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Design and Fabrication of Friction Stir Welding End-Effector for an ABB IRB1410

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Abstract: The paper purpose modelling and fabrication of friction stir welding end-effector for ABB IRB1410 robot. A dynamically developing version of pressure welding processes, join material without reaching the fusion temperature called friction stir welding. As friction stir welding occurs in solid state, no solidification structures are created thereby eliminating the brittle and eutectic phase's common in fusion welding of high strength aluminium alloys. In this paper, Friction stir welding is applied to aluminum sheets of 3 mm thickness. A prototype setup is developed to monitor the evolution of main forces and tool temperature during the operation. Pressure of a gripper plays a major role for tool rotation and developing torque. Fabrication of the tool has done. Force calculations are done by placing the sensors on the outer surface of gripper. Methods of evaluating weld quality are surveyed as well.

Keywords: Friction Stir Welding; fabrication; pneumatic gun; weld quality

1. INTRODUCTION

Friction stir welding (FSW) is a relatively new and promising solid state welding technology developed by The Welding Institute (TWI) of UK in 1991 [1]. Due to its energy efficiency, environment friendliness and versatility, this joining technology has been widely applied in various industrial applications in recent years, such as shipbuilding, railways, automotive and aerospace industries. Compared to conventional fusion welding technologies, FSW is mainly characterized by joining material without reaching the fusion temperature, avoiding the problems caused by melting metals [2]. As a result, almost all types of aluminum alloys, even those that are classified as non-weldable by traditional fusion welding techniques, can be welded through FSW process [3].

Industrial robots have been increasingly used in the FSW process to replace commonly-used dedicated machines because of their excellent repeatability, production flexibility and low cost [4]. Smith et al. (2003) [5] developed a FSW system which was integrated to an ABB IRB 7600 articulated robot and the capability of implementing three-dimensional contours welding in various positions with excellent force feedback control was proved. Bres et al. (2010) [6] established a model-based framework which allows the simulation, analysis and optimization of FSW processes of metallic structures using industrial robots. Applied on-line [7] sensing and path compensation methods to obtain a strong and defect-free welding in robotic FSW process. [8] Demonstrated a successful development and evaluation of a closed-loop control system for robotic FSW that controls plunge force and tool interface temperature by varying spindle speed and commanded vertical tool position.

A. Welding Process

In FSW the parts to weld are joined by forcing a rotating tool to penetrate into the joint and moving across the entire joint. Resuming, the solid-state joining process is promoted by the movement of a non-consumable

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tool (FSW tool) through the welding joint. FSW consists mainly in three phases, in which each one can be described as a time period where the welding tool and the workpiece are moved relative to each other. In the first phase, the rotating tool is vertically displaced into the joint line (plunge period). This period is followed by the dwell period in which the tool is held steady relative to the workpiece but still rotating. Owing to the velocity difference between the rotating tool and the stationary workpiece, the mechanical interaction produces heat by means of frictional work and material plastic deformation. This heat is dissipated into the neighboring material, promoting an increase of temperature and consequent material softening. After these two initial phases the welding operation can be initiated by moving either the tool or the workpiece relative to each other along the joint line. Figure 1 [9] gives a schematic representation of the FSW setup and operation.

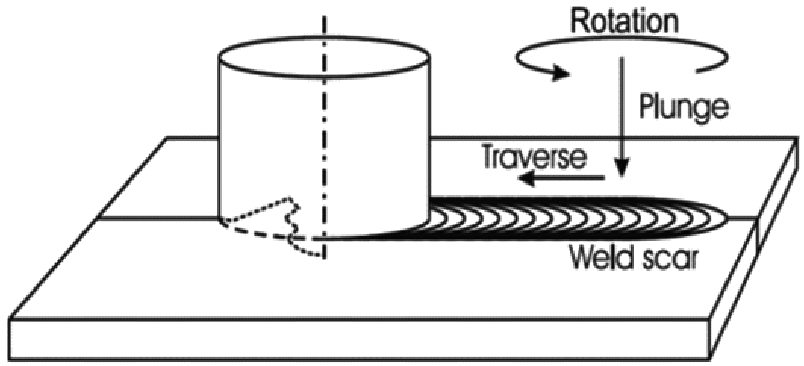

Figure 1: Friction Stir Welding Setup

This paper is organized as follows: The experimental methodology is introduced in Section 2. In Section 3, the data of design, followed by the fabrication of the tool and frame. Section 4, force analysis by using the LAB View. In Section 5, conclusion and future. Finally, acknowledgement of the paper are given in Section 6.

