Condition Monitoring and Diagnostics Engineering Management - COMADEM

4th International Conference

Senlis, France, July 15 - 17, 1992

pp 94 - 99

THE MANAGEMENT OF INDUSTRIAL ARC WELDING BY NEURAL NETWORKS

J.R. McCARDLE., K.L. TAYLOR BURGE, R.R. STROUD, T.J.HARRIS
Department of Design, Brunel University, Egham, UK.

Abstract
New methods of monitoring industrial process variables are constantly being sought with the aim to improve control efficiency.

It has been observed that skilled welders subconsciously adapt their manual arc welding technique in response to a variation in the sound produced from the process.

This paper proposes an approach to the control of an automated submerged arc welding process using:-

1. Real time monitoring of acoustic emissions
2. The application of neural networks to predict the point of instability of the process variables.

Keywords: Process Control, Signal Processing, Neural Networks, Real Time Monitoring.

1 Introduction

Artificial Neural Networks (ANNs) are attracting a widening interest in their development and applications as an alternative to standard digital control and expert system techniques. Complex signal analysis with inherent noise characteristics have proven difficult, if not impossible, to process with expert systems often causing data explosions.(BRITE EuRam project).

The Department of Design at Brunel University, UK, has directed its research at the development of 'intelligent ' products and control systems incorporating ANNs. One focus of attention has been the development of a fully integrated , hybrid control system for industrial automated weld processes.

An approach successfully adopted has been the real time interpretation of ultrasonic scans of a submerged arc welding process. An ultrasonic transiever optimally positioned at the welding head can monitor the weld penetration and position of the weld pool in relation to the prepared seam (seam tracking). The ultrasonic data is processed by a weightless or Logical Neural Network (LNN) to achieve on line control.(Stroud R.R, *et al*, 1990-91, Harris T.J, *et al*, 1990).

Observations of skilled manual welders has shown a subconscious tendency to change the angle of the electrode and length of arc by listening to adverse fluctuations in process noise, thereby making intrinsic decisions based on a biological monitoring system. Attempts have been made to analyse these acoustic emissions by use of conventional signal processing and expert system techniques. Preliminary research undertaken at the Cranfield Institute of Technology, UK, utilised digital signal processing and expert systems in an attempt to interpret audible acoustic data for on line control. The inability of these systems to respond correctly to erroneous, novel or incomplete data yielded negative results when faced with identifying salient features within the erratic acoustic emissions.(BRITE EuRam project).

Evidence exists for the successful implementation of ANNs systems, both software simulated and hardware modelled, to imitate human attributes. The 'Silicon Ear' and 'Retina' (Mead C, 1989), the 'Phonetic Typewiter' (Torkkola K. & Kohonen T, *et al*,1991) and the advancements in hand written character recognition illustrates the success in non discrete data processing (Nellis J, *et al,* 1991.).

The aim of this research is the development of a feasible ANN oriented system which isolates features relating to weld parameter fluctuation within acoustic data in real time. It is anticipated that the proposed method will complement the existing ultrasonic monitor to advance the development of a fully integrated on line weld control system.

2 The Welding Process

Submerged arc welding (SAW) is a semi-automated process which uses a sacrificial electrode to strike an arc under a cover of gravity fed granulated flux. In an industrial situation it is used to join structural steel plates between 6mm and 40mm in thickness in a 'downhand' position (FIG. 1). Existing systems utilise software data tables to set optimum parameter values prior to the commencement of the weld. Certain weld parameters can change steadily during the process.

There are six major variables whose optimum settings dictate the final quality of the weld, these are :

welding voltage
welding current (determined by the rate of feed of the sacrificial electrode)
position of the electrode (seam tracking)
speed of the welding head along the seam
continuity in feed of the granular flux
weld plate preparation (fit up)

