Observation about the Application of Arc-Air Gouging Process in Shipyard

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Summary

It is a well recognized fact that the arc-air gouging process is more advantageous than the pneumatic chipping method in point of economy. In carrying out the gouging in Japanese shipyards there arises an important problem because their electric source is of alternating current whereas the arc-air gouging should be of direct current.

Considering this special situation of Japanese shipyards, authors have made different types of carbon electrodes for arc-air gouging in order to investigate their applicabilities and ascertained the usefulness of carbon electrode for use with alternating current in shipyards.

1. Problems concerning arc-air gouging in shipyard.

The pneumatic method had hitherto been employed for back chipping butt joints of hull structure but since the announcement in 1954 in the welding Journal\(^1\) of the arc-air gouging process (that is, to remove metal by utilizing the carbon arc and compressed air), this process has been adopted in our country and because of its undisputed superiority it has entirely replaced the pneumatic chipping method.

Table 1 shows the comparison of the hitherto costs of the arc-air gouging process and the pneumatic chipping method. That the former is far superior to the latter has already been testified and reported in numerous papers\(^2\).

However, there has arisen one problem in adopting the arc-air gouging process, namely the need for D.C. welding machine, which entails considerable initial cost.

Therefore, when the rate of operating welding machine is extremely low, the ratio of interest and depreciation of the D.C. welding machine in the entire cost of the gouging arc increases and naturally the merit of the reduction of cost by the use of arc-air gouging becomes nil.

Let us then explain the need of D.C. welding machine for the arc-air gouging process by taking Kawasaki Dockyard as an example.

Suppose one welding machine is needed for the area with the radius of 20m, as many as 60 D.C. welding machines are needed for the whole area of sub-assembling slabs, assembling slabs and building berths.

When fitting wharves, docks and the sites of steel structure constructions are added to be considered, 60 D.C. welding machines should be available for use.

On the other hand, from the view point of man-hours, when arc-air gouging process is adopted, the man-hours for the back chipping are, for example, 2% of the whole welding man-hours for a

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>LABOUR COST</th>
<th>CONSUMPTION COST</th>
<th>EQUIPMENT COST</th>
<th>SUM TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNEUMATIC CHIPPING</td>
<td>78</td>
<td>AIR 3</td>
<td>TOOL 10</td>
<td>100</td>
</tr>
<tr>
<td>ARC-AIR GOUGING</td>
<td>26</td>
<td>AIR 1</td>
<td>D.C.WELDING MACHINE 4</td>
<td>60'</td>
</tr>
</tbody>
</table>

NOTE: JOINT IS VEE GROOVE OF 19MM THICK.

* Kawasaki Dockyard Co., Ltd. Shipbuilding Dep’t.
cargo ship of 13,000 D.W.T., 3% for an oil tanker of 45,000 D.W.T., and 2.5% for an ore and oil carrier of 45,000 D.W.T.

After all, in shipyard having 400 welders per day, about 10 persons per day would be sufficient for the undertaking of the gouging process.

Under the condition of using 60 D.C. welding machines and employing 10 persons for the whole shop, the depreciation, the interest and the expenses for maintenance and repairing of welding machines would increase by six times as much as that of the item shown in Table 1 and the benefit that could be obtained by improving the efficiency will be lost.

The following ways and means of decreasing the number of welding machines needed would be suggested:

(1) To move welding machines frequently from place to place.

According to this method, in theory as many number of welding machines are needed as there are workers but it is impracticable on the part of the shipyard as it takes two hours in moving one single welding machine, inclusive of the hour needed to wait for crane.

(2) To extend the cable more than 20m.

The area with the radius of 20m, which is mentioned above, means the area which is enough to use one or two 20m cables. When the area is bigger than that, there would be some difficulties in moving cables and controlling electricity so that the hour needed for preparations increases while the working hour decreases.

(3) To adopt together with the pneumatic chipping method.

The D.C. welding machine should be set at the place where much amount of work has to be done and the pneumatic chipping method should be used for the area where less work is required but because much time is spent for the exchange of tools, the working efficiency becomes lower.

As mentioned above, each method has its merits and demerits. The method of improving the working efficiency by combining these methods is generally used at present.