2. METHODOLOGY

The approach towards the making of the end-effector has been split into different steps which goes like designing, fabrication, quality control and controlling of the robot. Figure 2 says the steps of the methodology of project. First step is initialize and identifying the problem. The second step is developing the concept to overcome the problem which has been identified in the first step. Once the concept is developed for the identified problem, the different possibilities of the concept is sketched out and studied. The optimum solution for the concept is arrived after the studies. The next step is to develop the conceptual idea into a 3 dimensional model using modelling software by SOLIDWORKS. The various calculations are done such as DH parameters. Then analysis of the complex model in order to identify fundamental properties had been carried out. Next stage is to fabricate the weld tool and interface to ABB IRB1410. Then an algorithm and program is to be developed for the ABB Robot for the purpose of friction welding operation by friction stir welding end-effector.

Finally, the friction stir welding is interfaced with the robot for verifying the algorithm and program in real time.

A. Material Used

Various materials where proposed and their properties are studied. Some of the material proposed is as follows: Aluminium alloys, HCC (High Carbon Steel), Chromium.

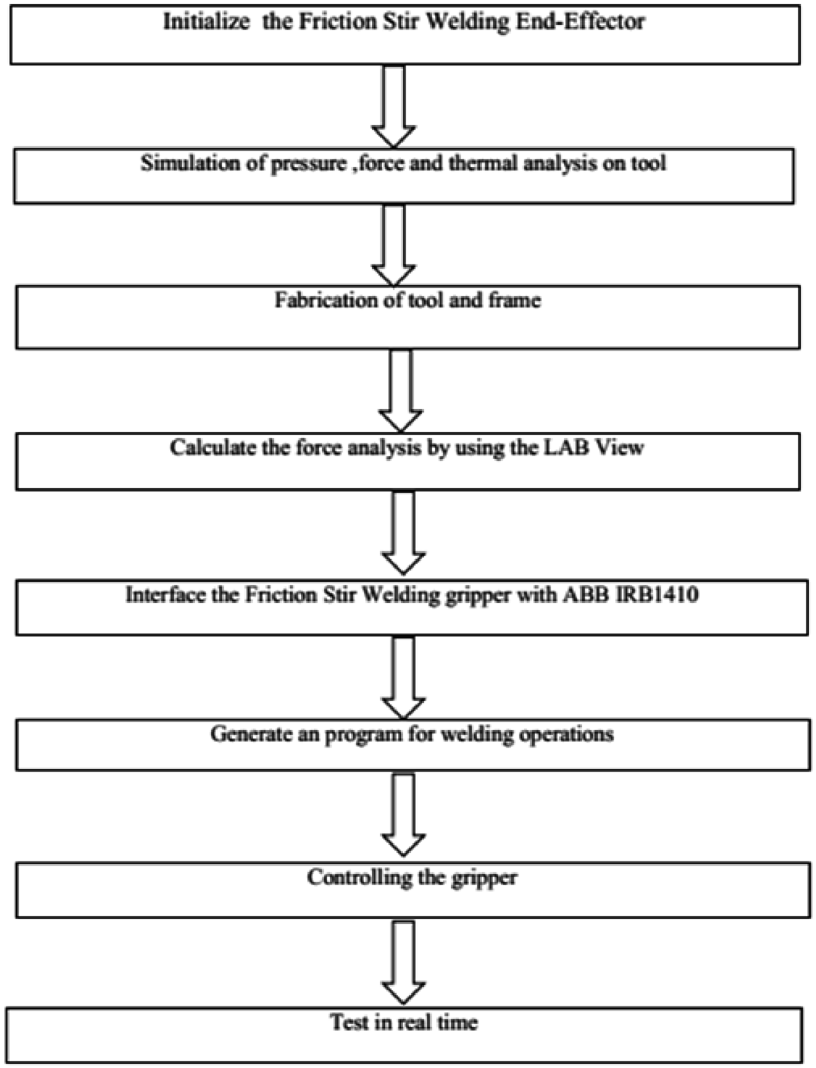

Figure 2: Flow chart of Methodology

3. DESIGN

3D modeling software was used to design the model of the friction stir welding. The model will be with a rigid aluminum structure as the body with a H13 tool cover at the bottom and pneumatic gun. Each model of the segment were created separately and assembled. Calculations done to determine the torque required to move these designs by a pneumatic gun.

