To study the effect of magnetic field on bead geometry, mechanical properties and welding speed of air and water welds

Yaqoob Ali Ansari[1], M.I Khan[2], S. Alam[3]
[1, 2, 3]Department of Mechanical Engineering
[1, 2, 3] Integral University,Lucknow, India

Abstract- *The major fabrication technique for offshore structures is welding. Sub-oean or underwater welding is both difficult and costly.Underwater wet welding offers significant cost saving over other repair technique for submerged structures,but the weld metal mechanical properties are not equal to those of surface welds.the problem of porosity and oxidation of weld pool .The last two decades have seen tremendous developments in exploring the seas for natural resources beneath their beads.. Because of the high cost of "dry habitate" welding, the primary thrust on reaserch and developmennt has been with open water "wet welding" fusion welding causes coarsening of weld metal and heat affected zone grains. This affects weld joint strenght and its corrosion resistantance. Under- water welding has an additional problem of the formation of undercuts. The present work uses electromagnetic oscillation of the welding arc as a means of refining the weldmetal grains and eliminating the undercut.The efects of superimposition of magneic field on weld charactristics and weld metal mechanical propertis has been investigated.In the present work Lacquer paint coated oidising iron-oxide elecrodes in 5mm sizeusing 25-26 V,200210 A arc parameters and revers polarity have been found to deposit sound weld beads at a welding speed of 3mm/s in fresh water at 200mm depth. It has been possible to increase the welding speed to 4.5 mm/s and 6.2mm/s and yet eliminate undercuts by using alternating magnetic fields of Gauss and 135 Gauss respectively in underwater wet-welding. Magnetic field superimposition improves weld strenght properties by 15-18 % and the angle of bend in face and root bend testing improves by 23.7% and 41% respectively for wet welding. Effects of salinity of sea water and water depth on weld charectristics have also been discussed.*

Keywords- Underwater Welding, Wet Welding, Arc Welding Underwater, Arc Under Magnetic Field, Magnetic Arc Oscillations.

I. INTRODUCTION

Underwater wet welding with coated electrodes has proven to be a valuable repair process on offshore platforms.pipers, ships, and in nuclear power plants. Wet welding is selected over other repair options because it can be quickly implemented with relatively simple equipment,thereby dramatically reducing repair cost and downtime.wet welding is being used increasingly as an underwater repair technique due to reaserch and development in recent years leading to improved weld quality(1).although the quality of wet welds has improved, the mechanical properties are still not equal to those exhibited by dry welds. Mechanical properties of under water wet welds are a strong function of depth. Due to increasing oxidation and porosity.The huge tonnage of offshore tubular structures built into oil platforms have exposed new problems to welding engineers requiring immediate attention. During sub- Ocean welding two major problems arise. Firstly, the grains of the heat affected zone (HAZ) and weld metal are usually coarsened and consequently their susceptibility to cracking increases and toughness and corrosion resistance reduce. If the grains of theweld zone could be refined, it would result in a major improvement in these properties. A number of methods of refining weld metal such as arc oscillation, pulsed arc stirring or arc stirring by magnetic or ultrasonic means have been suggested by watanabe et al. (1989). Of these methods electromagnetic stirring is most effective. The second most serious problem in underwater welding is the appearance of undercuts.Superimposition of axial magnetic field has been reported by othman and khan (1990); villafuerte and kerr(1990); chernysh(1984); gupta(1975); basler, erdman-jesnizer and rehfeldt(1974) to be effective in eliminating the undercuts and refining the grain structure of the welds produced in air. This field has, therefore, been used in the present work to refine weld metal grains and to investigate its effect on weld characteristics and weld meata mechanical properties. Laboratory simulation of sub-ocean welding was carried out by using an experimental set-up similar to the one use brown et al.(1974).to make the results more useful, the welding was carried out in fresh water. Depending upon the type of water and its depth the results may be suitably modified. Effect of salinity and depth of water have been considered in the discussion of results.

