气电焊在造船业的应用

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摘要:近年来,造船业的产量不断增长,而气电焊工艺也更多地得到应用。气电焊在造船中的船体装焊中频繁使用。单丝和多丝焊也像气电焊一样结合其他焊接工艺得到应用。全机械化气电焊可大大增加焊接产量。就装焊方面,气电焊比手工焊、半自动焊更适用于厚板焊接。特别注意,高输入热量对基材机械特性的影响,根据IACS分类要求对焊材和基材进行了讨论。

关键词:气电焊;船体焊装;基材和焊材分类
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Electrogas welding in shipbuilding

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Abstract: In recent years,the demand of the shipbuilding industry for an increase in productivity has resulted in enhancement of electrogas welding procedures.In shipbuilding,electrogas welding is most frequently used for assembly welding of block sections.One-wire-and multi-wiretechniques are applied as well as electrogas welding in combination with other welding processes.

The fully mechanised electrogas welding leads to a considerable increase in productivity.This applies to the upper range of plate thickness in particular compared to the welding processes commonly used for assembly welding,e.g.manual metal arc welding,semi mechanised flux cored wire or solid wire metal active gas welding.

Special attention has to be paid to the influence of the extremely high heat input on the mechanical-technological properties of the base metal.The resulting requirements of a classification society shall be discussed hereafter.

Key words: electro-gas;assembly welding of block section;classification of base materials and welding consumables

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Electrogas welding-Fundamentals

Electrogas welding(EGW)is a continuous vertical position arc welding process developed in 1961,in which an arc is struck between a consumable electrode and the workpiece.Figure 1 shows the principle of eletrogas welding.

EGW uses a constant voltage,direct current welding power supply,and the electrode has positive polarity.The welding current can range from 100 A to 800 A,the voltage can range between 30 and 50 V and travel speed can range from 2 m/h to 12 m/h (depending on plate thickness).A wire feeder is used to supply the electrode,which is selected based on the material being welded.A shielding gas-generally carbon dioxide-can be used with a solid

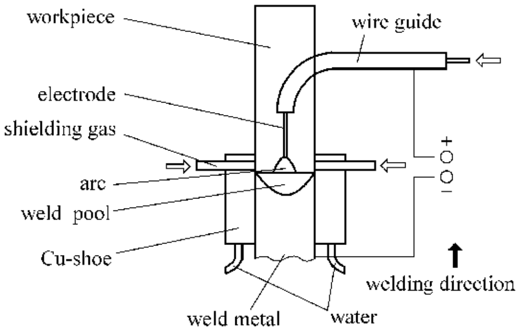

Fig.1　shows the principle of eletrogas welding[1]

wire electrode to provide the weld with protection from atmospheric contamination.Also flux-cored electrodes can be used for additional protection.

The welding head is attached to an apparatus that elevates during the welding process.Also attached to the apparatus are backing shoes which restrain the weld to the width of the workpieces.To prevent them from melting,they are made of copper and are water-cooled.They must be fit tightly against the joint to prevent leaks. Also ceramic backing can be used.

In case of an application of electrogas welding combined with another welding process the root pass is welded first using the manual welding process.That means that the root-pass is used as a backing run for the subsequent electrogas welding.

The welding machine is provided with a mechanism for holding of the stick out length to a constant.The rising speed of the carriage is controlled by detecting the welding current.

In order to avoid poor fusion at the weld start,the process has to be started on a run-up plate which closes the bottom end of the groove.

Electrogas welding is characterised by a high deposition rate(single pass welding!) and correspondingly by a high heat input.Since the welding process is fully automatic it can be applied with a high process reliability resulting in a low number of weld defects.

Depending on the plate thickness,tubular cored wires are used with diameters of 1.6 mm to 3.2 mm.In case of higher plate thicknesses,an oscillation device can be used for the wire (cf.Figure 2) in order to ensure the side wall penetration.The oscillation will also lead to smaller wire diameters and thus to lower heat input.With regard to the upper range of plate thickness,welding machines with two melting-off tubular cored electrodes and oscillation device are used[2](Figure 3).Suitable power sources are rectifiers with a slightly dropping static characteristic. When using single wire welding machines,the electrode is connected to the positive pole.In case of twin wire welding machines,one electrode is poled positive and the other one negative,in order to improve the arc stability.