A. Design of Weld Tool

The first step of design process is to develop the weld tool for friction welding. Here the pin is threaded with dia. 3 mm the connecting the shoulder here the dia.10mm, with concavity which is shown in Figure 3.

The next step of assembly is to mate the base plate to the tool and mounted to the base plate of end effector which has been shown in the Figure 4.

The next step is to assembly the pneumatic gun with a revolution per minute (RPM) 22,000, torque 2.1N-m which mount on the base plate with assembly of tool to the pneumatic gun which is shown in Figure 5.

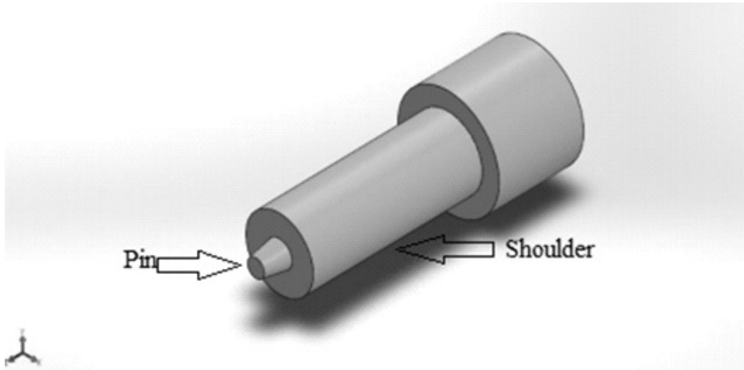

Figure 3: Design of weld tool

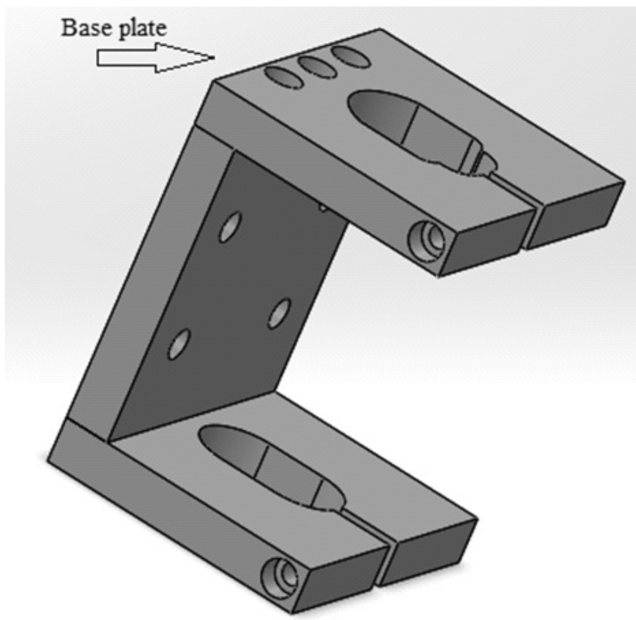

Figure 4: Design of Base Plate

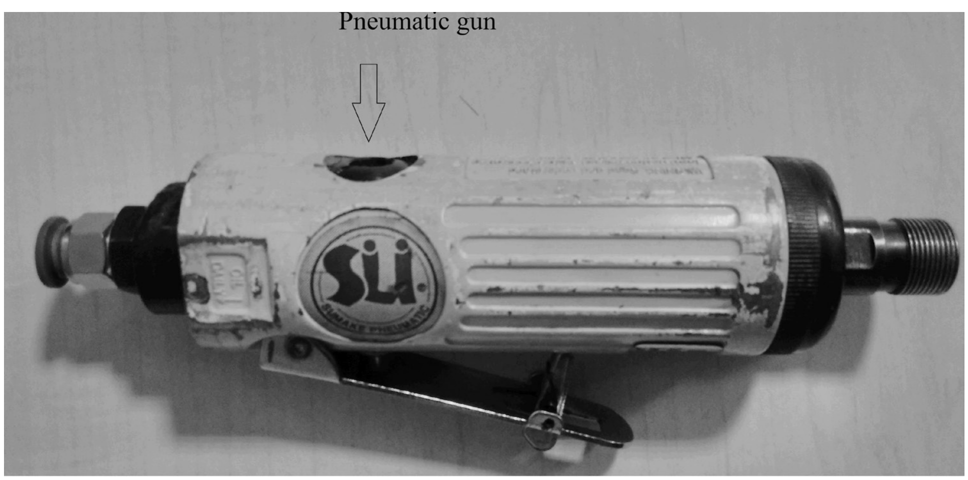

Figure 5: Pneumatic Gun

B. Fabrication and Mounting to Robot

The fabrication of weld tool with the H13 material, with the required hardness of material heated up to 900°C and quenched in oil as shown in Figure 6.

