evolution of virtual reality techniques and machine vision approach for robotic assembly is proved. A six-degree reconfigurable gripper system is designed for the flexible fixtureless assembly system. The human considerations in automotive assembly systems for conceptual design, manufacturing modelling and management control are exhibited. The scope of an industrial robot is explored for future industry. The influence of heat input and the torch weaving movement is analyzed for robotized welding. A knowledge based systems is implemented with advanced techniques and standard data values for robotized arc welding process. The data communications, computer network standards are interfaced with the convergence of technologies working in synchronization. The dissimilarities of automation and control in the sense of the requisites and information technology are differentiated. The safety practices in welding, cutting, hazards environment and allied processes are revealed.

SOLUTION METHODLOGY

The Present market conditions are more suitable to small and medium batch manufacturing, due to high competition and adoptable changes on the market in accordance to the customized solutions. In case of the above condition, the implementation of robotic production setup produces the best "cost per unit" performance, greater than the manual work and hard automated setups as represented in the Figure 4. The drive axle casing of the truck is an automotive component which employs welding application for joining of components. If, the welding operations are incorporated with some kind of automation, with robots and flexible machines to handle multi task, controllers, etc., it produces cheaper products, since productivity, quantity and quality can be increased and production costs, manpower can be decreased. The *MIG* welding method is complex, multi parameterize techniques based on observations, and experience under specific conditions. The standard procedures and data values of welding, and various approaches are reviewed below, related to weld quality. Technological parameters include weldability of metals, power supply and equipment, shielding gases, filler wire, welding machine setup. The weldability of material is most suited to metals like mild steel, aluminium, stainless steel, more alloys and combination of metals. The power supplies are referred as constant voltage, which produces an electrical current at a consistent level, and wire feed system is used to feed the filler wire to the weld joint Inches per minute.



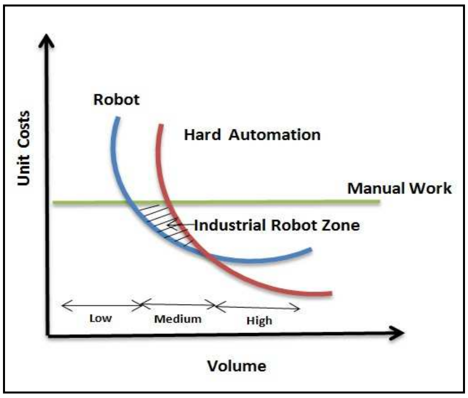


Figure 4: Industrial Robotic Zone **Figure 5: Overview of Welding Control System**

The *MIG* gun shields the weld area from the air; produce an arc and ignites the welding process by feeding wire to the weld joint. The welders have three important settings such as shielding gas flow rate, voltage setting, wire feed speed. The shielding gas flow rates range in cubic feet per hour and voltage settings depends on metal thickness with electrode size and the wire speed controls transfer types and amperage settings in determining the weld bead properties. The implementation of robots with welding tasks requires various R&D efforts.

The overview of robotic welding control relationships between the variables and the parameters are shown in the Figure 5. The *MIG* welding robot is used to weld and the process controller is used to vary the input and output feedback signals. All the parameters are integrated and corrected in order to achieve a desired output, with a fully automatic robotic welding system. There are two types of output parameters, such as geometry and metallurgical. Geometrical parameters include penetration of metal fills to the welding joint called the bead width, the bead height and metallurgical parameters include accuracy and close tolerance, good quality.

The Correct Position of Striking an Arc and Electrical Stick Out

The electrode sticks out of the *MIG* gun is extremely important. The correct electrical stick-out is ¾ of an inch or less stick-out and if longer stick-out results in porosity and leakage of shielding gas with porosity in the weld. A shorter stick-out has been always better because it provides better gas coverage as shown in the figure 6.