However, according to the recent reports of the researches carried out by the Carbone Lorraine in France and the Research Institute of Metal Construction in Yugoslavia, the A.C. welding machine is used even for the arc-air gouging process, and the good results have been attained to some extent by using the special electrode.

The A.C. carbon electrode is produced by Arc-air Co. in the United States, according to the Welding Journal of August 1959 issue. When the arc-air gouging process using the A.C. welding machine is possible, the dilemma mentioned above would be solved by using the D.C. welding machine for the area where much amount of work is required and the A.C. welding machine, which is set for the purpose of welding, should be used for the area where less work is needed.

2. Arc characteristics in arc-air gouging.

It has been well recognized that electric source for arc-air gouging
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process should not be applied with direct current in straight polarity (D.C.S.P.) nor with alternating current (A.C.), but with direct current in reverse polarity (D.C.R.P.), while no explanation has been given to clarify these phenomena.

It is no question of doubt that arc characteristics can be influenced by many factors, such as materials, atmospheres, electric sources, electric currents and arc length.

Authors have photographed the arc phenomena of arc-air gouging process by using high-speed motion picture camera as shown in Fig. 1. At the same time arc current and arc voltage were recorded by magnetic oscillograph. Shown in Table 2 are physical properties of the home-made carbon electrodes used in the test and the aforementioned carbon electrodes made in France and Yugoslavia.

Fig. 2 shows the typical examples of films indicating the arc phenomena in arc-air gouging process.

Under D.C.S.P., arc is originated only from the cathod spot, which is the small surface area at the tip of carbon electrode. Comparing with D.C.R.P., arc energy seems to be rather small and arc is somewhat unstable.

Under D.C.R.P., it is clear that arc originates from the large surface area of the tip of carbon electrode, so-called anode

Table 2 Physical properties of tested carbon electrodes

<table>
<thead>
<tr>
<th>CARBON</th>
<th>USE</th>
<th>ELECTRICAL RESISTANCE (Ω-CM)</th>
<th>BENDING STRENGTH (KG/MM²)</th>
<th>HARDNESS (SHORE)</th>
<th>REALLY DENSITY</th>
<th>APPARENT DENSITY</th>
<th>POROSITY RATIO (%)</th>
<th>ASHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>STANDARD (HOME-MADE)</td>
<td>D.C.</td>
<td>0.0022</td>
<td>600</td>
<td>51</td>
<td>2.07</td>
<td>1.77</td>
<td>14.50</td>
<td>0.3</td>
</tr>
<tr>
<td>ROUND SECTION WITH ONE CORE</td>
<td>A.C.</td>
<td>0.0069</td>
<td>350</td>
<td>57</td>
<td>1.99</td>
<td>1.57</td>
<td>21.00</td>
<td>1.0</td>
</tr>
<tr>
<td>(HOME-MADE)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40.3</td>
</tr>
<tr>
<td>ELLIPTICAL SECTION WITH TWO</td>
<td>A.C.</td>
<td>0.0016</td>
<td>590</td>
<td>52</td>
<td>1.94</td>
<td>1.77</td>
<td>8.8</td>
<td>1.0</td>
</tr>
<tr>
<td>CORES (FRANCE)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23.3</td>
</tr>
<tr>
<td>ELLIPTICAL SECTION</td>
<td>A.C.</td>
<td>0.0053</td>
<td>250</td>
<td>34</td>
<td>2.02</td>
<td>1.61</td>
<td>20.3</td>
<td>13.3</td>
</tr>
<tr>
<td>WITHOUT CORE (YUGOSLAVIA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2 Typical examples of films showing the arc phenomena in arc-air gouging process.
crater. According to this film and oscillograph, it is recognized that arc is very strong and stable.

Using standard gouging carbon electrode under A.C., arc can not be continued for short circuit happens frequently.

On the contrary, when using special carbon electrode for A.C. use, arc becomes stable and lighting and vanishing take place regularly in accordance with alternating cycle of electric voltage. It seems that arc becomes stronger while carbon is anode and becomes weaker while carbon is cathode. The fact that stable arc can be obtained by special carbon electrodes shows the possibility of arc-air gouging by using A.C. welding machine.