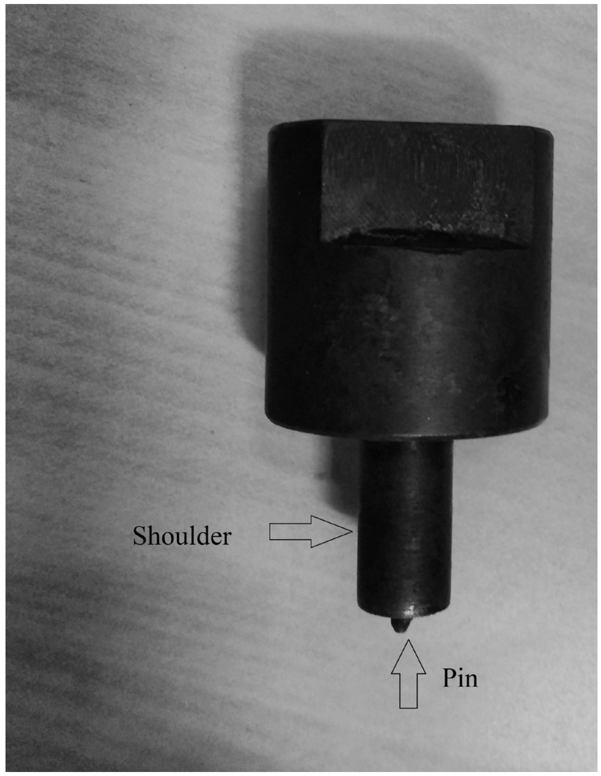

Figure 6: Weld tool

The frame with cast iron material which having a stability to avoid the vibrational feature and to withstand with the robot as seen in Figure 7.

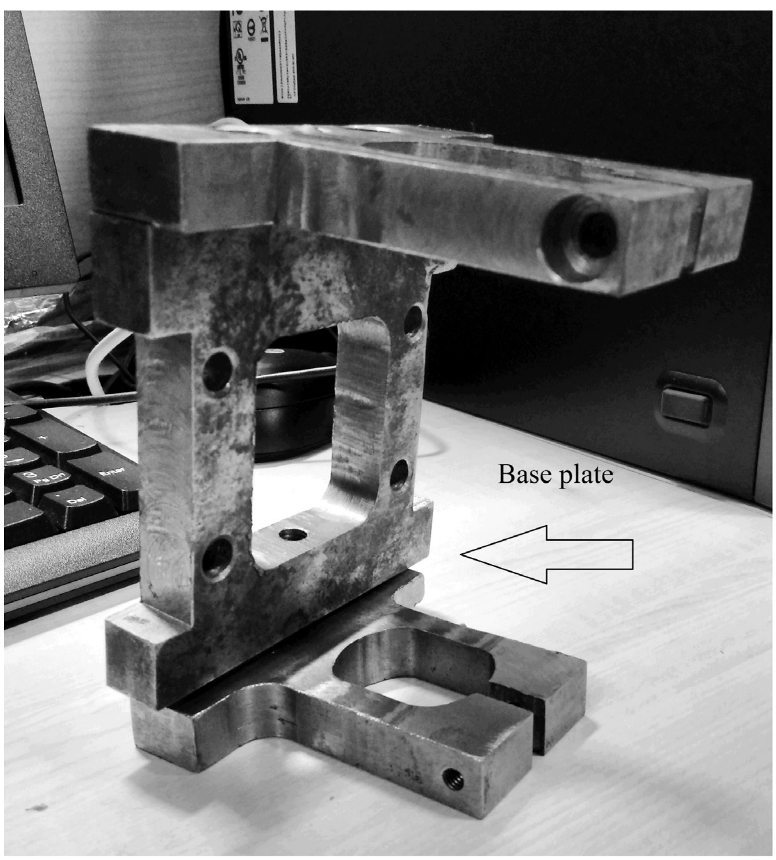

Figure 7: Frame

This robotic welding system is used to implement a FSW operation of some aluminum alloy plates. In this operation, the spindle of the robotic system is controlled to weld in x direction of the tool frame with a constant travel speed v and rotation speed ω. The other welding conditions for the experimental parameters are listed in Table 1.