Application of electrogas welding in shipbuilding

With regard to container vessels,electrogas welding is applied when assembly welding of block sections(hull plating-figure 4)sheer strake and hatch coaming in vertical position in order to minimise welding times.Furthermore electrogas welding is used in subassembly of block sections(Figure 5)for longer weld seams (>1 m) and the upper range of plate thickness.

The major advantage of electrogas welding is the high productivity due to the high deposition rate.Furthermore, preheating can be omitted in most cases because of the high heat input (depending on the base material).The reduction of the included angle,which is typical for electrogas welding,minimises distortion and reduces consumption of welding consumables.Due to the reduction of manual work,weld defects caused by poor workmanship of the

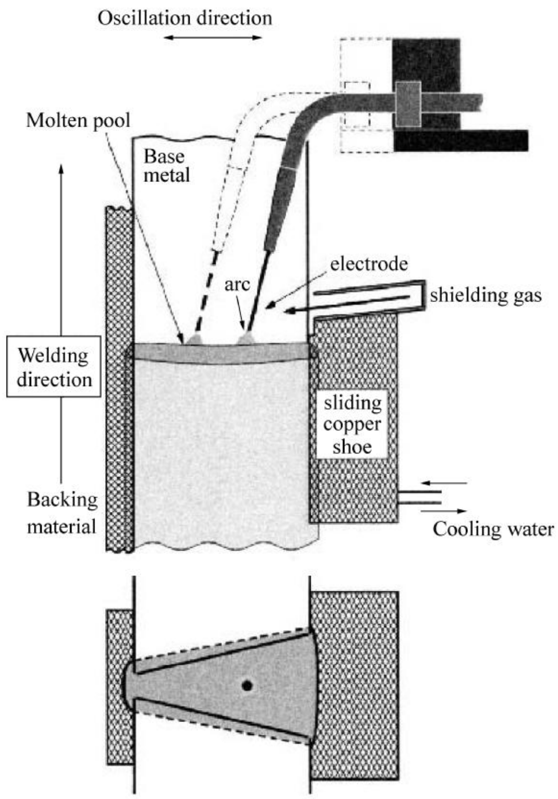

Fig.2 Single-electrode VEGA®[2]

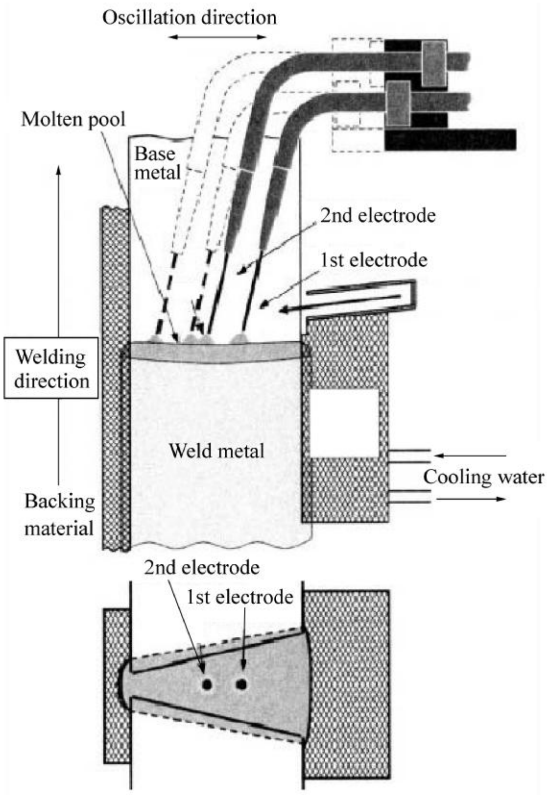

Figure 3 twin wire VEGA®[2]