II. EXPERIMENTAL WORK

A 250 litre fresh water tank mounted on a mechanised table was employed and the specimen plate was 200mm deep in water during welding. Bead –on-plate welds were deposited on 20mm thick Fe-410 plates to study the effect of axial magnetic field on the metallurgical and geometrical charactristics of welds. The magnetic field which demonstrated the maximum beneficial effect was then used to deposit bead-in-groove welds to further investigate its influence on metallurgical structure and mechanical properties of welds produced.E-6020 oxidising iron-oxide electrodes 5mm size, waterproofed by cellulosic lacquer paint and held in afully insulated electrode holder were used based upon the results of the earlier work by author(1991).a welding generator with flat drooping charectristics and 80V,500A capicity was employed for welding using 25-26V,200-210A arc parameters and a welding speed of 3mm/s . it was possible to increase welding speeds and yet eliminate undercuts by using magnetic fields of suitable intensities.

Axial magnetic field was produced by using a coil of hollow copper tube of 3.5 mm inside diameter and 0.65mm wall thickness, coverd with an insulating sleeve all along its lenght. The coil used , had 9 turns and was placed in an insulating fixture. The two ends of the coil were connected to the magnetising current source and water was circulated through the coil during use so as to conuct away the heat generated. Magnetic field intensities use during the investigation varied between 0 to 180 Gauss.

III. RESULS & DISCUSSION

The absence of data on the effect of superimposition of magnetic field on the metallurgical charactristics and mechanical properties of welds obtained with flux coated MMA welding electrodes in air and underwater, made it difficult to select a set of welding and magnetic field parametres for a particular use without conducting a series of experiments. Trial runs were, therefore,made in air and in water to assess the effect of the superimposition of magnetic field on weld charactristics.

- **Initial investigation**

constant axial magnetic fields with clockwise current and anti-clockwise current in the coil were used. Welding was carried out in straight as well as in reverse polarity welding conditions. The effect of these conditions on weld shape charactristics of welds was studied.the results were compared withthose obtained with altrnating axial magnetic field in straight as well as reverse polarity welding conditions. The results are shown in fig-1 preliminary experimnts conducted under similar conditions for underwater welding indicated similar trends. With the results of preliminary study at hand, detailed investigation were carried out. The results of the detailed study are discussed in the following paragraphs.

3.11 Welding parameters

welding arc- voltage increases and arc- current decreases with increase in magnetic field intensity both in stright as well as in reverse polarity welding conditions. This increase in arc- voltage and corresponding decrease in arc-current is due to static characteristics of welding power source. In underwater welding the increase in arc-voltage and decrease in arc- current are more than their corresponding values in air welding (fig-2). This may be due to higher arc column temperature during underwater welding which causes higher rotational speed of the arc column resulting in higher cooling effect on the arc and consequent arc constriction and increase in arc voltage. Weld bead ripples refine with the application of magnetic field in air as well as in underwater welding. Alternating axial magnetic field gives better bead appearance in underwater welding as compared to constant field.

3.12 Weld-bead geometry

an increse in constant magnetic field causes the droplet spinning force to incrrease causing the metal droplets to spread over a larger area this result in an increase in weld wi increase inincrease in magnetic field intedth and decrease in weld depth of penetration and reinforcement height. Width alternating axial magnetic field, however, there is a decrease in weld width initially, with an increase in magnetic field intensity.with a further increase in magnetic field intensity the weld width increases as usual. Weld depth of penetration and reinforcement height decrease with increase in magnetic field intensity. The initial decrease in weld width with increase in magnetic field intensity could be due to relatively higher reduction in arc-current with increase in alternating magnetic field intensity. A further increase in field intensity increases the weld width due to a combined effect of the reduction in arc-current and increase in arc stability. These results are in agreement with the results of gupta et al. (1977). The decrease in penetration is due to:1-the transformation of arc shape from cylindrical to conical due to arc rotation and 2- loss of power under the action of axial magnetic field. Weld reinforcement height decrease due to the spreading of metal droplets over a larger area under the influence of axial field.