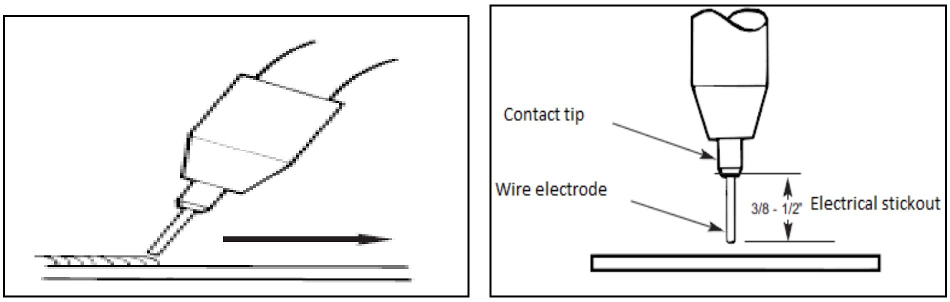


Figure 6: Electrical Strikeout Position

Angle of Torch

The structural welding position requires fixing the MIG gun at a certain angle towards the direction of the weld and the depends on the type of weld such as Lap weld, butt weld, edge welds, corner welds, and fillet weld, etc. As shown in the figure 7. Lap Welding is well suited for the welding operation.

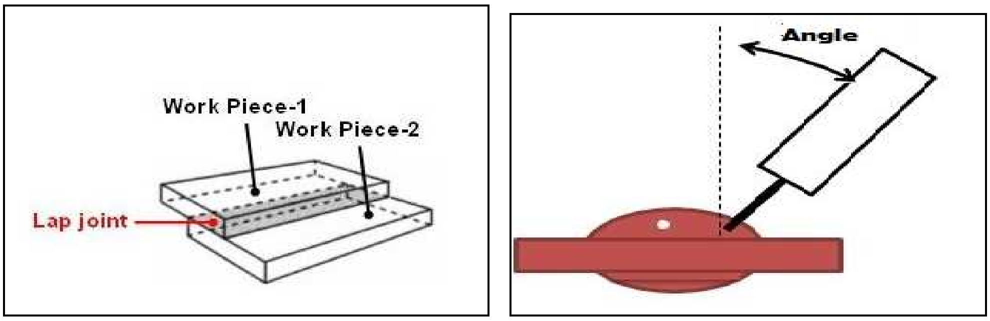


Figure 7: Torch Angle

Weld Bead Geometrical Parameters

The strength of the weld joint is determined by the bead width, bead height and complete weld penetration in to the job as shown below in the figure 8.

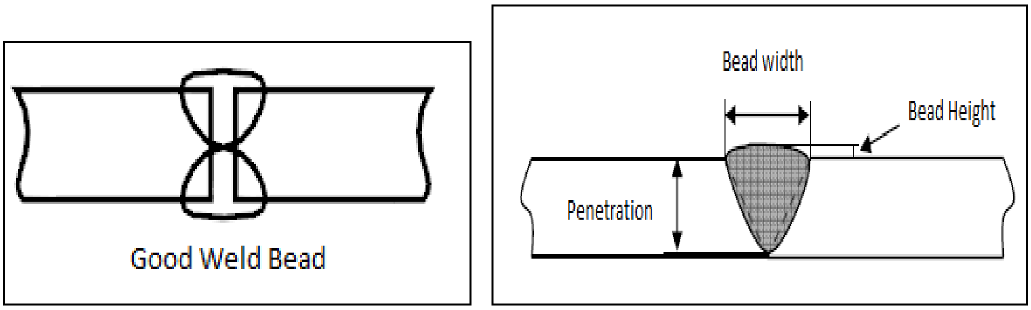


Figure 8: Weld Bead Geometrical Parameters

CONCLUSIONS

In this paper, the conventional system procedures and difficulties of industrial MIG welding practices for drive axle casing is demonstrated. A detailed overview of robotic welding technology and their limitations are presented along with author's outlook. The standard data values of welding parameters such as current, voltage, welding speed, shielding gas, arc length, welding procedures are referred. In fact a new version of the automatic welding system is being explored by an industry associate to redefine the present system problems which are related to human machine interfaces. The new automatized system consist of power wave source [1] which is a high performance, digitally controlled inverter capable of complex and high speed wave