Table 3 Effects of polarity on arc voltage (Extruction from the study of J.L. Myer)

<table>
<thead>
<tr>
<th>POLARITY OF CARBON</th>
<th>CATHOD DROP (VOLT)</th>
<th>ANODE DROP (VOLT)</th>
<th>TOTAL (VOLT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANODE</td>
<td>Ni 11.2</td>
<td>C 13.6</td>
<td>24.8</td>
</tr>
<tr>
<td>CATHODE</td>
<td>C 8.7</td>
<td>Ni 8.2</td>
<td>13.9</td>
</tr>
</tbody>
</table>

In arc-air gouging, the arc voltages are greatly affected by electric source. It is considered that the cause of this phenomenon may be the characteristics of cathod and anode drop which is believed to vary due to the material and polarity. It seems that arc length has no great effect as its length is too short.

According to the study by J.L. Myer,5) cathod and anode drop in C-Ni arc are changed remarkably by polarity as shown in Table 3.

It is interesting to know that common trend was observed as the results of both experiments carried out by Myer and by the authors irrespective of the differences in materials, circumstances and currents.

The authors also investigated the relations between whole energy supplied from arc and the thermal energy absorbed by steel plate. No air jet was supplied during the test in order to maintain the fusion zone and to measure the heat input. Arc voltage noticed in this test was lower than in the case where exists the air jet that would be considered to play the role of cooling electrode and arc plasma, and of raising arc voltage as a result. Further tests were carried out in connection with various properties of the fusion zone.

Table 4 Effect of polarities on heat input, arc voltage, and sectional area, carbon content and Vickers hardness of fusion zone.

<table>
<thead>
<tr>
<th>CARBON</th>
<th>POLARITY</th>
<th>HEAT INPUT (Joule/Sec.)</th>
<th>HEAT INPUT ARC ENERGY (%)</th>
<th>ARC VOLTAGE (VOLT)</th>
<th>FUSION ZONE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SECTION</td>
</tr>
<tr>
<td>STANDARD</td>
<td>D.C.R.P.</td>
<td>5,800</td>
<td>82</td>
<td>17</td>
<td>11.3</td>
</tr>
<tr>
<td>FOR D.C.</td>
<td>D.C.R.P.</td>
<td>11,000</td>
<td>72</td>
<td>38</td>
<td>19.9</td>
</tr>
<tr>
<td></td>
<td>A.C.</td>
<td>5,800</td>
<td>75</td>
<td>20</td>
<td>15.7</td>
</tr>
<tr>
<td>ROUND</td>
<td>A.C.</td>
<td>6,100</td>
<td>61</td>
<td>25</td>
<td>15.1</td>
</tr>
<tr>
<td>SECTION</td>
<td>(FOR A.C.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: DIAMETER OF CARBON : 8 MM §
ELECTRIC CURRENT : 400 AMP.
RUNNING SPEED : 110 MM/MIN.

The results of these aforementioned tests are summarized as shown in Table 4.

Obtained from the case of D.C.R.P. were the largest values concerning heat input, arc voltage, sectional area of the fusion zone, carbon content and maximum hardness, followed by the cases of A.C. with carbon rod for A.C. use, A.C. with standard carbon rod and D.C.S.P. in the order. The above results well agree with the order of metal removing rate.
3. Experiment for practical use of A.C. arc-air gouging process.

As the results of researches for arc phenomena during execution of gouging process, as described above, and of preliminary tests we confirmed the fact the ordinary carbon electrode for gouging can not be used because its arc is unstable if operated by A.C., but the carbon electrode with core made for A.C. is acceptable because steady arc is available.

Fig. 3 shows the metal removing rate per a unit sectional area of electrode when the ordinary gouging carbon is used in D.C.S.P., D.C.R.P. and A.C. Generally speaking, it is only 1/2 of D.C.R.P. in either A.C. or D.C.S.P. if the diameters of the rods are equal. As for the current value, we aimed at the correct current value recommended in general. Since it is rather difficult to maintain the arc in this current value in A.C. and D.C.S.P., we used considerably higher current. For example, in case of a rod of 8mm dia. the current is in the vicinity of 300 amp. in D.C.R.P. but it requires 400 amp in both A.C. and D.C.S.P. If the current value is kept constant, still greater difference is presumable.

