WELDING TECHNIQUE FOR IMPROVING QUALITY FOR SHEET METAL FABRICATION BY USING ROBOTIC WELDING CELL

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ABSTRACT
The aim of the present work is to study the controlling of weld defects and dimensions by using robot cell which associated with MIG/MAG welding process. The base metal is evaluated through the chemical analysis, mechanical tests and micro-structure tests. Filler metal is also selected and analyzed according to AWS specification. The various welding conditions are chosen to be as suitable as possible such as welding current, arc voltage, travel speed, stick out, protective gases and there is another effective parameter called as torch inclination angles, which has an obvious effect on the weld bead dimensions. Robotic arc welding has been applied and analyzed for the welding of a complex sheet metal product named as product X-11. The product X-11 required 33 arc welds with total length of (182.8 cm) of welds. Two complete weld programs development are carried out. The weld program consists of two stages, which are the front side and the back side. The cycle time calculates for each program. It is obvious that the productivity is increase to about 186 %. Some of quality control tests are curried out for the purpose of improving in weld quality. Some of inspections and tests are achieved for finding out the defects in the weldments in the mass production which is considered as attributes data. Pareto diagram is also set up to show the important defects in the production. The presence of defects in the final products may belong to many factors (e.g. poor fits for welding parts, impurity of protective gases, etc.).

الخلاصة
البحث يهدف إلى دراسة السيطرة على عيوب اللحام وأبعاد اللحام من اجل تحسين نوعية الملحومات باستخدام الإنسان الآلي في لحام (MIG).ان معدن اللحام تم تحديده من خلال فحوصات التحليل الكيمياوي و الاختبارات الميكانيكية و اختبارات البنية المجهرية0 المعدن الإضافي خضع إلى فحوصات التحليل الكيمياوي0 متغيرات اللحام المختلفة و المتعلقة بعملية لحام (MIG) اختيرت كأحسن ما يمكن من خلال ملاحظة تأثيراتها على شكل و ابعاد درزة اللحام مثلا تيار اللحام ، فولتية اللحام ، سرعة اللحام ، بروز واير اللحام ، الغازات الحامية و كذلك زوايا مشعل اللحام0 بعد ذلك تم استخدام لحام القوس الكهربائي باستعمال الإنسان الآلي في لحام منتج معقد التركيب مصنوع من صفيحة فولاذية نحيفة السمك0 المنتج المصنع يدعى (X-11) و الذي يتطلب (33) لحام قوس و بطول أجمالي يصل إلى (182.8) سم من اللحام. تم تهيئة برنامجين للحام هذا المنتج مع حساب زمن اللحام كاملا لكل برنامج0 بعد تطبيق برنامج اللحام المؤتمت تم التوصل إلى انه الإنتاجية تزداد بمقدار 186% باستعمال الإنسان الآلي .بعض اختبارات السيطرة النوعية أجريت لغرض تحسين نوعية الملحومات المنتحة0 تم الفحص

عن العيوب للملحومات المنتجة بألروبوت في أثناء الإنتاج الكمي و التي اعتبرت كتجميع بيانات للسمات ألتمييزية للملحومات. مخطط باريتو أستعمل ليبين العيوب المهمة في المنتج و إعطاء الأولوية في معالجتها.

KEY WORDS
Robotic welding, MIG/MAG robotic welding, Statistical quality control, Techniques of quality control, Improvement of welding quality.

INTRODUCTION
Over the last twenty years or so automation in the field of welding has been spreading. In 1985-1990 s there was great advance in joining technology in recent years has bean the development of welding robots [Sebah , Jenan 1989], because of the beneficial effect of these devices on productivity and fabrication costs, and because of the impact on the manner in which manufacturing will be done in the future. The primary capability of the robot is its flexibility of motion, which results in a manipulative capability similar to that of the manual weldor. Additionally, its inherent reprogrammability makes it adaptable to a variety of applications. Arc welding robot is in essence manipulating device, which simply moves the welding torch along the joint line thus performing some of the functions of human weldor. The arc welding system used with robot is MIG process. When comparisons are made between this form of welding and manual arc welding operations, many advantages are gained which benefit the manufacturing operations associated with producing a finished welded product. Robotic arc welding provides flexibility for welding of a family of products and is capable of producing consistent weld appearance and quality.