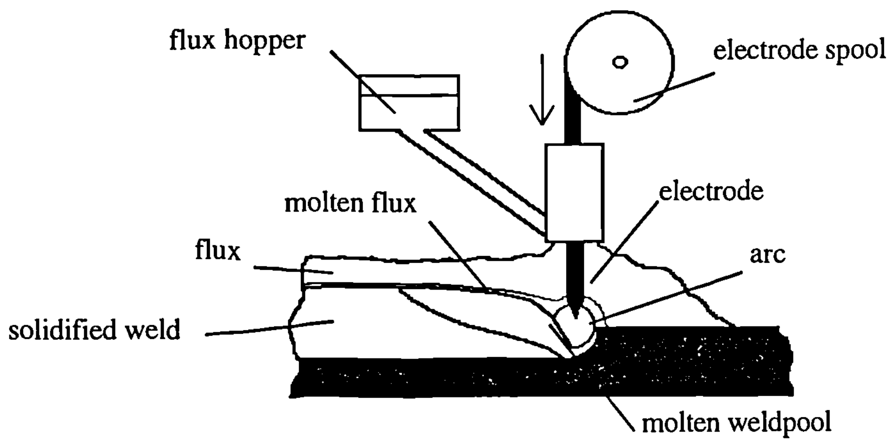


Fig. 1. Submerged arc welding process

The main aim of this research is a system capable of the real time monitoring of the welding voltage to operate in conjunction with the existing ultrasonic weld penetration and seam tracking equipment. This would render a system capable of maintaining an optimum balance between the weld voltage and current parameters and hence achieve weld stability.

The nature of raw acoustic data however, is such that emissions contain information

concerning other parameters which can be utilised for diagnostic purposes and investigation will be given to the identification of each parameters acoustic signature.

2 Proposed experimentation

Audible acoustic emissions have been successfully employed in machinery diagnostic systems such as pused laser welding and internal combustion engines (Vu V.V.*et al* 1991). The proliferation of acoustic transducers renders the collection of data relatively simple. Preliminary experimentation has highlighted the effective use of Electret Condenser Microphones (ECMs). Such transducers exhibit a large bandwidth over the audible frequency range as well as being uninfluenced by induced noise created by the magnetic flux emitted from the arc area.

The ECM and associated pre-amplifier, suitably noise shielded, will be mounted in the vicinity of the weld head. Signals collected will be transmitted to a series of banpass filters to isolate the three spectra of infrasound, 0Hz - 15Hz, audible sound, 15Hz - 20kHz and ultrasound, >20kHz as illustarated in Figure 2. Although the main consideration is given to the audible frequency range, investigations will include the possible influences of infra and ultrasound frequencies. The upper limit of ultrasound will be dictated by the sampling rate of the ADC of 2MHz providing a practical frequency limitation of circa 800kHz.

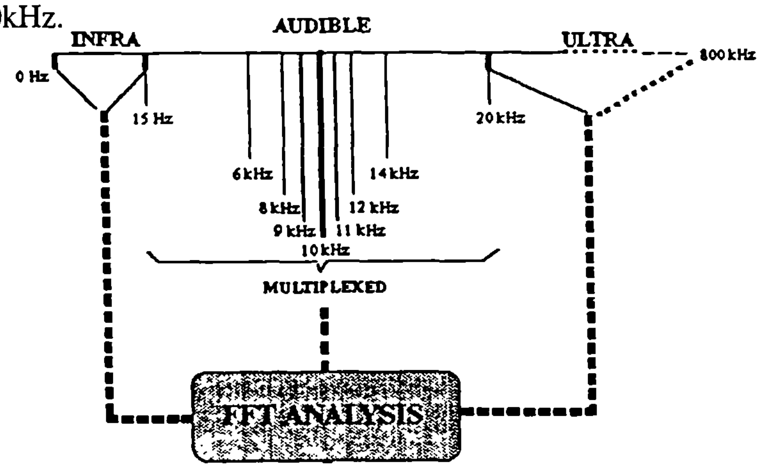


Fig. 2. Audio frequency spectrum

The deterioration of human hearing towards the extremes of the audible spectrum indicates that manual welders possibly extract information from the central range. Therefore, this sectrum is further filtered by eight bands in a Normal Distribution.

The final set of bands are multiplexed via an analogue switch array to enable each band to be utilised as a stop or passband to maintain experimental flexibility.

Isolated bandpasses are to be subjected to an FFT analysis to extract salient features within the frequency domain when the system is stimulated by intentionally unstable inputs. Once identified, the frequencies associated with the acoustic signatures of each parameter can be isolated by means of hardware filtration.

