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# TEMPERATURE DURING THE ARC PHASE OF THE GMAW PROCESS[1)]

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The temperature was determined from the intensity ratio of the Fe spectral lines. The time dependence of the temperature during the arc state of the gas shielded consumable metal electrode arc welding process is given. The measurement and data processing were done by the microcomputer system.

## I. INTRODUCTION

Gas shielded welding with consumable metal electrode (GMAW) was first used by N. G. Slavyanov in 1890 [1]. The low cost is the main advantage of this welding process in comparison with other welding techniques. The GMAW is short-circuiting process, i.e. there exists an immediate connection between the soft iron wire and the work piece (between the welding electrodes).

Fig. 1 illustrates the various stages of the GMAW process. There is the time development of the voltage and current during the GMA welding shown in Fig. 1. It is evident from this figure that there are three phases of the GMAW process: 1 - arc phase: an arc discharge exists between electrodes, the voltage is higher than 20 V; 2 - short - circuiting phase: an immediate connection exists between the welding electrodes, the voltage is lower than 8 V; 3 - absence: there is no connection between electrodes (there exists no arc and no short circuiting), current does not flow between electrodes.

Moreover Fig. 1 shows that the parameters of the GMAW process (voltage, current - light emission too) change very rapidly having a statistical character. A microprocessor system is needed to examine the accidental processes in GMAW.

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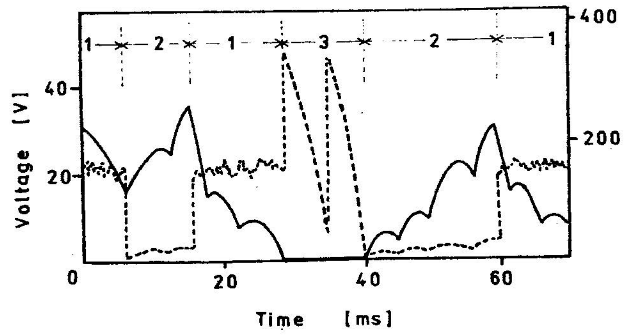


Fig. 1. Time development of the voltage and the current during the GMA welding process.

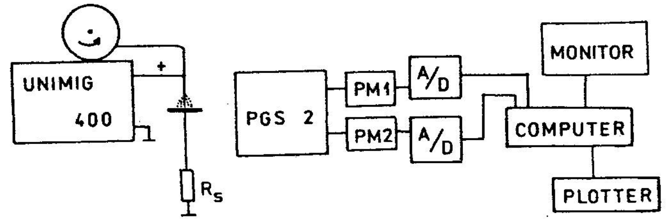


Fig. 2. The experimental arrangement.

The mechanisms of the GMAW have not been completely understood so far. The knowledge needed for the control of the welding source is mainly gained by experience [2]. The paper presents the measured values of temperature of the arc stage of the GMAW process at various welding parameters.

## II. EXPERIMENTAL SETUP AND PROCEDURE

The experimental arrangement is outlined in Fig. 2. A standard welding source UNIMIG 400 with feeding was used. The main part of the measuring apparatus was the PGS 2 spectrograph (Zeiss Jena), in which a grating is used to disperse the radiation into its spectral components. The radiation was focussed on the entrance slit of the spectrograph by means of an optical system with two quartz lenses. The distance from the arc to the entrance slit was about 1 m, the entrance slit width 0.05 mm. The intensities of the spectral lines were registered with photomultipliers M 12 FQS 35. The signals from photomultipliers were amplified (A1, A2) and were converted into a digital information (by an A/D convertor). The measurement was carried out by a computer program in the machine language of the microprocessor MHB 8080. The sampling frequency of the microcomputer system was 60 $\mu$s. The data processing program used 3000 measured values for the intensity of each spectral line. The time dependence of the temperature and the mean temperature with its standard deviation were calculated from these values.

On the assumption that a local thermodynamic equilibrium (LTE) exists in the arc plasma (of a small optical thickness) the temperature can be determined from the relative intensities of the atomic lines [3]:

$$\frac{I_1}{I_2} = \frac{A_1 g_1 \nu_1}{A_2 g_2 \nu_2} \exp\left(\frac{E_2 - E_1}{kT}\right),$$

where $g_1$, $g_2$ are the statistical weights of the initial states, $A_1$, $A_2$ the transition probality of the atomic line, $\nu_1, \nu_2$ the frequencies of the emitted radiation, $E_1, E_2$ the energies of the excited states, $T$ the temperature, and $k$ Boltzmann's constant.