Fig. 4 Assembly welding of block sections

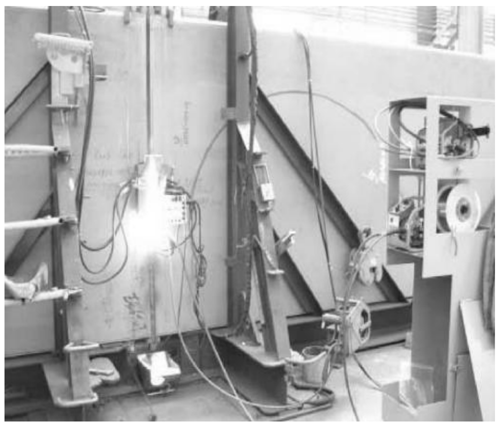

Fig.5 Block joint

welder are reduced.This leads to additional economical benefits.

Because of the high heat input compared to other welding procedures, a larger heat affected zone and coarse grain region are generated.This leads to a decrease of toughness in the heat affected zone.Long-time exposure to temperatures of more than 1 500°C and low crystallisation rates are responsible for this.The same applies to the weld metal[1].

By using thermo mechanically rolled steels particularly suitable for high heat input, the grain size can be limited and acceptable toughness properties can be achieved(Figure 6, 7 and 8).

The maximum reduction of strength can be found close to the fusion line as shown in Figure 9.

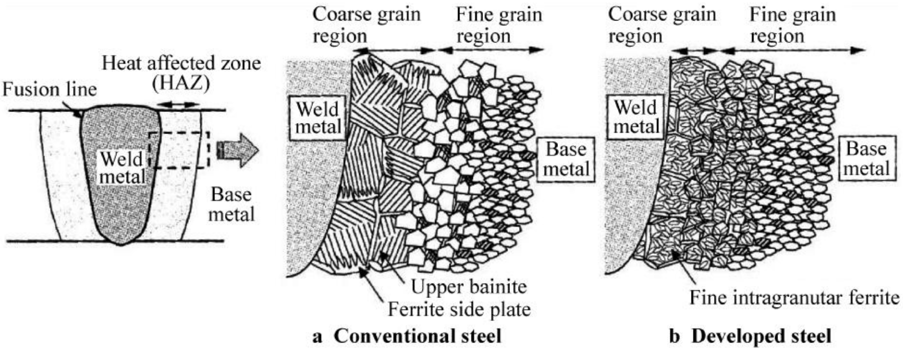

Fig.6 Scheme of coarse grain region of different base metal after welding with high heat input[3]

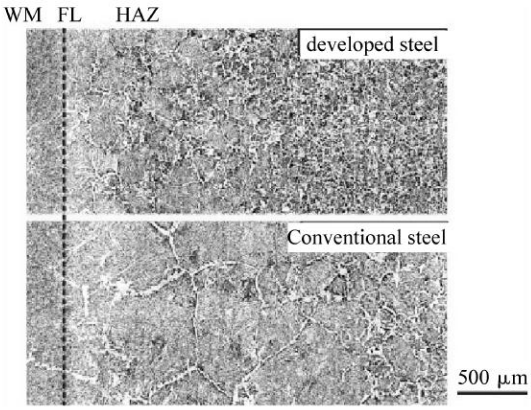

Fig.7 Microstructure of different base metal after welding with high heat input[4]

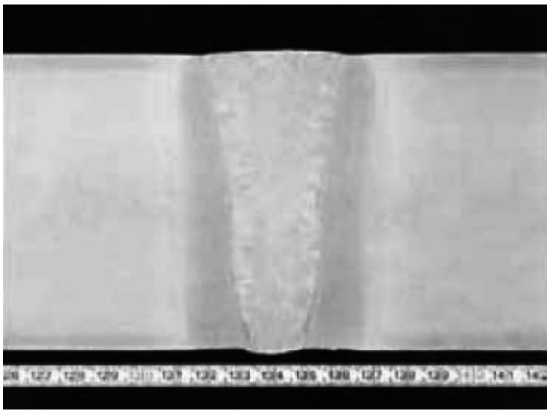

Fig.8 Macro photo of electrogas welding with a heat input of 680 kJ/cm and a plate thickness of 80mm[4]