FEATURES OF THE ARC-WELDING ROBOT
The robot is programmed by the teaching mode method using a hand-held control and the program must be quick to produce easy modified to suit the real conditions for variations of fit up and component tolerance. Five axes are generally required with wrist rotations of greater than 360 degrees. The robot need 6-degrees of freedom, which gives it the capability to move the end effector through the required sequence of motions. If there are more than 6-degrees of freedom, then will be redundancy. This means that the arrival of the end effector to the particular position and orientation is then attainable by an infinite number of combinations of joint positions, which reach. It is possible to obtain more degrees of freedom (axes of motions) by putting the robot on a track or slide [Groover1984]

Or by using an auxiliary axes such as a rotating table which has two-degrees of freedom movements of rotation and turning. Continuous path robots have a capability to follow through points which describe a smooth compound curve, in this type of robots the memory and control requirements are greater than PTP. Since the complete path taken by the robot must be remembered rather than merely the end points of the motion sequence. The robot must have a positioning repeatability of no more than ± 0.2 mm to MIG weld material down to 1mm thickness.

FEATURES OF THE ARC WELDING EQUIPMENT
The present study was carried out in the robotic welding cell. The robot welding facility is configured form:

1- An articulated arc welding robot and control.
2- A two-axis, robot-compatible table type positioner.
3- A power supply, wire feeder.
4- A welding gun and supply of water for cooling the torch.
5- A real of electrode wire.
6- A remote control device.

7- A supplier of gases with gas regulator and flow meter and connections.

The robotic cell consists from robot, equipment of welding, and control. The robot type is Earnest one- Sapri S.P.A, which has 9-degrees of freedom.It may be able to perform some operation on one or more objects, which is fed into robot working volume and then remove away when the operation have been completed. The object must be constrained while the robot operates on it. A mechanical device is called fixture, which is used for holding the objects during the robots are operating on them. Robotic welding process is intended to give fast deposition rates of high quality welding with a consistently reliable performance welds are applied many times faster than by manual arc and gives better and uniform appearance, and there is an absence of frequent stops and starts.

WELDING MATERIAL AND CONSUMABLES

The base metal used in the investigation, is low carbon steel type " St. 3" according to DIN standard. It is sheet metal with nominal thickness of (2mm). This material is chemically analyzed, table 1 shows the nominal and actual laboratory results for the base metal material. **Table (2)** shows the mechanically properties for this material as nominal properties according to DIN standard [Din Deutschies Institute 1976] and the actual laboratory results. The filler wire is 1.2-mm diameter, copper – coated, solid mild steel wire. Its grade was chosen according to AWS specification. The filler must be similar or better to base metal in the chemical composition and mechanical properties. Therefore, the filler wire grade choose is "ER70S-6". **Table (3)** shows the nominal composition of the filler metal, which is taken from AWS specification, and actual laboratory results. **Table (4)** shows the mechanical properties of the filler metal according to AWS specification. The shielding gas is a mixture of approximately (Ar + 20% CO_2). CO_2 gas is in liquid form then passed through pressure reducing valve and a heater to ensure that gaseous CO_2 is supplied to the mixture device. The Argon gas also is passed through reducing valve and then it is mixed with CO_2 gas so that the gas flow rate for each gas is (2-3) L/min CO_2 and (9-10) L/min AR gas. Where, the total flow rate of mixed gases is 12 l/min and the mixture proportions are as following: (75-80) %Ar and (25-20) % CO_2.

WELDING PARAMETERS

The welding conditions are the more important factors to get qualified product. In this work many tests are done to establish the optimum welding conditions.

Welding Current

The current type is direct current reverse polarity 'DCRP' which is recommended to use since this condition leads to a stable arc with smooth metal transfer, low spatter and good quality weld bead. During this practice, it could be seen that there is direct relationship between the current and the penetration. Therefore, the operating range for this practice is within (100-140) amps, but the more suitable value was (130-135) Amps. Since this range give stable arc, uniform bead with right appearance, and no burn-through or undercutting in the joint.