- **Welding speed**

welding production rate can be increased by using higher welding speeds. This necessitates higher currents to be used to obtain the same weld cross-section characteristics. At higher speeds with higher currents undercuts appear on the weld bead surface. By superimposing the welding arc with axial field these undercuts have been found to be eliminated. It has been found that with alternating axial magnetic fields of 85 Gauss and 135 Gauss the welding speeds could be increased from 3mm/s to 4.5mm/s and 6.2mm/s respectively and welds free from undercuts could be obtained. Better results have been obtained with straight polarity welding in air as well as in water. The filling of the undercuts can be attributed to the spreading of the weld-metal droplets over a larger area due to arc rotation.

3.14 Micrstructure fusion

welding causes coarsening of weld metal and HAZ grains. This tendency is further enhanced in underwater welding as the grain size depends upon the peak temprature reached and the lenght of time this temprature is held in a particular area. According to brown(1974), the microstructure within the grains depends upon the cooling rate of austenite in regions whose maximum temprature exceeds the lower critical temprature. Weld metal and HAZ microstructures of air welds and underwater welds have been compared with those obtained with the superimposition of magnetic field in air and in under-water welds (fig3). Electromagnetic oscillation of the welding arc has been found to cause the columner dendrites in weld zone to break down during nucleation and growth to provide a larger number of sites for the nuclei to form and grow.thus a finer microstructure is obtained in weld zone. In HAZ also a finer microstructure has been observed(fig3).

3.15 Mechanical properties

the results of mechanical properties tests are given in table1-3. It can be seen that the yield strenght as well as ultimate tensile strenght increase by 9-15% and 19-26% respectively with the superimposition of axial magnetic field of 110Gauss. The charpy impact value increses by 34% and the angle of bend for initiation of cracks increases from 55 to70 degrees for face bend testing and from 30 to 60 degrees for root bend testing for underwater welds.

3.16 Effect of salinity and depth of sea water:

acording to madatove (1961) salinity of sea water stabilises the arc. Stalker (1976) has also advocated the use of oxidising iron oxide electrodes although he could use basic and rutile electrodes to deposit welds at pressure up to 32 bars.as the depth increases the arc constriction effect increases .according to madatove (1966) underwater arc core temprature is around 9000 to 11000K (at 10 m depth) as compared to 5000 to 6000K for air welding. Madatov(1969) also found that the arc is easy to initiate and maintain in saline water and penetration increases. Leven and kirkley (1972) suggested that oxygen from dissociation of water was taken up by the oxidants at a rate which increased with water depth. This led to the development of special underwater welding electrodes with added deoxidants. Kirkley (1973) also reprted loss of mechanical properties with depth.

Table 1

All weld metal tensile test results for underwater welds (data mean of 4 observations). Fracture was located within gauge –lenght and no deffects were observed. Welding energy input: 1.5kj/mm

S.No	Medium	Polarity	Mag.Field	Yield.St N/Mm	UTS N/mm %	Elongation %	Red.in area%
1	Air	S.P	Nill	402	475	27	65
2	Water	S.P	Nill	391	443	7.3	9.9
3	Water	R.P	Nill	414	476	10.2	12.0
4	Water	S.P	110 G	450	560	14.0	15.5
5	Water	S.P	110 G	455	567	14.5	15.5

Table2

Charpy v-notch impact test results for welds deposited in air and underwater (data shows mean of 4 observatios). No defects were observed. Test temprature:27 0c, welding energy input:1.5 kj/mm

S.No	Medium	Polarity	Mag. Field Gauss	Energy Absorbed Joules	Lateral Contraction %	Shear%
1	Air	S.P	Nill	118	1.1	100
2	Air	S.P	110	127.2	1.15	100
3	Water	S.P	Nill	51.5	1.0	56.56
4	Water	R.P	Nill	69.1	1.1	70.50

Table3

Results of transverse face and root bend test using 4-t former for specimens prepared under the superimposition of alternating axial magnetic field of 110 gauss.