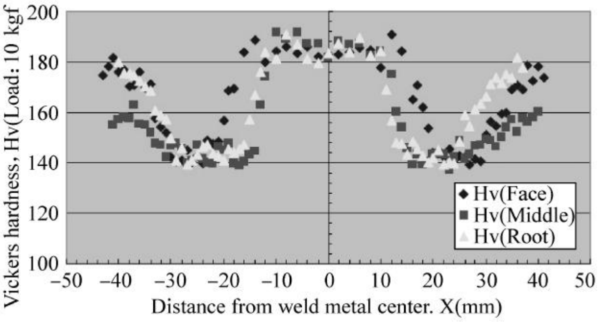

Fig.9 Vickers hardness test (HV10) with local hardness drop in HAZ of an electrogas welded butt joint

Classification requirements for application in shipbuilding

Classification requirements shall be agreed between the shipyard and the classification society before production.Requirements concerning the base metal,the welding consumables,approval of welding procedures and qualification of welders have to be fulfilled.

Base Materials

In order to allow a trouble free application of the base materials the manufacturer of the base metal has to carry out a so-called" weldability test" according to the IACS Unified Requirements[5].This test considers the important parameter of maximum heat input.

A corresponding marking of the steel with the appropriate maximum heat input (e.g" E36 - W300" for maximum heat input of 300 kJ/cm)may be added to the material certificate and the stamping then.This is also necessary in order to avoid later mixing-up with other steels at the shipyard.

Welding Consumables

The welding consumables are to be tested according to the Rules for Classification like e.g.welding rules of Germanischer Lloyd[5] with regard to electrogas welding and you have to use welding consumables appropriate for electrogas welding and approved by the classification society.

Welding consumables for electrogas welding are approved for normal strength hull structural steel grade A to E with grade 1 V,2 V and 3 V(rising number for increasing toughness and V for vertical welding position) and for higher-strength hull structural steel grade A32 to E36 with grade 1YV,2YV,3YV or 4YV (Y for yield controlled). For the approval a butt weld test specimen has to be welded in vertical up position according to Figure 10 with the base materials,plate thicknesses,welding parameters(max.heat input),diameter of wire,shielding gases,backings, joint preparation(max.root gap width) as for the future application at the shipyard.The coordination between manufacturer of welding consumables,shipyard and classification society is highly recommended for these tests.In table 1, welding consumables approved by Germanischer Lloyd are specified.

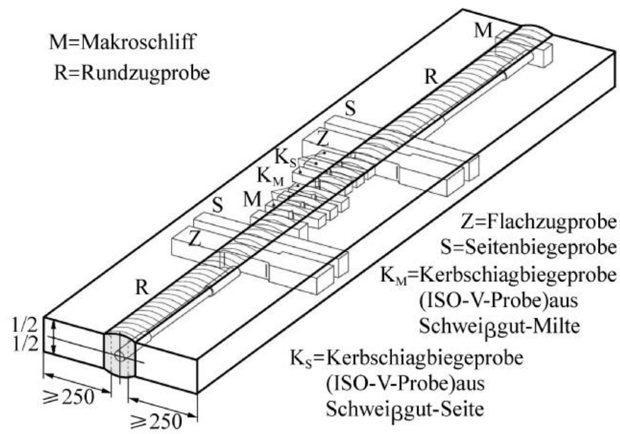

Fig.10 Test speciment and test coupon for electrogas welding for the testing of welding consumables[6]

Tab.1 GL approved welding consumables for electrogas welding

Brand name	Gas/EN439	Backing	Manufacturer	Grade
DWS-43G	C1	KL-4GT	Kobe	3YV
DWS-50GTF/DWS-50GTR	C1	KL-4	Kobe	5Y40V
DWS-1LG	C1	KL-4	Kobe	6Y40V
Vertomax 2MG	C1	Not stated	ESAB	2YV
NITTETSU EG-3	C1	Nittetsu SB-60V	Nippon	4Y40V

Welding Procedure Tests

Before starting the production, procedure tests for electrogas welding have to be carried out according to the Rules for Classification[6].