Arc Voltage

The Arc voltage is selected in this work and adjusted at the power source to the required amount, during this regulation of arc voltage, the following features were noted:

When the arc voltage was increased, the weld bead becomes flater and wider.

When the arc voltage was too high (e.g. V=20 or more) volts, the weld bead is wide and irregularly shaped and excessive spatter resulted. Therefore, the operating range of arc voltage is recommended of (16-19) volts.

Filler Metal Type and Size

The electrode diameter is 1.2mm, which selected depending on the work-piece thickness. The filler wire type (ER70S-6) is suitable for the base metal. Since it is used to weld sheet metal where smooth weld beads are desired. The quality of the weld will depend on the degree of surface impurities.

Wire Feed Speed

Wire feed speed is automatically changed. It is a function of current. In the optimum welding conditions the wire feed speed is equal to (3.2) m/min, which is calculated by determining the length of wire through 10 seconds.

Travel Speed

During selection the correct values for travel speed, it is seen that when travel speed is too low results in excessive fusion of base metal, excessive penetration, and even burn-through. But when greater increase in travel speed, less thermal energy will be imparted to the parent metal and then the parent metal melting rate would be reduced. When the travel speed is excessive, defect type undercutting will occur along the edges of the weld bead, because the deposition of filler metal is not sufficient to fill the path melted by the arc.

Electrode Extension (stick out)

The stick out is chosen dependently on the electrode diameter, and the base metal thickness as shown in the **Table (5)** [Dr. Parmer 1995]. The suitable amount of stick out for given diameter (1.2mm) is 13mm.

Gas Flow Rate

During experimental work when high gas flow rate is used with the same conditions, some of welding defects are appeared such as porous and blowholes and poor appearance as shown in **Fig (1)**. It shows that the failure of specimen occur in the welding zone due to these defects. When the gas flow rate is too low then there was loss in protection action of the weld zone from contaminaters and atmosphere. Therefore, the sufficient amount is 12 L/min (as mixture gases).

Electrode-to- work-piece angle "torch angle"

It is one important variable in the welding which may considerably affect the bead geometry. It refers to the position in which a welding gun may be held perpendicular to the work piece or with an angle, which may be longitudinal angle or transverse angle. The longitudinal angle may be trailing or leading angle. The trailing angle gives a narrow and peaky weld with deep penetration. The leading angle results in weld with shallow penetration but wider bead. The skew angle which is the relation between the electrode and the joint in the plane perpendicular to the longitudinal plane. In butt-welding of equal thickness sheet, in the flat the angle always 0° (perpendicular). Changes in torch angle inclination are inevitable in automatic such as in the application of robot welding in industry for mass production when constant torch angles cannot be mentioned in the robot. Robot torch angle some times varies during the work, which may affect the other parameters with consequent effects on bead shape and penetration.

APPLICATION OF ROBOTIC WELDING

The used robot is programmable type which is programmed by the teaching mode method using a hand-held control and the program must be quick to produce easy modified to suit the real conditions for variations of fit up and component tolerance. It is capable of smooth and variable speeds around any contour. The speeds of the torch along the trajectory must be compatible with the range of welding speed required by the process. In robotic work cell, it is required to develop program and good maintenance, robot reprogramming and rest-up, tooling, weld procedure development, etc. The present study has sought to provide information and data relative to such aspects. In particular, a feasibility study has been performed for a low-volume complex sheet metal fabrication with care taken to weld program development.

OVERVIEW OF WELDING ASSEMBLY

The object of this investigation has a base component, which assembles with its component parts. This assembly is for a product namely (X-11). The primary base member is pierced and formed from low carbon steel sheet (2mm) thick. The base dimensions are (310)*(310) mm. Four vertical support members, and eight vertical side supports are formed from the same material but with (3mm) thick. The X-11 product contains a central part, which is welded in the center of the base. Casting and then machining to the final form can produce this part. It should be mentioned that the design of the part is primarily determined by rigidity requirements. All parts are tacking manually with help of the fixture, which held individual vertical support members for tacking. The product requires 33 manual arc welds. These include (16) fillet welds, (16) square butt welds. The welds vary from 1.0 cm to (8.5) cm in length with a total of (182.8) cm of welds. This product was welded by manual shielded arc welding. The welds were visually inspected. A balanced-type positioner is used in manual production to allow rotation for back side welding. The robot table-type positioner did not allow such access. As result, it is necessary to manually turn the base over in the fixture for backside welding.