Multiplexed signals will then be digitised at a frequency of 2MHz and a resolution of 8 bits and interfaced with software simulated or hardwired ANNs. The output of the neural analysis will dictate the corrections to be made by the controlling software of the welding parameters.

The experimental equipment is summarised in Figure 3.

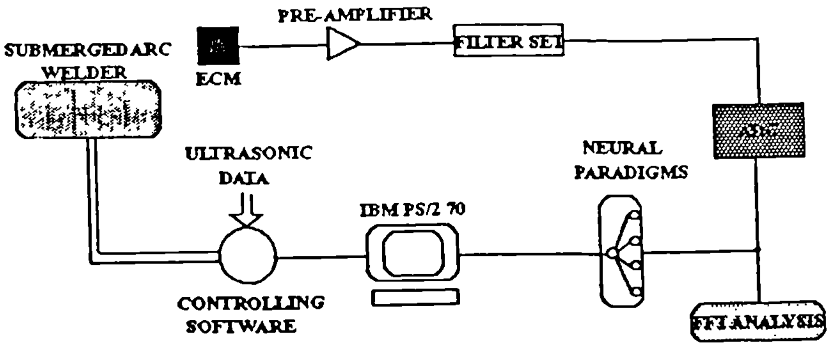
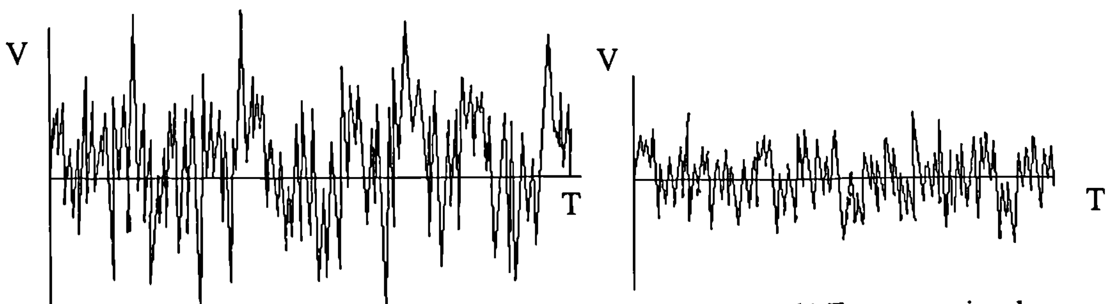


Fig. 3. Experimental schematic

3 Neural Networks

To achieve real time control of the welding process a fast signal processing system is required to recognize the characteristics associated with weld parameter fluctuation from noise polluted data. Evidence exists for the successful implementation of ANNs in systems where the predictive assessment of data is required (Tanaka T & Endo H, *et al*, 1991) as well as generalisng on noise affected signals (Vu V.V, *et al*, 1991).

Preliminary analysis of raw acoustic data provide signals typical to that shown in Figure 4. Figure 4.a. illustrates the emission of an optimum weld at a point where all set parameters remained stable and post weld inspection indicated a good quality weld. Figure 4.b. was recorded at a point where an unplanned flux blockage created weld instability. An amplitude degredation is evident, however, the signal processing system is required to predict the onset of the transition between stable and unstable signals as well as the recognition of the parameter/s causing the error.



a) Optimum weld emission

b) Erroneous signal

Fig. 4. Acoustic emissions

Complex signal processing and pattern recognition problems require the utilisation of both neural and knowledge based techniques. The trend in ANN application has steered towards the development of hybrid and multi-architectural systems, exploiting the characteristics of certain topologies in series with others and in series or parallel with expert systems. (Fogelman Soulie F., 1991.).

For the parallel processing of noise inflicted acoustic data it is envisaged that three neural networks could be employed in series:

Back propogation networks (Hecht-Nielson R., 1991, Dayhoff J., 1990).
Kohonen self organising feature maps (Dayhoff J., 1990).
Weightless or logical neural networks (LNNs) (Aleksander I., 1991).

The recognition of usable patterns within complex erratic signals requires the extraction of salient features on which a pattern classifying network can base its considerations. Back propogation networks have proven successful in bandpass functions and signal enhancement. (Hecht-Nielson R., 1991) and have the inherent property of automatically isolating usable features. This technique will form the initial layer and can be considered the pre-processing network. Investigation will be given to the possible use of this technique to replace the FFT analysis and consequent hardware filtering of the acoustic data.

