Title	An Experimental Investigation of Dynamic Behavior of Arc Sensor in GMA Welding in Short-Circuit Transfer Mode(Physics, Process, Instrument & Measurements)
Author(s)	Ushio, Masao; Liu, Wenhuan; Mao, Wenjie
Citation	Transactions of JWRI. 1995, 24(1), p. 25-30
Version Type	VoR
URL	https://doi.org/10.18910/12428
rights	
Note	

An Experimental Investigation of Dynamic Behavior of Arc Sensor in GMA Welding in Short-Circuit Transfer Mode†

Masao USHIO*, Wenhuan LIU** and Wenjie MAO***

Abstract

In the present paper, the authors used a specially designed torch vibration device to investigate experimentally the dynamic characteristics of an arc sensor in welding in a short-circuiting transfer mode. The results revealed that it may be better to use the characteristic parameters Itc (current value at the instant of arc coming into short-circuit due to a droplet liquid bridge) and f_S *(the frequency of short-circuiting) for an arc sensor in this mode. The effects of the frequency and the amplitude of torch height variation on the response of* I_{tc} *and* f_S *were also investigated. The results showed that the highest response of* I_{tc} *and* f_S *can be obtained at around 3Hz but the sensitivities of both decrease with the increase of the amplitude of the torch height variation.*

KEY WORDS: (Arc Sensor) (GMA Welding) (Short-circuiting transfer Mode) (Characteristic parameter) (Short-Circuiting Frequency) (response) (sensitivity)

1. Introduction

Through-the-Arc Sensor (simply called arc sensor) refers to the technique of gathering the information about the torch height variation from arc electric signals such as welding current and voltage. Here, the torch height refers to the distance between the tip of the contact tube and the surface of the weld pool. It is well known that arc voltage is approximately proportional to the arc length. So welding voltage will increase if the torch height becomes higher. Certainly, welding current will also vary with the variation of welding voltage if the power supply used has a conventional output characteristic (the output voltage dropping down with current increase). The essential principles for using the arc sensor to control the change in the torch height and the weld seam tracking 1~5) and to sense the variation of groove geometry 6~7) are all based on these arc welding phenomena. Because the arc sensor has such advantages as no need for additional space intrusion in the vicinity of torch, real time control, low cost and no need for maintenance and so on, the arc sensor has become widely used in automatic welding control systems 8~9).

Nevertheless, its application in the short circuit transfer mode of GMAW is largely limited 10). This may be related with the particularity of the process in this mode. Rather than a steady DC welding, the process in the short-circuiting transfer mode is characterized by alternate changes between arc burning and short-circuiting which is induced by a droplet liquid bridge repeatedly formed between the tip of the electrode wire and the weld molten pool. As a result, welding current and voltage vary considerably in this mode. Because of this, satisfactory control of performances can not be maintained if the data processing technique for a steady DC welding process are used. How to remove the influence of the intrinsic variation of the arc electric signals, and how to abstract effectively the information about the variation in the torch height from these arc electric signals, therefore, become the key techniques to use the arc sensor successfully in this mode.

In this paper, aims are to investigate the essential characteristics of the arc sensor when welding is in a short-circuiting transfer mode. Namely, how do the real time wave forms of welding current and voltage change with the variation of the torch height, and which characteristic parameters in the wave forms best describe the response to that variation.

---

† Received on May 24, 1995

* Professor

** Visiting foreign researcher (associate professor of Qinghua University, China)

*** Graduate student

Transactions of JWRI is published by Welding Research Institute of Osaka University, Ibaraki, Osaka 567, Japan.