Weld Program

As mentioned above, the product X-11 is a complex weldment which has large number of welds and consists of sheet metal as a base metal, therefore, the present work is to use the robotic technique in welding this product with high quality and high productivity. The weld program consists of two stages which are the front side and the backside of the product X-11. The cycle time for manual welding of the front side of the product was (35 minutes), while the back side, which contains only circular welding for the center part to be welded with base, had cycle time at least (1.5 min) as manually welding. The robotic weld program consists two complete weld program developments are carried out. The complete weld sequence is programmed with out welding. Following this, the welds are sequentially made. The program of weld sequences is as follow:

Front Side of the Product X-11

The weld program for the front side of the product X-11 is performed to be consisting of the following movements: torch movements through the space, arc welding movements, table movements, and cleaning movements for the torch tip. The front side of the product X-11 include the following welds:

1- Four welds are straight with torch angle (leading/15°). Each weld is completed within 7.5 seconds. Even though there are four welds, but they require welding time of (23 seconds).
2- Eight welds, which are straight on the line of welding with, torch angle (leading/15°); each weld is completed with (30.9 seconds). The table positioner is turned to an angle of 36°, where the weld position is flat, and after each weld the table rotate 90°.
3- Eight welds which are straight on welding line, with torch angle (leading/15°). The weld position is vertical and each weld is completed with time 28.1 seconds.
4- Four welds which are circular welds with torch angle (normal) in order not to obstruct the other components in the base. The table is in flat position and it remains stationary during welding, the circular weld performed by a robot. Each weld is completed with time (12.5 seconds). After each weld, the table rotates ¼ cycle and so on.
5- Four welds, which are as the same as in, step (4), but the time that required for each weld is (4 seconds).

For complete the front side weld program, it is required the following groups of sequences:

a- FIRST GROUP, WHICH CONSISTS OF 4-SEQUENCES, EACH SEQUENCE CONSISTS OF 4-WELDS AND 12-PROGRAMMING POINTS.

b- Second group, which consists of 4-sequences, each sequence consists of 2-welds and 4-programming points.

c- Third group, which consists of 4-sequences, each sequence consists of 2-welds and 5-programming points.

Back Side of the Product X-11

The Backside program of the product x-11 requires 2-table movements and one weld with one programming point. this program is circular weld with constant speed for the table positioner. the angle of the is (trailing angle/ 15^0). in this program the robot arm, which is holding the torch, remained stationary on the correct position and the table rotate.

CYCLE TIME FOR ROBOTIC WELDING PROGRAM

The initial program was not intended to be optimum. The cycle time of the front side of the product X-11 was approximately (16 minutes) and the program cycle time for the backside is (57 seconds). The second weld program sequences are optimized as follows:

1- Redundant robot moves are eliminated to provide direct movements between welds.
2- Weld parameters are developed to allow higher welding speeds.
3- A number of table moves are eliminated whenever possible so as, the cycle time was reduced to (11 minutes) including the cleaning time for the torch nozzle and contact tube. Whereas backside weld is (44.5 seconds).
4- The loading time is reduced to minimum by using the two tables technology at the same time. So when the robot deals with the first table, the operator must load an other work-piece of the product X-11 on the second table. Therefore, there is no waiting for loading and setting up of the product.

Program sequence diagrams are maintained to provide more description for the weld program. As mentioned, each sequence consists of number of welds and programming points, the torch of the robot must pass through all these sequences during welding. Points are numbered as a sequence number, followed by a decimal point, followed by a two-digit point number within the sequence. The two digit points belong to the comutative number of the programming points for the sequence, which contain them. **Fig. (2)** represents the sequence diagram for the weld program. The main line contains all the table movements and number of the programming point during such moves. The sequences are separated by table moves during the program. Therefore, the main line contain 85 programming points labelled 0.01 to 0.85, of which only 15 are shown in **Fig. (2).** Sequences 1 through 12 welded the front side of the product X-11, while sequence 13 is for backside of the product X-11.