S.No	Medium	Polarity	Magnetic Field Gauss	Mean- Bend- Angle To Initiate 1.5mm Cracks		Type And Location Of Flaws
				Face - Bend	Root- Bend	Face - Bend
1	Air	S.P	Nill	180	180	Cracks in WM
2	Water	S.P	Nill	55	30	"
3	Water	R.P	Nill	56	32	"
4	Water	S.P	110	70	45	"
5	Water	R.P	110	70	45	"

Table4

All weld metal tensile test results from underwater welds made with or withought magnetic field (data mean of 4 observations). Welding energy input: 1.5kj/mm

S.No	Polarity	Yield Stress N/Mm2	UTS N/M m2	Elongation	Reduction In Area%	Fracture Location	Defects
No Magnetic Field							
1	R.P	391	443	7.3	9.9	Within gauge length	nill
2	S.P	414	476	10.2	12	do	Slag inc. chance
Alternating magnetic field 80 Gauss							
3	R.P	455	565	14.5	15.5	Do	Nill
4	S.P	457	568	14.4	15.5	Do	Nill

Table5

Charpy v-notch impact test results for weld made under magnetic field. Electrode e-6020, 5mm, test temp.-27 0c, welding energy input: 1.5 kj/mm, polarity: straight,alternating transverse magnetic field intensity 80 gauss.

S.No	Medium	Energy Absorbed Joules	Lateral Contra ction	Shere %	Defects
1	Air	130.8	1.15	100	Nill
2	Air	131.2	1.15	100	Nill
3	Air	122.3	1.15	100	Nill
4	Air	125.2	1.15	100	Nill
Mean values		127.5	1.15	100	Nill
1	Water	72.4	1.10	72.4	Nill
2	Water	69.2	1.10	70.1	Nill
3	Water	69.2	1.10	70.2	Nill
4	Water	70.0	1.10	70.2	Nill
Mean values		70.0	1.10	70.7	Nill

Table6

Results of transverse face and root bend test using 4-t former for specimens prepared under the superimposition of alternating transverse magnetic fields using e-6020 5mm electrode, welding energy input:1.5 kj/mm.

S.no	Medium	Polarity	Magnetic Field Gauss	Mean- bend-angle to initiate 1.5mm cracks		Type and location of flaws
				Face - bend	Root- bend	Face - bend
1	Air	S.P	Nill	180	180	Cracks in WM
2	Water	S.P	Nill	55	32	"
3	Water	R.P	Nill	56	34	"
4	Water	S.P	80	77	45	"
5	Water	R.P	80	77	45	"

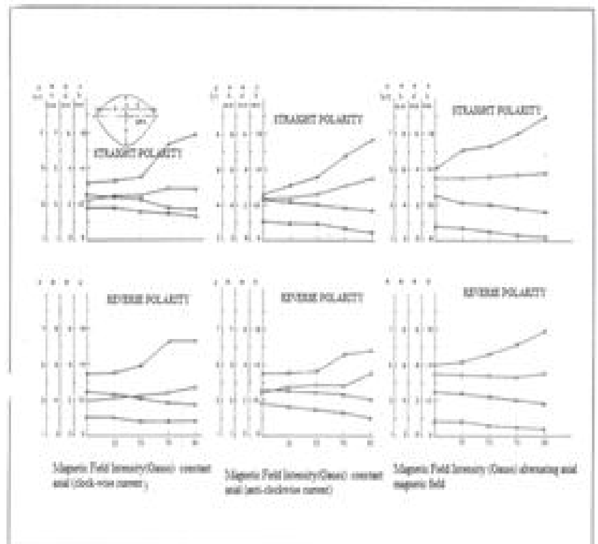
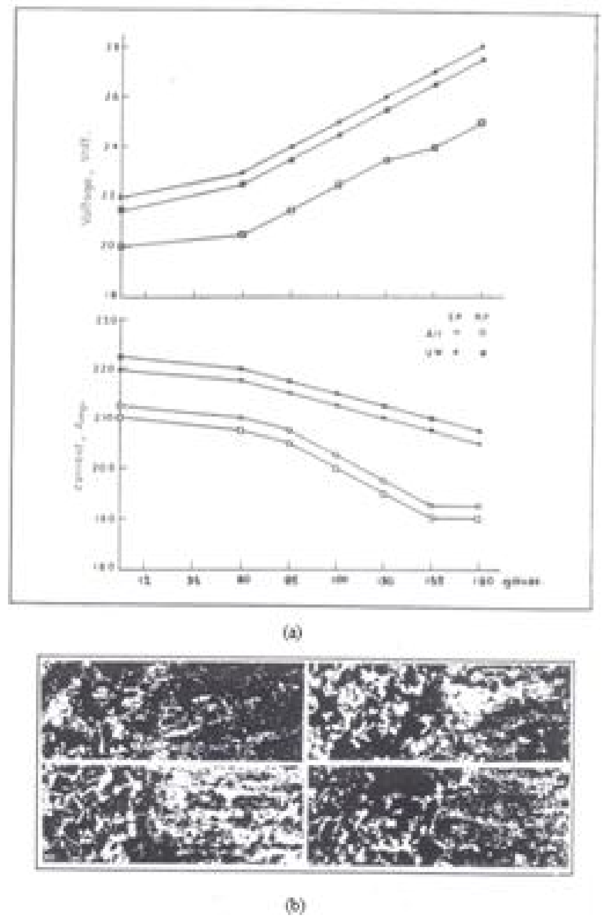