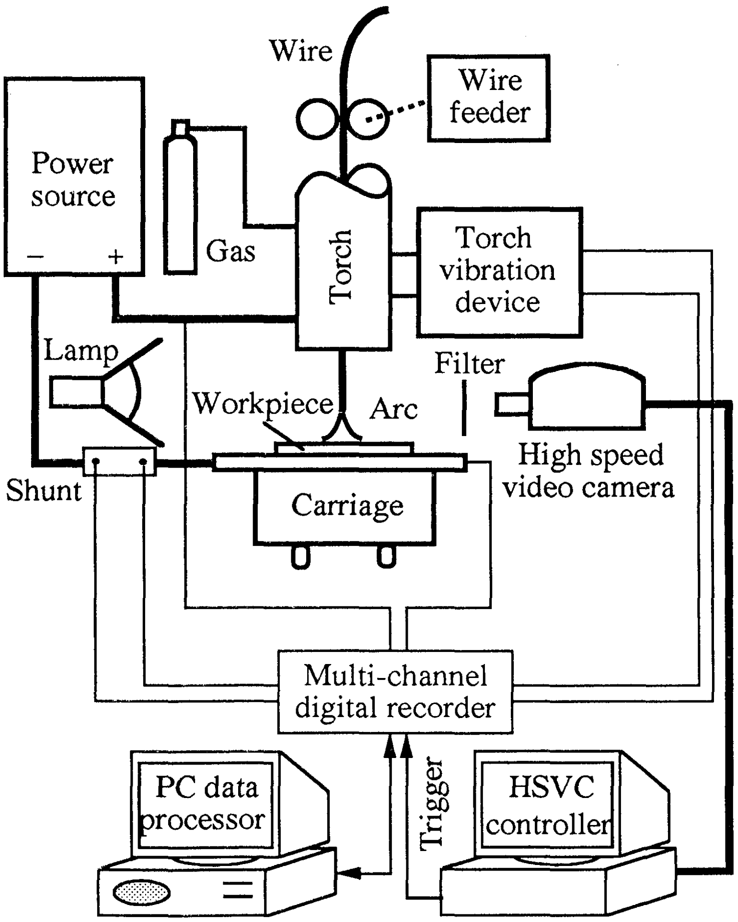
2. Experimental Equipment and Procedure

The experimental equipment is shown in **Figure 1**. The change in the torch height is stimulated by a specially designed device which can provide sinusoidal wave forms of up-down vibration with a frequency from 0 to 50Hz and an amplitude from 0 to 5mm. The welding current is supplied by a transistorized welding power source in which output U-I (voltage-current) characteristic can be changed continuously from CC(constant current output) to CP(constant potential output). The power supply can also control the varying rate of welding current in order to obtain a stable short-circuiting transfer of droplet and to reduce spatter. For checking the correlation between the electric signals of both welding current and voltage and the variation of the torch height, a multi-channel digital recorder with 1 micro sec. maximum sampling speed is used. The recorded data are transferred to a computer for data processing, analyzing and saving. In order to measure precisely the extension of electrode wire and the variation in the torch height, a high speed CCD video camera with a 45000P/s maximum shutter speed is used. The dynamic arc burning behavior and stability can also be observed by using this.

Welding was all down hand bead-on-plate, and typical welding conditions were set as follows: vibrating amplitude and center position of the torch height: 2.2 mm and 14.5 mm; electrode wire material and diameter: mild steel solid wire(MIX-50S) and 1.2 mm diameter; shielding gas and flow rate: 20%CO2+Ar and 16 l/min; and welding speed: 20 cm/min. The equivalent resistance and the reactor of welding power supply were at CP state(0.2V/100A) and 0.36mH.

3. Results and Discussion

In contrast to welding in a spray transfer mode , the process in the short-circuiting transfer mode is characterized by the alternation of arc burning and short-circuiting. In arc burning, the tip of the electrode wire is melted by arc heat and joule heat(mainly arc heat). As the molten metal forms a droplet and the droplet grows, the arc length gradually decreases. So welding voltage decreases during arc burning. Welding current also decreases since the reactor discharges after the arc has been re-ignited. When the droplet becomes enough large to come into contact with the surface of weld molten pool, a liquid bridge forms between the wire tip and the weld