The weld program sequences are timed with suitable welding conditions, which include : joint type, position of the weld, torch angle, work angle, weld travel speed, arc voltage, wire feed speed, stick out, welding current, and fitting up of the wire tip with the joint trajectory.

The average total cycle time for welding front side of the product X-11 is (16 minutes) and for the back side is 57 (seconds), which include robot, arc, table movements, and loading time. The optimisation for this program by modifying and eliminating the redundant movements and loading time. This results in satisfying cycle time of (12 minutes) or less for the front side, and (44.5 seconds) for the back side of the product X-11. The improvement in productivity and number of complete assemblies which produce per shift by using manual and the two programs can be shown in table 6.

QUALITY CONTROL TESTS

Weld quality is achieved by taking specimens for purposes of testing ang inspecting for improving weld quality. These include the control of weld bead, overfill, penetration, and tensile strength, which are considered as variable data. The inspection for finding out the defect in the weldments in the mass production is achieved by using required tests.

Visual Inspection

This test is necessary for checking the welding parameters during welding such as regulating the arc voltage, setting the welding current, limiting the gas flow rate and travel speed. It is widely used for evaluating the base metal and the filler wire before welding and it is widely used after welding for various purposes such as:

Visual inspection is used with other tests such as bending test, and with the torch inclination angles test to signalize the necessary remarks in this investigation.

Through this test, detection of the weld defects such as porosity, unfused welds, undercutting, excessive fusion of welding, weld profile defects, poor weld appearance, etc. which are used as input data for evaluation of statistical quality control techniques.

Dye Penetrant Inspection

Penetrant inspection is a method of locating defects open to the surface. It is simplest and can be used for ferrous, non-ferrous and nonmagnetic metals. Some of the defects that can be detected by this method are:

1- Fatigue crack. 2- Shrinkage crack.
3- Crater crack. 4- Pits.
5- Porosity. 6- Incomplete fusion.

Radiography (X-Ray) test

Radiography is one of the most useful of the non-destructive tests (NDT) which can be applied for assessing the quality of the welded joints. It can be used for inspection of welds of all types and thicknesses ranging from thin sheets to thick plates. X-ray can detect flaws of discontinuities, which are internal defects in welds such as:

- Cracks.
- Porosity and holes.
- Slag, flux or oxide inclusions.
- Lack of fusion between the weld metal and parent metal.
- Incomplete penetration.

The specimens are taken from the same welding procedure. The specimens are square edges butt welding with 150-mm length, and 2mm thick. They are tested as radiographically by using X-ray tube. The test was achieved in AL-Nasser Al-atheem Company. The device used is SEIFERT 300KV Germany Original the film used is Kodak type. The condition for this test is selected according to specimen thickness. So the specimen with 2mm thick can be examined with following conditions:

I	*V*	*TIME*
1.5 MA	*120 KV*	*1.0 MIN.*

Joint Strength Testing

This test is used to specify the tensile strength of the base metal and the welded metal. The specimen details and testing method are made according to ASTM and DIN standards. These specimens are tested on (Hay fielf Extometer Randoper) device. The maximum load is recorded as measure of the joiont strength.

Statistical Techniques for Controlling Weld Quality

After specifying the consistent conditions of welding which are dependent in this investigation and then getting on qualified welding operator and when the robotic welding process is qualified. Collection of the data associated with weld bead dimensions, strength of the weldments, and different defects, which may appear in the joints. The data are either measurements or observations. According to the type of the collected data. Therefore, they are divided into two groups as variables and attributes information.