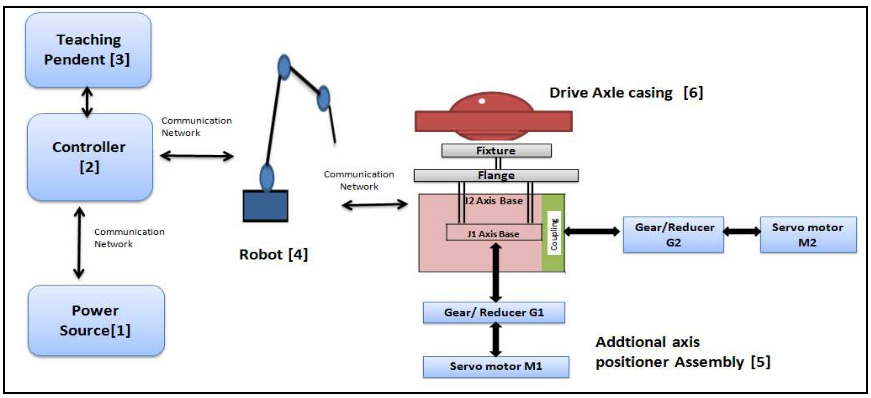


Figure 9: Automatic Welding System Layout

Form control for welding thick materials. It can sustain constant current, constant voltage, pulse welding modes and constant wire feed rate. The cabinet controller [2] is an enclosure containing a robots'controller, axis control module, input/output slots, control circuits and power supplies that progress the information and instructions to a robot. The axis control module manages the velocity, torque, direction of rotation and inputs/outputs peripheral permits the interaction of robot with the environment and the control circuit coordinates the robot programming, motion control and power supply provide voltage, current to a robot's motor. A teaching pendent [3] is an accessible build software device used to program and control robot movements. An industrial robot [4] is a programmable mechanical device that performs the welding operation with a high accuracy. The most significant factors for the robotic selection are degrees of freedom, payload, work volume, direction speed, mounting type, etc. A DC servomotor is used for precise positioning of robotic arm as defined by degrees of freedom. The Additional axis positioner [5] is a servo control assembly with hydraulic fixture for material handling. The positioner is configured by J1 axis drive and J2 axis drive mechanism in such way that J2 axis base is rotated by reducing the rotational speed of a servo motor with a gear/reducer. The J2 axis base is supported on the J1 axis base through gear/reducer and coupling as represented in the below figure. The hydraulic drivers are used for fixturing of hollow component base which is connected to J1 axis base. Based on the welding requirements the positioned motion of the J1 axis base and J2 axis base are estimated to be 360^{o} and 165^{o} of rotation respectively. As a result, two layers of welding operations are achieved with component rotation of 135^{o}. All the components are interconnected through ethernet cable or communication network or protocols via robot teach pendant, robotic systems and the controller. The drive axle casing [5] is a hollow spherical component inside with the differential carrier at the front end and a spherical cover plate at the rear end. Consequently, the two layers of weld joining are performed.

The application of the new proposed system will reduce cost of production of efficient usage of energy, reduced time in the completion of the job and human power. The improved product quality and quantity, safety issues and minimization of accidents are accomplished using automated precision machines. The present solution proved a big reduction of human physical welding difficulties and enabling user friendly advance concepts which is very easy to stimulate and adapt to the changes. In future, manufacturing and installation of automized assembly and feasibility experiments were conducted to obtain an overall understanding about the capability of machines and its limitations. Further developments are needed to describe all the industrial environments situations. Nevertheless, the results obtained depicts that a general customizable solution can be achievable by the addition of simple mechanism to turn on key plants.

ABBREVATIONS

MIG- Metal Iner Gas

GMAW- Gas Metal Arc Welding

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