Following test was carried out in A.C. to compare the four kinds of electrodes shown in Table 2. The results are shown in Fig. 4. The home-made electrode for A.C. use showed good applicability in A.C. as compared to the other types of electrodes for A.C. use.

Then, we carried out following experiment to compare the home-made carbon electrode for A.C. use with the standard carbon electrode.

We used carbon electrode of round section with core in A.C. and standard carbons in both D.C.R.P. and A.C., and investigated resultant groove shape, metal removing rate and carbon consumption.

If we arrange metal removing rate per minute and metal removing quantity per unit carbon length on the basis of the current quantity, we obtained the results shown in Fig.5. Metal removing rate increased in proportion to the increase of the current. In the same current, the case of carbon electrode
with core used in A.C. has steady arc with improved metal removing rate when compared with the case of standard carbon in A.C., but showed great difference in the case of D.C.R.P. On the other hand, as for metal removing quantity per unit carbon length, there was practically no difference in the current in either A.C. or D.C.R.P.

The important factor to determine the upper limit of the correct current of arc-air gouging is the carbon consumption rather than to permissible maximum current. For instance, in the case the carbon of 8 mm dia. is used in D.C.R.P. the correct current range is 250 to 350 amp. but actually it can be used in 450 amp. However, under such high current, the consuming rate is too fast and the copper coating melts away as shown in Fig. 6.

Fig. 7 shows the comparison of D.C.R.P. and A.C. on the basis of carbon consuming rate.

As clearly shown in this figure, in the case of 8 mm dia. rods, 300 amp. of D.C.R.P. is on a par with A.C. 450 amp. in respect of groove shape, gouging speed and arc energy. Based on this observation, correct range in A.C. is most desirable at about 50% increase of D.C.R.P.


The authors carried out the following experiment to compare the operation qualities of A.C. and D.C. arc-air gougings by selecting nine working men at random. Those nine men were composed of some well experienced and some without practical experience in arc-air gouging.

The sizes of the test pieces and the standard of judgement for technical ability are shown in Fig. 8. Each man carried out gouging process on two test pieces, one in A.C. and the other in D.C.
The carbon electrodes used in this experiment were A.C. carbon electrodes of 6.5 mmø with core for A.C. test and standard carbon electrodes of same dia. for D.C. test.

The test pieces and the standard of judgement comply with a part of the Standard Qualification Procedure for Arc-air Gouging Technique of Kawasaki Dockyard. Those who pass this test are qualified for arc-air gouging of single-vee groove weld.

The result of this test is summarized in Fig. 9. In this figure, a line is drawn from the starting point in 45° diagonal upward direction. The points existing above this line indicate that their scoring points in D.C. exceed scoring points in A.C. The points below this line show that their scoring points in A.C. exceed those of in D.C. The scoring points are average of two gouging works.

According to this result, there is no distinct difference between D.C. and A.C. as far as the operation quality is concerned. With the exception of some, those men have had no experience in A.C. gouging. Therefore, this experiment proved the fact that any man having experience in D.C. gouging can carry out A.C. gouging without additional technical training. Hatched zone in the figure shows those qualified in this technical test.

5. Summary.

(1) The Authors have carried out researches concerning various arc phenomena for the combinations of different electric currents and carbon electrodes by using high-speed motion picture camera. Results showed the remarkable differences among these combinations. Carbon electrode for A.C. use gives the arc as stable as that for D.C. use.

(2) Above results complied with those obtained by osillograph. It has been revealed that estimation for carbon electrode, "of good performance", is closely connected with the phe-
nomenon of arc stability.

(3) In the case of A.C. use, carbon electrode of round section with one core showed good applicability as compared to the other types of electrodes.

(4) So-called suitable range of current depends on the electric source. Suitable range for A.C. is higher than that for D.C. In each suitable range, the former compares favorably with the later in both points of economy and appearance.

(5) No special training would be required to master the A.C. gouging process for the operators who are already skillful in the D.C. process.

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2) for instance, Nakahara, K., "Gouging by the Arc-Air Process", The Welding Review, 4 (10), 62-63 (1956)
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