Variable measurements

These measurements include width of the bead, penetration, and overfill or reinforcement. The data are collected in form of samples where, during each batch of production a sample is taken, they are of size 5-pieces. Then these pieces are machined and prepared for macro and tensile tests. This method of collection continued for 25 batches of production. Each part taken for macro-test is linished, cleaned carfully and etched for macroscopic vision with magnifying X2. The tensile strength pieces are machined to standard form of tensile test specimens (DIN 50120). The $\overline{X}$ -R charts are plotted for each case, and then the histogram for each case is plotted.

Attributes Control Charts

These control charts are concerned with conformance and non-conformance with requirements. In the present study the attributes control charts are applied to the most important defects in welding process such as a porosity, overlap, and undercutting, poor appearance of the bead, excessive fusion, and lack of fusion. The adopted method of data collection is as samples where sample size is 50-pieces of welded products. Each part is visually inspection for each of the above mentioned defects. The inspection is carried out with help of quality skilled staff using standard forms for comparison to indicate the defects. However, the defects, which are very small (micro-defects) such as micro-cracks or micro-porosity, have less effect on quality than the macro defects which have much effect the quality of welding and impaired the strength and toughness of weldments. After collecting the necessary data for each defect for 25 samples, a plot of the p-chart is achieved for each case. In this section of control charts the inspected piece may be either conformance or non-conformance to specification. The word conformance means that there is no defect in the piece therefore, it is accepted, but the ward non-conformance means that the inspected piece has defects therefore, it must be rejected from other side if there is small amount of defects in the piece that are within the limits that the designer recommended. In this case, the piece is acceptable to the designer requirements, but in the same time it is unacceptable as welding quality requirements. In the preset study, each piece consists of (33) welds as described above. If any defect appear in one of these welds then this piece would be signal as defective one according to quality requirements, but in the same time it is considered acceptable according to consideration of production plans.
Pareto chart was set up for the defects to specify the effective defect and then make attempt to reduce this defect by examination the causes and reasons which lead to its existence, so as to reduce it to a minimal. **Fig (3)** shows pareto diagrqam, where the horizontal axis represents the defect causes which arrangement from max. to min. and the vertical axis represent the frequency for each one. It is clear that the porosity and poor appearance are the most two defects affect the quality of robotic welding technique.

CONCLUSIONS

Concerning the experimental work conducted in the present work, the following conclusions can be drawn:

1- Short-circuit arc technique is suitable for thin sheet(2 mm or less). Because it permits metal transfer with lower heat input, adequate penetration is obtained and the risk of burn-through is minimized.
2- The welding current is within the range (100 -140) amperes for obtaining good appearance with out burn-through or lack of fusion for the weldment. So the quality of welding is acceptable with the selected welding conditions.
3- Skew angle gave more spatter and asymmetry bead when the angle increase.
4- Trailing angle technique gives a more stable arc, less spatter and a narrower, more convex weld bead with deep penetration.
5- Leading angle is more suitable for thin sheet metals because it gives shallower penetration, which is suitable for sheet in order not to cause burn-through.

6- Seam tracking is necessary so as not to obtain misalignment between the electrode tip and the axis of joint which lead to defect of lack of fusion or poor root penetration in the backside of the joint.
7- Porosity defect is the major defect and its causes may be the purity of protective gases, rest and other inclusions on the surface of the metal to be welded, or unsuitable amount of productive gases.
8- Weld bead dimensions are within statistical control, this led to produce products with good quality.
9- Tensile strength of weld joints is with statistical control and all tested specimens are failed out side the weld zone with tensile strength more than that for base metal.

Table (1) Chemical composition of the base metal.

Element	%C	%Si	%Mn	%S	%P	%Mo	%Ni	%Cr	%Fe
Nominal Compositn	0.1 max	0.03-0.15	0.2-0.45	0.04	0.04	-----	----	----	Rem.
Actual st.3	0.067	0.025	0.249	0.01	0.012	0.006	0.015	0.01	99.7

Table (2) Nominal and actual mechanical properties of base metal.

Mechanical properties	Yield stress Mpa	Ultimate stress Mpa	Elongation %	HB	Bending
Nominal properties	----	278-372.6	35	-------	Pass
St.3 properties		336.875	29	100-123	

Table (3) Nominal and laboratory chemical compositions for filler wire.