←

Fig. 1 Schematic diagram of experimental apparatus

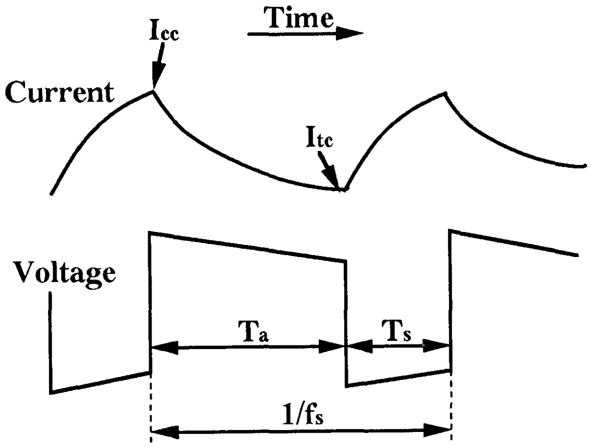


Fig. 2 A typical pattern of welding current and voltage waves in GMA welding in a short circuiting transfer mode

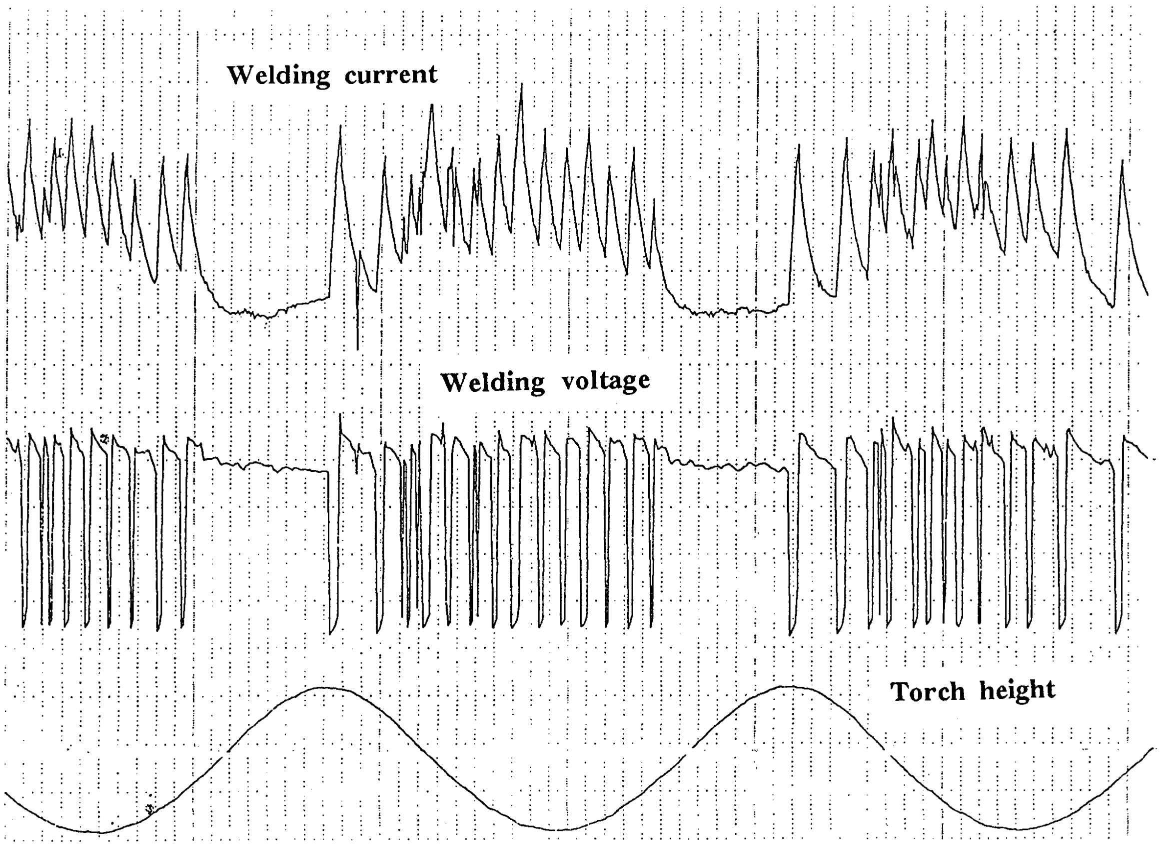


Fig. 3 Real time response of welding current and voltage to the variation of the torch height in GMA welding in a short circuiting transfer mode