The Kohonen network forms the second layer of the system. This self organising paradigm can identify similarities in input patterns when primed with a set of suitably prominent features. The similarities isolated will group the signals common to unstable weld parameters and separate them from stable parameter inputs. A capability of thus recognizing the features associated with the signal transition bands, indicative of global instability and hence of single or multiple parameter fluctuation.

The logical neural network is a system devised jointly by Brunel University and Imperial College, UK. Utilising conventional RAM technology to store responses to trained patterns, a series of hardwired RAMs can be used to discriminate between novel and learned patterns. Manipulation of the threshold of a triggering function ensure that similar patterns yield similar responses therefore exhibiting generalising characteristics. This system has been proven in the real time application to video data for facial and written character recognition (Nellis J. & Stonham T.J., 1991, Aleksander I., 1991). This system forms the final neural layer to discriminate between successive Kohonen generated features to identify a potentially unstable parameter.

The neural system is summarised in Figure 5.

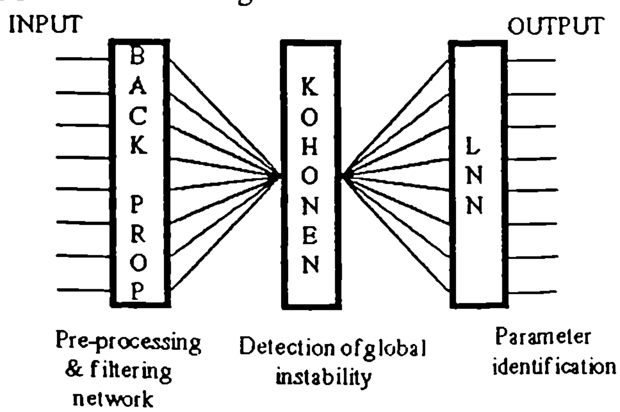


Fig. 5. Hybrid Neural system

4 Conclusion

Successful applications of ANNs to interpret erratic video and ultrasonic data in real time provide the basis for a feasible multi-architectural system to process acoustic data. The solution of complex pattern recognition problems often require the combination of neural network characteristics and expert system techniques.

The speed of parallel processing offered by ANNs provide advancement in the area of automated weld control.

Research and development in the area of weld automation continues with the aim of providing a fully integrated welding system.

5 References

Aleksander I., **Connectionism Or Weightless Neurocomputing?**, ICANN-91, Espoo, Finland, June 1991. Vol 2, p991.

BRITE EuRam project-**BREU 0415 BE-4006-90**

Dayhoff J, **Neural Network Architectures An Introduction**, Van Nostrand Reinhold, 1990.

Harris T.J., Stroud R.R. & Taylor Burge K.L., **Neural Networks in a Weld Control System**, AINN'90, Zurich, June 1990.

Hecht-Nielson R., **Neurocomputing**, Addison-Wesley Publishing Company, 1991.

Mead C., **Analog VLSI And Neural Systems**, Addison-Wesley, Reading MA, 1989.

Nellis J., Stonham T.J, **A Fully Integrated Hand-Printed Characture Recognition System Using Artificial Neural Networks**, IEE Second International Conference On Artificial Neural Networks, Conference Publication No. 349, Bournemouth, UK, November 1991. p219.

Stroud R.R., Harris T.J.& Taylor Burge K.L., **Applications of Neural Networks in Control Technology**, Proc 1st ICANN, Helsinki, Finland, June 1991. Vol 2, p1703.

Tanaka T. & Endo H. *et al* **Trouble forecasting by multi-neural network on continuous casting process of steel production**, Proc 1st ICANN, Espoo, Finland, June 1991. Vol 1 p835.

Torkkola K., *et al*, **Status Report Of The Finnish Phonetic Typewriter Project**, ICANN-91, Espoo, Finland, June 1991.Vol 1, P771.

Fogelman Soulie, F., **Neural Network Architectures and Algorithms: A Perspective**, ICANN-91, Espoo, Finland, June 1991. Vol 1, P605.

Vu V.V, *et al*, **Time Encoded Matrices as Input Data to Artificial Neural Networks for Condition Monitoring Applications**, COMADEM '91, Southampton, July 1991. p31.