Table 1
Robotic FSW experimental conditions

Parameters	*Name/Value*	*Unit*
Weld material	Al6082	
FSW tool type	H13	
Material thickness	3	mm
Torque	2.1	N-m
Rotational speed	22,000	rpm

The next step is to assembly the tool and frame and the pneumatic gun, to the ABB robot as shown in Figure 8.

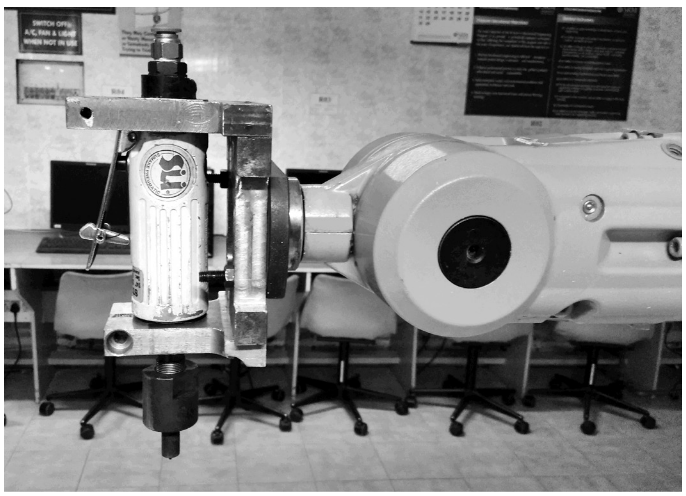

Figure 8: Assembly of setup

The overall view of the setup, mounted to the robot after the fabrication as shown in Figure 9.

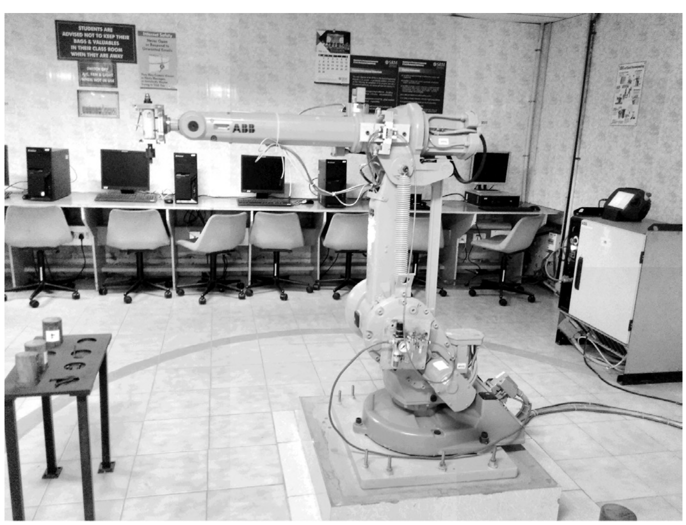

Figure 9: Overall Setup

4. FORCE MEASUREMENT

The force measurement can be detailed by using LABView software by taking the pressure sensor which is mounted to the base plate, the force analysis which shown in Figure 10.

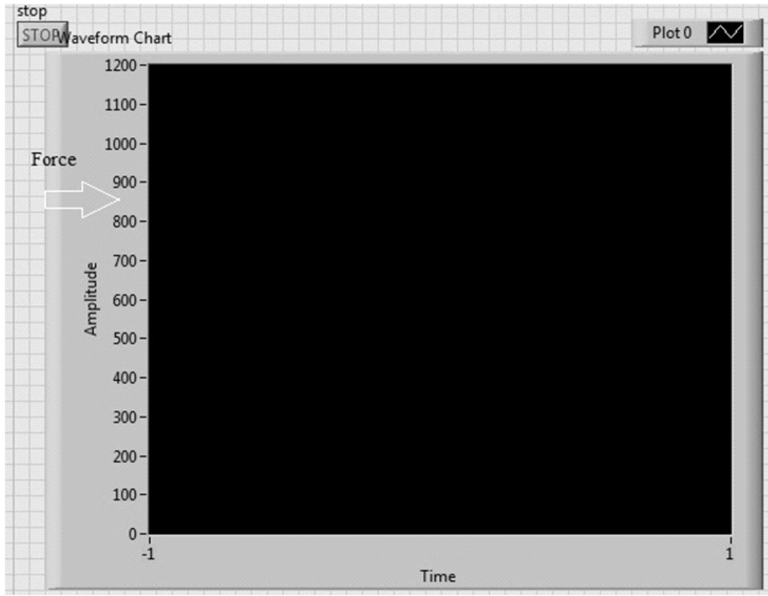

Figure 10: Force measurement

The next step is the wire diagram of the pressure sensor is been mounted on the baseplate to read the generated pressure and force by the weld tool is shown in Figure 11.