molten pool. In the next stage, a neck quickly occurs at the liquid bridge and then becomes thinner due to both capillary action and the electromagnetic pinch force produced by short-circuiting current. Finally, the liquid bridge is broken at the neck. In this stage, therefore, both welding current and voltage increase. **Figure. 2** shows a typical pattern of the real time wave forms of welding current and voltage in one cycle of the process. The main characteristic parameters in the wave forms are:

(1) I_{cc}: the current value at the crest point of the real time wave form of welding current,

(2) I_{tc}: the current value at the trough point of the real time wave form of welding current,

(3) T_a: arc burning duration,

(4) T_s: short-circuiting duration,

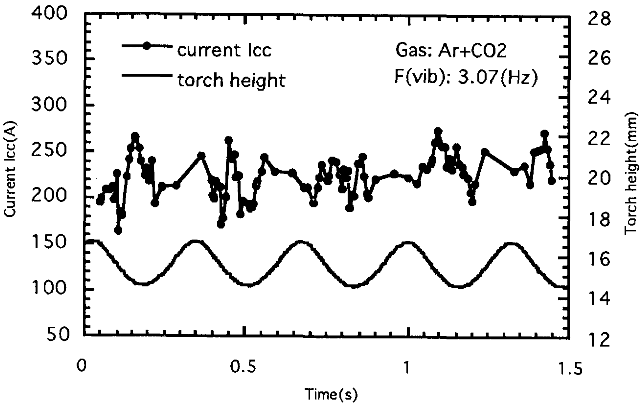
(5) f_s: short circuiting frequency $(=1/(T_a+T_s))$.

As a result, I_{tc} corresponds to the current at the instant of a droplet liquid bridge formation and I_{cc} the current at the instant of the droplet liquid bridge rupture.

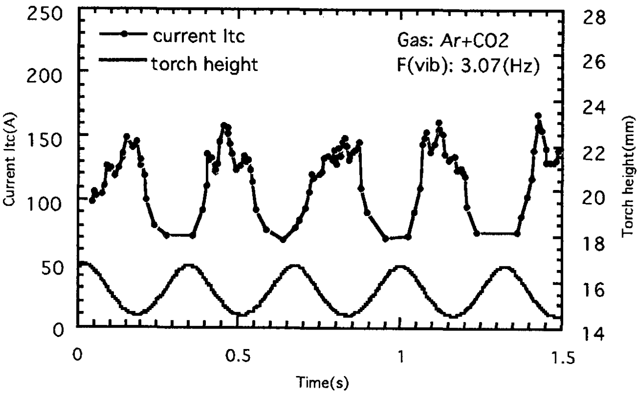
Figure 3 shows the typical real time responses of welding current and voltage to the sinusoidal wave form change of the torch height in the short-circuiting transfer mode. It can be seen that there are some changes in the waves of welding current and voltage corresponding to the variation in the torch height. If the torch height increases, the level of welding current decreases but the phase of the change is delayed. On the other hand, the short-circuiting frequency seems to decrease also.

Regarding the characteristic parameters of I_{cc} and I_{tc}, however, it can be found from **Figure 4** that only the response of I_{tc} exhibits comparative good correlation with the change in the torch height. The correlation between T_a, T_s and f_s and the variation of the torch height are respectively shown in **Figure 5**, where, the short-circuiting frequency, f_s, exhibits the best correlation with the change of the torch height.