Fig.1 Effect of Type of axial Magnetic Field on Bead Geometry of Welds.



Underwater welds Air welds

Fig.2 (a) Influence of alternating axial Magnetic Field on Arc Voltage / Current in Air / Underwater /S.P /R.P.Welding.
Fig 2 (b) Weld metal and HAZ microstructures of welds without and with Magnetic Field

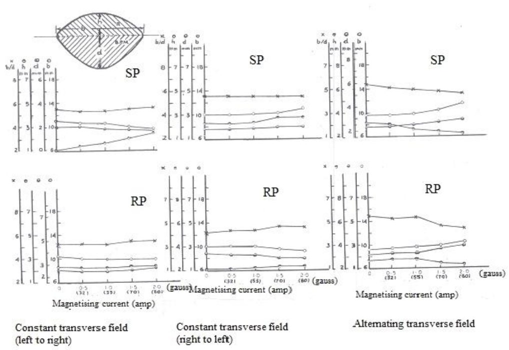


Fig.3 Effect of constant and alternating transverse magnetic field on Air-Weld bead- geometry.

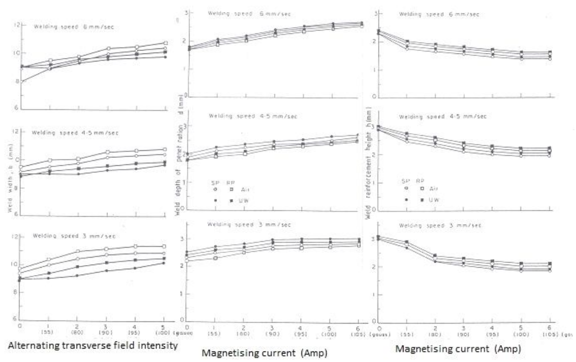


Fig.4 Effect of alternating transverse magnetic field on Underwater Weld bead geometry at 3, 4.5 and 6mm/s speeds.

IV. CONCLUSIONS

- Superimposition of magnetic field improves the weld bead smoothness, regularity and geometrical charactristics in air as well as in underwater welding. Alternating field gives better weld charectristics than constant field of the same intensity.
- Welding arc –voltage increases and arc-current decreases with increase in magnetic field intensity both in straight and in reverse polarity welding conditions. This effect is more pronounced in underwater welding than in air welding.
- Weld width increases and depth of penetration and reinforcement height decreases with increase in magnetic field intensity.
- It has been possible to increase the welding speed from 3mm/s to 4.5 mm/s and 6.2mm/s by using alternating magnetic field of 85GAUSS and 135 Gauss respectively and welds free from undercuts have been obtained.
- Weld and HAZ grain size refines by the superimposition of magnetic field.
- Magnetic field superimposition improves weld tensile strenght by 15%, impact value by 18% and bend angle in face and root bend testing improve by 27.3% and 41% respectively.

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