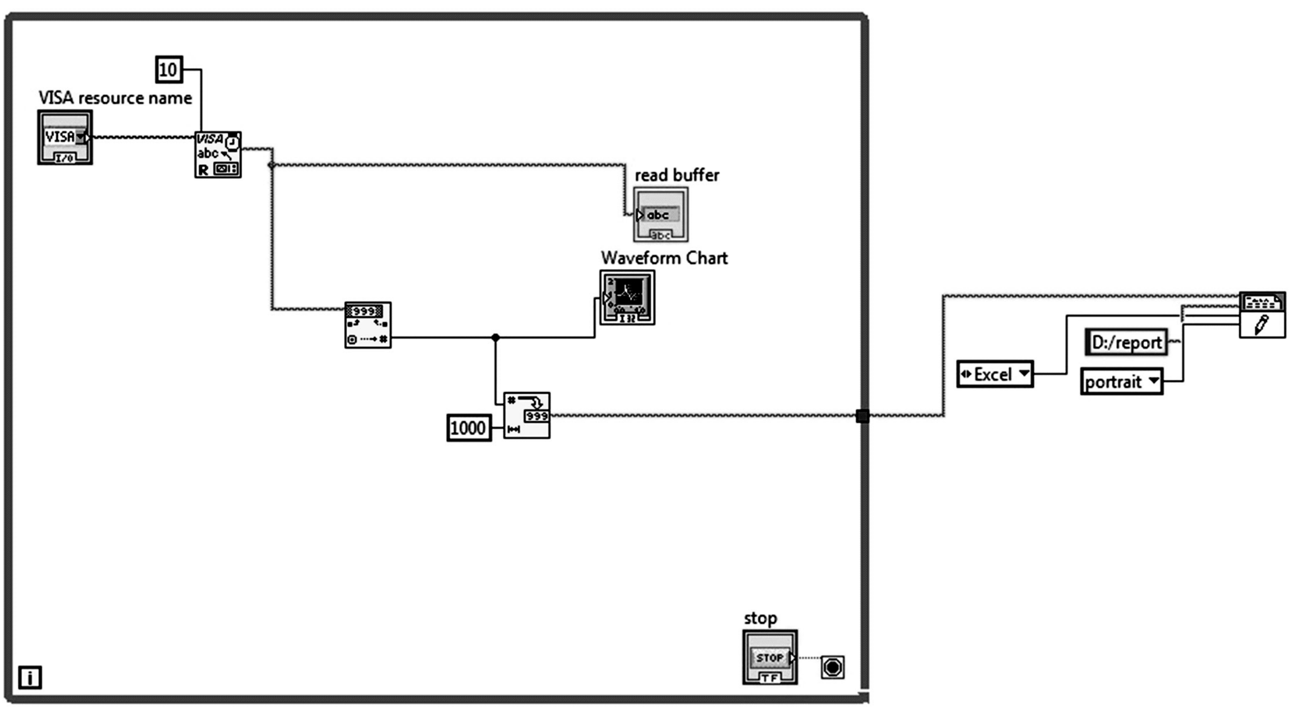

Figure 11: Wire diagram

5. CONCLUSION AND FUTURE WORK

A detailed study over various welding robots has been done. Friction stir welding can adapt to various diametric changes of shoulder and pin diameter weld tool. This friction welding by ABB IRB1410 robot can say the lighter material easily be welded and can be control the RPM of pneumatic gun by flow control valve. This robot can move within it robot work cell with its reachability. Design of weld tool and base plate were done and fabrication has done, trails were made, analysed and rectified for the friction welding. Weld quality test will be carried out as the future work. The experimentations are carried out on the robot to make it efficient enough to move over the material to weld the similar and dissimilar weld plates.

Acknowledgment

I feel greatly indebted to my project guide Mr**.** V. Raghavendra Rao**,** and I thank him for the deep interest he has shown in this project and for motivating me to do my best.

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