The reasons for above results have not yet been made quite clear, but a simple explanation may help to qualitatively understand these phenomena. It can be considered that a longer arc length must result in a larger bulk size of droplet. So T_a and T_s will increase. Fig. 5 (a) and (b) exhibit this tendency to some extent. Actually, the sum of T_a and T_s namely the short-circuiting frequency f_s shows the tendency strongly as Fig. 5 (c).
On the other hand, a longer T_a tends to make I_{tc} lower, but the increase of T_s will increase I_{cc}. Therefore, I_{tc} should decrease and I_{cc} increase when arc length becomes longer with the increase of the torch height. However, it



(a) Icc response



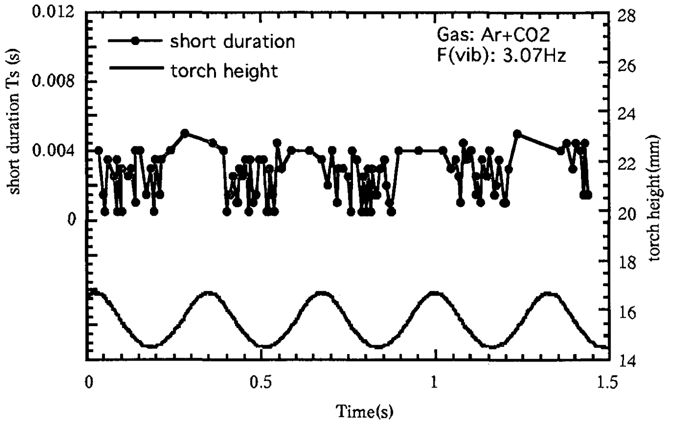
(b) Itc response

Fig. 4 Response of the characteristic parameters I_{cc} and I_{tc} to the variation of the torch height

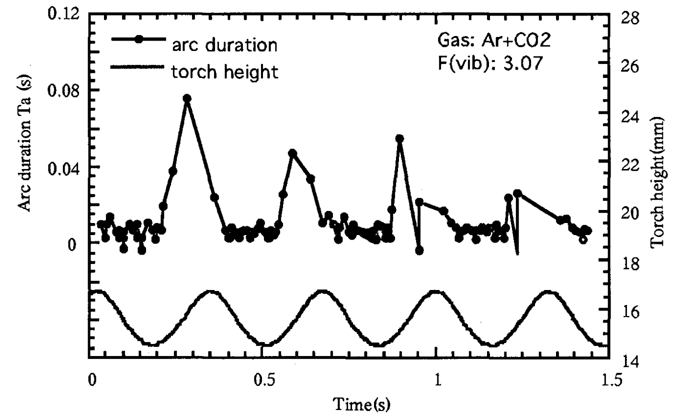
can be seen from Fig.3 that there appears to be an interaction between I_{tc} and I_{cc} because welding current rises from I_{tc} in the duration of T_s and declines down from I_{cc} in the duration of T_a. As a result, the increase of I_{cc} will be constricted by the decrease of I_{tc}. This could be a reason for the phenomenon that the response of I_{cc} to the change of the torch height is hardly definable.

Since it is known that the characteristic parameters I_{tc} and f_s show the best performance in the response to the variation of the torch height, the following investigation is concentrated on the effects of the vibration frequency of the torch height on the response of I_{tc} and f_s. The results are shown in **Figure 6** and **Figure 7** respectively, where the responses of I_{tc} and f_s are changed with the torch vibrating frequency. The highest response seems therefore to be obtained at around 3Hz.

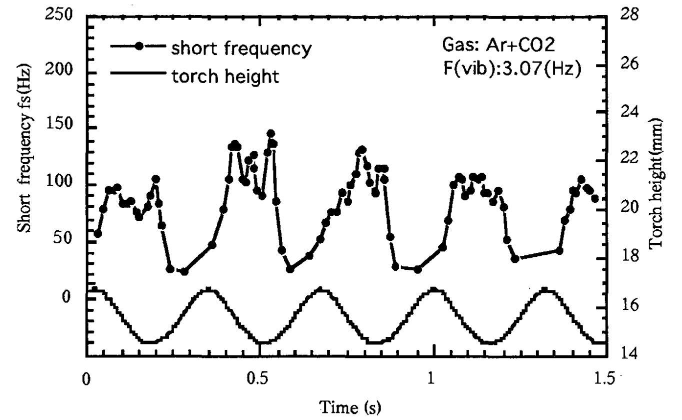
At 3Hz of the torch vibrating frequency, the influence of the torch vibrating amplitude on the response of characteristic parameters I_{tc} and f_s were also investigated. Experimental results are shown in **Figure 8**. It can be seen that the responses of both I_{tc} and f_s decline with the increase in torch vibrating amplitude in the amplitude range of 1~3mm. In experiments, it was found that welding process became very unstable if the torch vibrating amplitude was greater than 3mm. since the welding arc was often broken down