Element	%C	%Si	%Mn	%S	%P	%Ni	%Cr	%Cu	%Al	%Fe
Nominal, AWS	0.07 -0.15	0.8-1.15	1.4-1.85	0.035	0.025	*	*	0.5	0.5	Rem.
ER70S-6	0.11	1	1.5	0.029	0.02	---	---	0.3	---	Rem.

*These elements may be present but are not intentionally added

Table (4) Mechanical properties of filler wire. [AWS, 1989].

Mechanical propertis	Yield stress Mpa	Ultimate stress Mpa	Elongation%
Nominal AWS standard	420	500	22

Table (5) shows the electrode diameter and electrode stickout [Dr. Parmer 1995]

Electrode wire diameter mm	0.8	1.0	1.2	1.6	2	2.4
Electrode stickout mm	6 - 12	7 - 13	8 - 15	13 - 20	15 - 25	15 - 30

Table (6)

Technique	Total cycle time min	Product /shift	Improvement in Productivity %
Manual	36.5	13	…….
First program	16.95	28	115.3
Second program	12.74	38	186.5

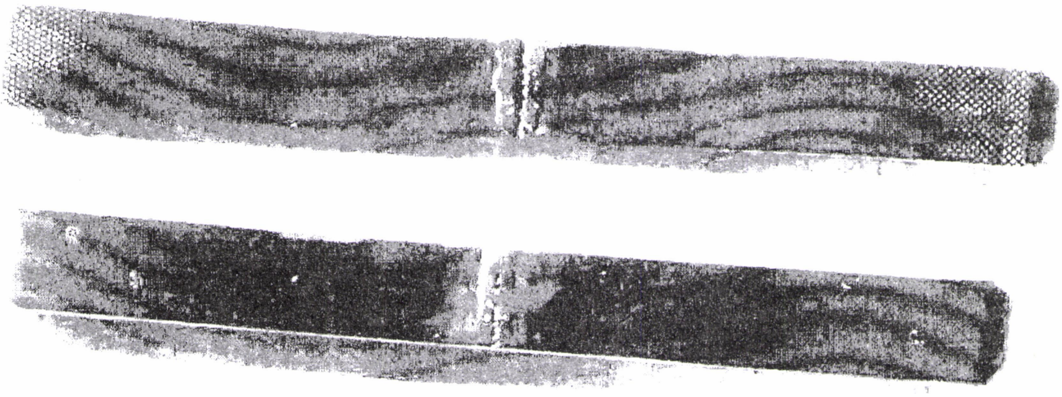

Fig. (1) shows presence of porosity in welding zone due to unsuitable gas flow rate