The length of test pieces(length of weld)for fully mechanized and/or automatic welding processes shall be similar to the weld length to be deposited during later fabrication work, subject to a minimum length of 1000 mm.In the case of vertical welding, the length of the test piece shall conform to the size of the jig used in fabrication. Particularities, like welding operations performed through the deck, have to be considered when choosing the form of the test coupon.

Additional tests e.g.notched bar impact tests of the coarse grain region or the root area and round tensile tests of the weld metal are to be considered.

In case that the standard size tensile tests carried out during the pre-production phase, fall below the minimum requirements of the tensile strength, wide width tensile tests considering the real geometry of component may be required additionally(Figure 11).

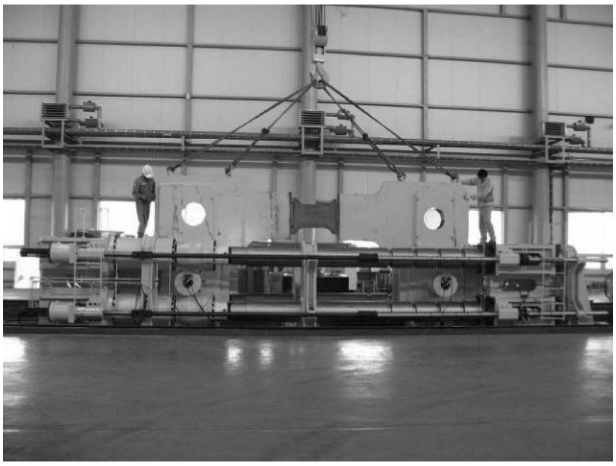

Fig.11 Large tensile test specimen and 3 000 t tensile testing machine

In comparison to standard tensile test specimen, wide width tensile test specimens provide higher strength because of the"supporting effect" of the surrounding material and represent a testing closer to the conditions of the construction. The supporting effect results from the higher strength of the consumable(always overmatching!)and from the unaffected strength of the base material.Moreover, the relative width of the HAZ(relation between plate thickness and width of the HAZ)plays a decisive role for the possible supporting effect.An additional theoretical estimation of the weld strength of the weld[5] by means of a series of hardness tests and of the relative width of the HAZ may help to reduce the number of wide width tensile tests.

In order to guarantee a trouble-free welding process under production conditions, the weld preparation(weld preparation angle, max.root gap width, misalignment)has to be controlled before welding according to the valid welding procedure specification.These fit-up inspections are an essential part of the procedure approval.

Until a reliable and reproducible application of the procedure is achieved, the production welds(at minimum) have to be examined by visual inspection and non-destructive testing(surface crack test, X-Ray-or ultrasonic testing)with an inspection scope of 100%.

In case of upper range of plate thickness with very high heat input, additional production tests including tensile test, bend test, notched bar impact test and macrograph with Vickers-hardness test are recommended.

Welding operators

All welders must have a valid welder qualification certificate.The qualification of the operating staff for electrogas

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welding has to be demonstrated by a welded test coupon during e.g.procedure tests or production tests.

Since successful welding depends on a precise preparation(e.g.weld preparation angle, max.root gap width) the operators shall be exceptionally trained to observe the welding procedure specification.In case of deviations from the WPS, negative influences on the weld quality can not be excluded, e.g.a larger root gap width resulting in a higher heat input will lead to reduced toughness and strength values and/or weld defects like lack of fusion or insufficient penetration.

Prospect

The increasing application of higher strength shipbuilding steel of larger thicknesses up to 100 mm reinforces the requirement of higher productivity in welding technology in the long run.Due to the progresses regarding the base materials, welding consumables and welding technology, electrogas welding can contribute to an increase in productivity.We deem it advisable to carry out further tests concerning fatigue limit, fatigue strength and fracture mechanical testing, because electrogas welding is also used in highly stressed areas of the ship structure.

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