(a) Ts response



(b) Ta response



(c) fs response

Fig. 5 Response of the characteristic parameters T_s, T_a and f_s to the variation of the torch height

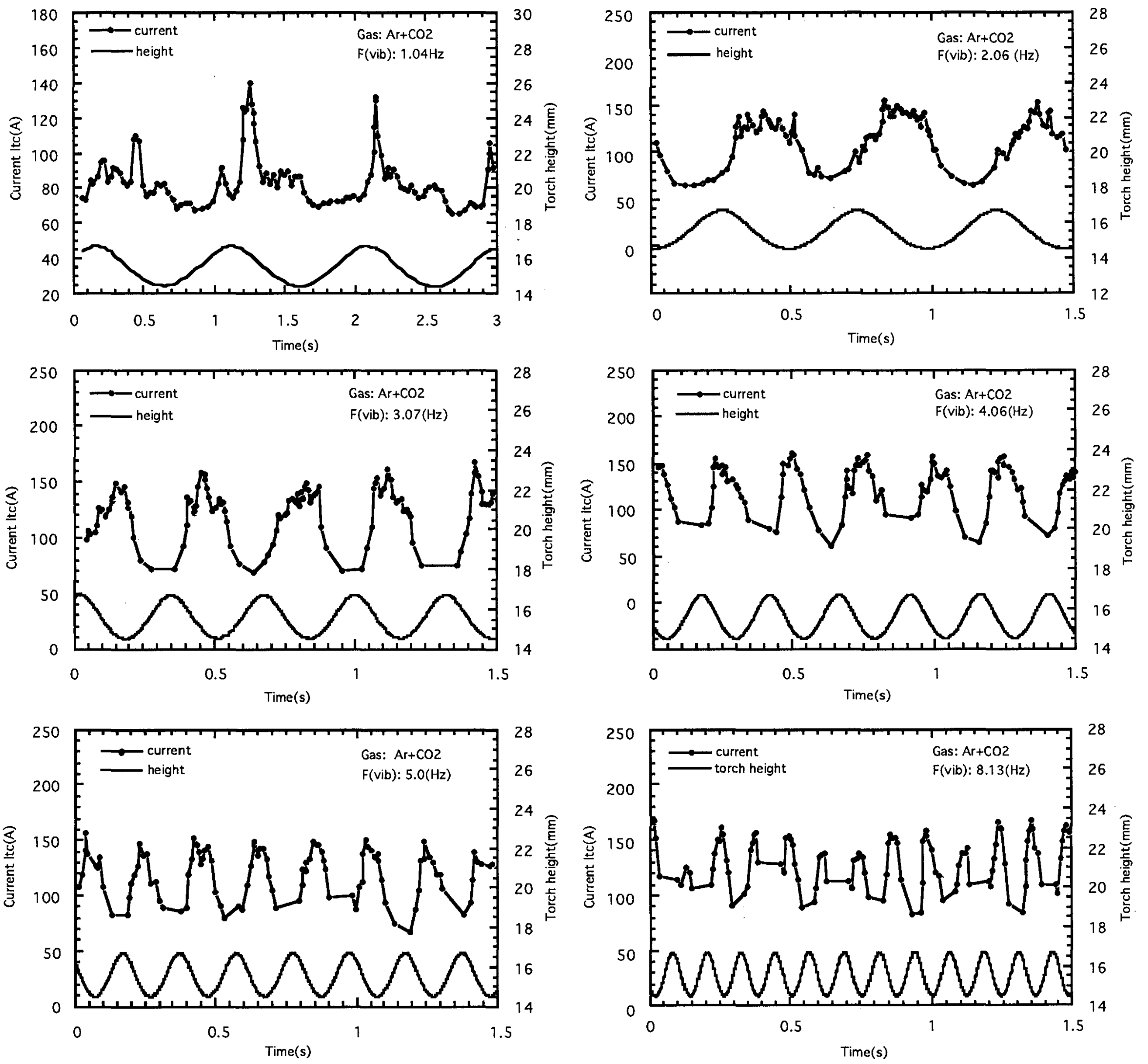


Fig. 6 Response of the characteristic parameters I_{tc} changes with the variation frequency of the torch height

4. Conclusion

In this paper, the dynamic behavior of the arc sensor in GMA welding in the short-circuiting transfer mode was investigated experimentally. Main results obtained in this work are concluded as follows:

(1) In GMA welding with a short-circuiting transfer mode, the characteristic parameters I_{tc} and f_s show comparatively good responses to the variation of the torch height. So it would be better to use these parameters for the arc sensor.

(2) The responses of I_{tc} and f_s to the variation of the torch height are affected by the varying frequency of the torch height. It was found that the maximum response can be obtained at around 3Hz in our experiments.

(3) The sensitivities of I_{tc} and f_s to the variation of the torch height are affected by the varying amplitude of the torch height. In the amplitude range of 1~3mm, it was found that the sensitivities of I_{tc} and f_s decrease with an increase in the amplitude of the torch height.

Reference

1) W. F. Iceland: *U. S. patent, No.3204081*, 1962.
2) S. Takaki and J. Nishida: *Japan patent, No.S56-17992 (JP, B2)*, 1976.
3) H. Nomura and Y. Sugitani: *Japan patent, No.S57-3462 (JP, B2)*, 1977.
4) T. Isotani, M. Mishiro and N. Yokoshima: *Japan patent, No.S54-106049 (JP, A)*, 1978.
5) G. E. Cook and G. J. Merrick et al: *Japan patent, NO.S56-11184 (JP, A)*, 1980.