In our case we chose $Fe^I$ spectral lines $\lambda_1 = 542.97$ nm and $\lambda_2 = 460.294$ nm, the optical thickness was assumed to be small. The validity of the LTE is currently assumed for the arc discharge [4]. The parametrs $g, A, E$ for the chosen spectral lines are given in [6,7]. Since the diameter of the arc is only 2–3 mm and the position is rather unstable, we did not dare to determine the radial distribution of the temperature. For this reason only the average temperature of the arc was determined.

A correction due to the dependence of the detector sensitivity on the wavelength was performed. The background due to the continuum radiation was taken from the intensities in the wavelength regions in the immediate vicinity of the chosen spectral lines.

## III. RESULTS

For the determination of the temperature we have measured the spectral lines intensities at various values of current and voltage. Fig. 3 gives a time dependence of the elctron temperature in the arc at a welding current of 160 A, a voltage of 26 V in the shielding gas $CO_2$. During the short circuiting phase of the GMA process there exists no plasma and so there were no values of temperature determined.

Some measurements were performed in air too. Fig. 4 gives a time dependence of the electron temperature in the arc at a welding current of 160 A, a voltage of 26 V in air.

The standard deviations were calculated for each measurement. The values of the standard deviations were about 600–700 K.



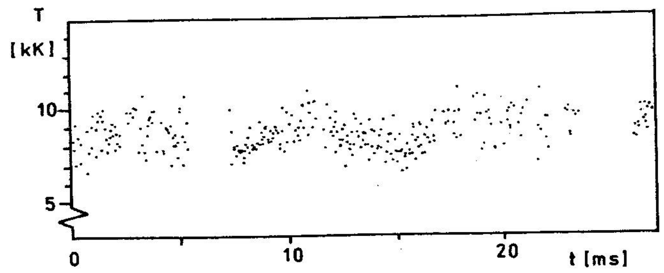


Fig. 3. Time dependence of temperature in the arc at the welding current of 160 A, voltage of 26 V in $CO_2$.

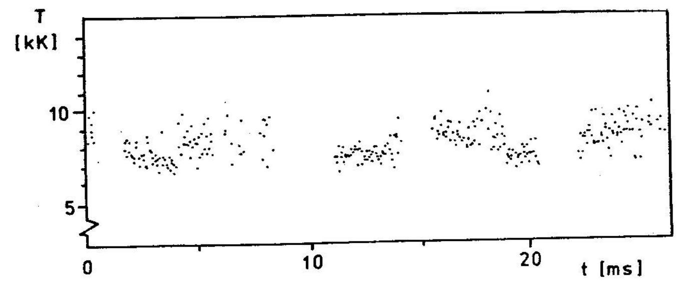


Fig. 4. Time dependence of temperature in the arc at the welding current of 160 A, voltage of 26 V in air.

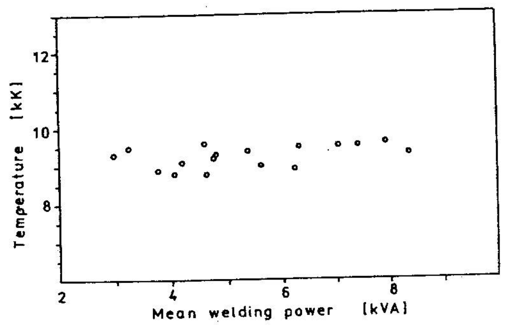


Fig. 5. Mean values of the electron temperature at various welding powers.

Fig. 5 gives the mean values of the electron temperature at various welding powers. The mean welding power was calculated as a product of the welding current and the welding voltage.

## IV. CONCLUSIONS

All measurements suggested that the temperature during the arc phase of the GMA welding has only fluctuations and there exists no time dependence of the temperature during the arc phase of the GMA process. This fact is interesting because the current, the spectral line and the background radiation intensity decrease with time during the arc phase of the GMA process.

The comparison of the results at various welding powers with respect to the standard deviation show that there is no strong dependence between the electron temperature and the mean welding power. The electron temperature for the measured region of the welding parameters is $9100 \pm 700$ K. This value of temperature can be used as a plasma temperature for the energy balance of the anode to evaluate the energy transported to the anode from the arc column [8].

Moreover, the proposed experimental arrangement with microcomputer is a very effective system for the temperature measurement which can calculate the temperature immediately after measurement and so the data processing is very convenient.

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## ТЕМПЕРАТУРА ДУГИ В ПРОЦЕССЕ СВАРКИ В ОХРАННОЙ АТМОСФЕРЕ ГАЗА

Температура определена на осовании отношения интенсивностей спектральных линий железа. Приводится температурная зависимость температуры дуги в процессе дуговой сварки металлическим электродом в охранной атмосфере газа. Измерение и обработка данных проведены на микрокомпютерной системе.