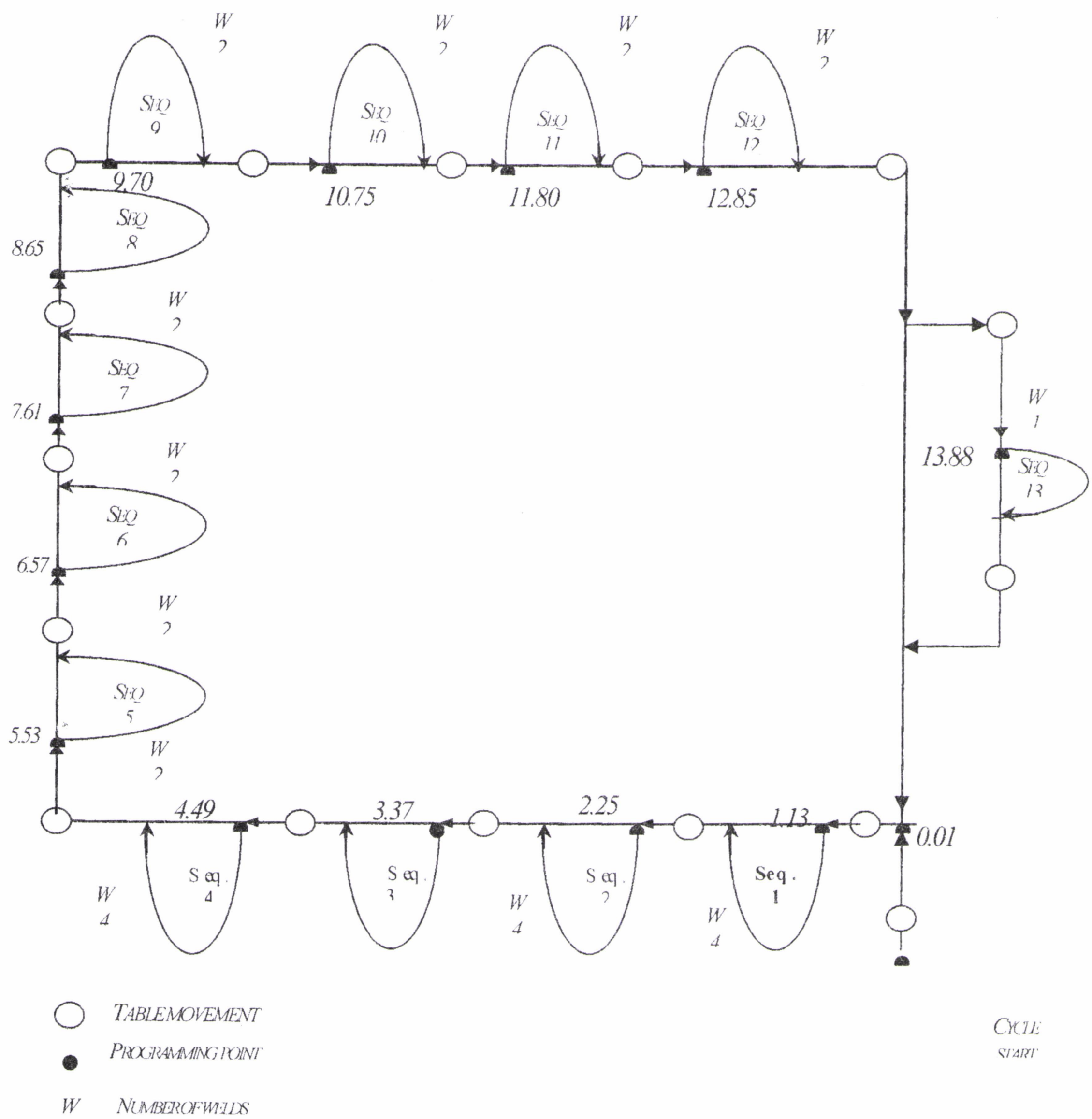

Fig. (2) weld program sequence

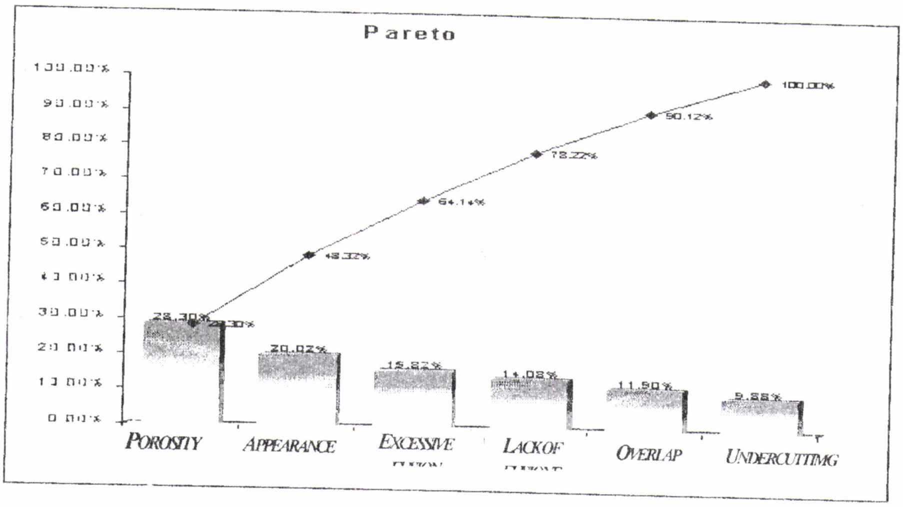

Fig. (3)

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