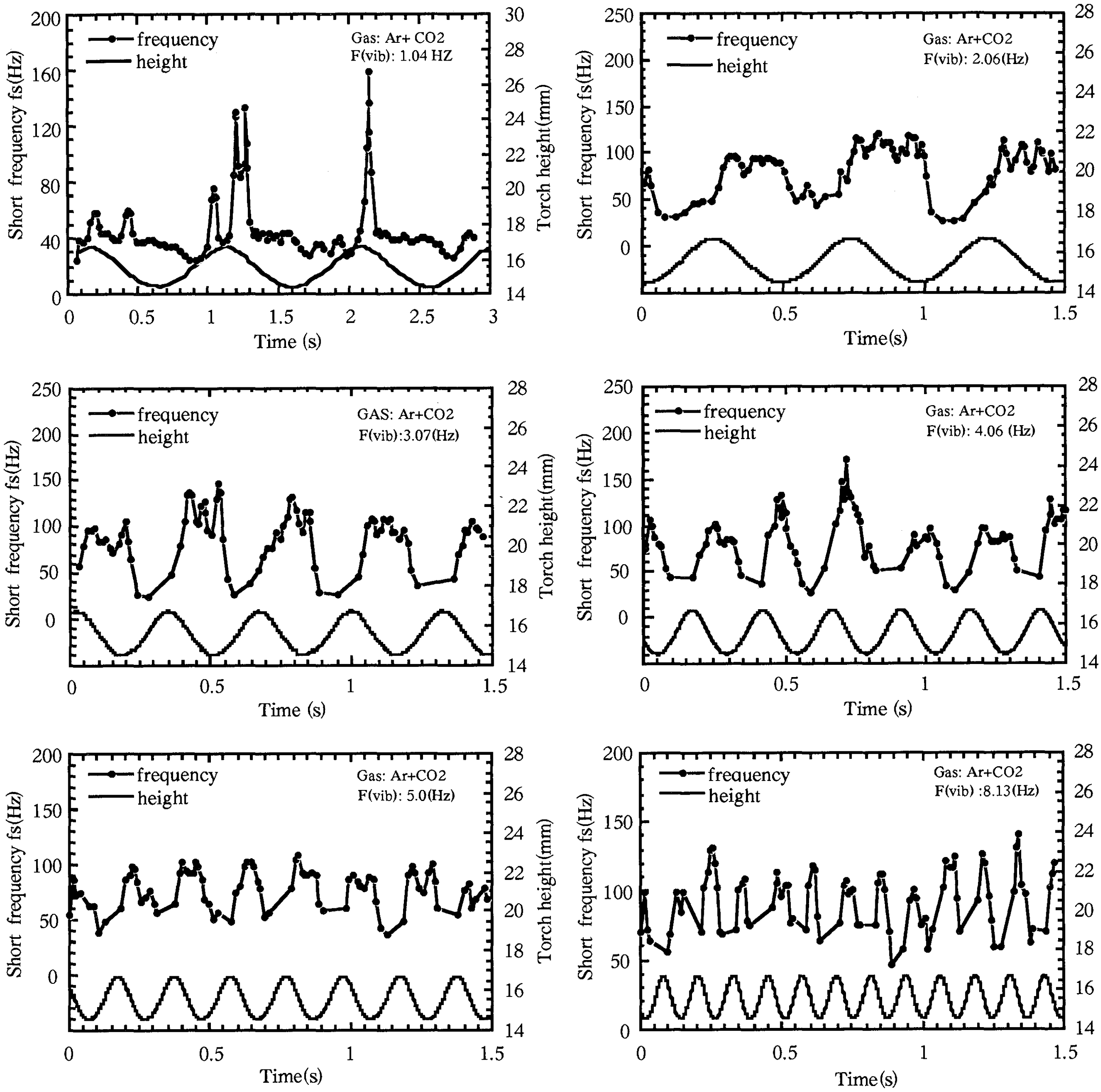


Fig. 7 Response of the characteristic parameters f_s changes with the variation frequency of the torch height

6) H. Nomura, Y. Sugitani and N. Tamaoki: *Trans. of JWS,* 1987, Vol.18, No.2, pp. 43-50

7) Y. Sugitani and W. J. Mao: *Quarterly J. of JWS* (in Japanese), 1994, Vol.12, No.4, pp. 468-476

8) Technical Commission on Welding Process of JWS: *Journal of JWS* (in Japanese), 1993, Vol.62, No.6, pp426-431.

9) M. Ushio and W. J. Mao: *Trans. of JWRI,* 1994, Vol.23, No.2, pp. 135-141.

10) Technical Commission on Welding Process of JWS: *Sensors and Control System in Arc Welding,* Kuroki Publishing House, 1991.

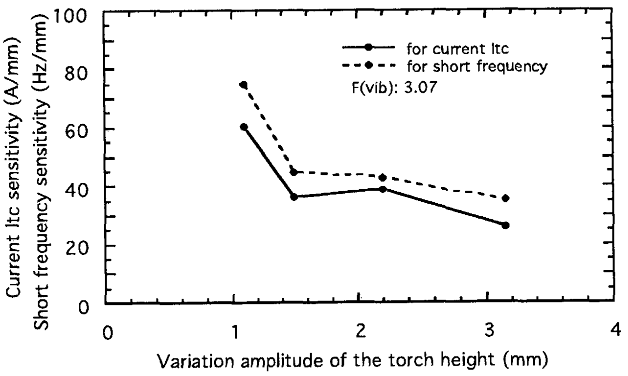


Fig. 8 Sensitivity of the characteristic parameters I_{tc} and f_s changes with the variation amplitude of the torch height