The International Association of Science and Technology for Development IASTED

" Computer Applications in Industry"

Alexandria, Egypt, May 5 - 7, 1992

pp24 - 27

THE APPLICATION OF NEURAL NETWORKS FOR THE CONTROL OF INDUSTRIAL ARC WELDING.

J.R. McCardle B.Sc., Karen Taylor Burge M.A., B.Sc., Ray R. Stroud M.Tech, Ph.D., Tom Harris B.Sc.

Department of Design, Brunel University, UK.

ABSTRACT

The use of automatic closed loop control is well established in all areas of manufacturing industry. New methods for measuring system variables, data processing and process control are being sought to improve system efficiency.

Skilled welders are able to subconsciously monitor a manual arc welding process by listening to the sound and repositioning the electrode in response to a change in arc noise.

This paper describes the real time monitoring of acoustic emissions from an automated submerged arc welding process and the application of Neural Networks to predict the point of instability of the process variables.

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

INTRODUCTION

The Design Department at Brunel University, UK, has aimed its research at the development of "intelligent" products incorporating Artificial Neural Networks (ANNs). One focus of attention has been the development of a fully integrated and hybrid control system for industrial welding processes.

To date ANNs have been successfully implemented to interpret ultrasonic scans of a submerged arc welding process to achieve real-time monitoring of the weld penetration and positional control of the welding head.[1,2,3].

Observations of skilled manual welders has revealed a subconscious tendency to alter the electrode angle and length of arc in response to a variation in the sound emitted from the process. Attempts have been made to analyse these acoustic emissions using conventional and expert system techniques.

Preliminary work carried out at The Cranfield Institute of Technology, UK, utilised an expert system in an attempt to interpret acoustic signals for the on-line control of automated welding equipment. The inability of expert systems to respond correctly to erroneous or novel data yielded discouraging results when attempting to isolate salient features from the erratic acoustic emissions.[4].

ANNs have been successfully implemented in systems which imitate human attributes including visual and audio recognition [5,6,7,8].

The aim of this research is to propose a feasible ANN oriented system to automatically control an industrial submerged arc welding process by imitating the biological experience of a human operator.

THE WELDING PROCESS

Submerged arc welding is a semi-automatic process which utilises a sacrificial electrode to strike an arc under a cover of granulated flux.(FIG. 1). In an industrial situation the process is used to join steel plates of typical thicknesses between 6mm and 40mm in a "downhand" position. For the purposes of this experimentation, plates will be standardised at 25mm.

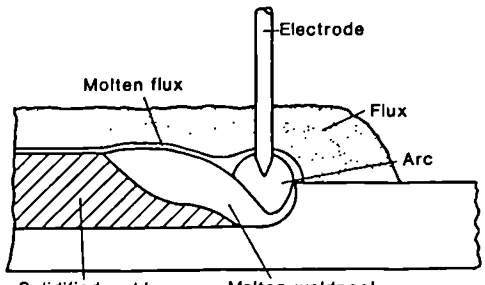


Figure 1. Submerged Arc Welding

There are six major parameters whose optimum settings dictate the overall quality of the the weld :-

i) weld plate preparation (fit up)
ii) welding voltage
iii) welding current (determined by the rate of feed of the sacrificialelectrode)
iv) position of the electrode (seam tracking)
v) rate of welding head travel along the seam
vi) continuity in feed of the granular flux.

A deviation from the optimum setting of any of the parameters can result in such welding faults as porosity, lack of fusion, insufficient root penetrations and undercuts resulting in stress raisers.

Although the nature of raw acoustic emissions is such that data acquired could contain usable information concerning parameters ii) to vi) it is considered that the prime directive of this research is the control of the welding voltage. This is to complement the existing ultrasonic weld penetration system which controls the welding current. The result will be a combined system that maintains an optimum balance of these parameters to obtain weld stability.

Secondary attention will, however, be given to the remaining parameters to serve a diagnostic function.

PROPOSED EXPERIMENTATION

Audible acoustic information has been successfully employed in diagnostic systems for pulsed laser welders [9] and internal combustion engines [10]. Acquisition of raw acoustic data will be achieved by use of an omni-directional electret condenser microphone (ECM). Such transducers exhibit a large bandwidth over the audible frequency range as well as being uninfluenced by induced noise caused by the magnetic flux emitted from the area of the arc.

The microphone and pre-amplifier will be appropriately noise shielded and mounted in the vicinity of the welding head and connected remotely to a series of bandpass filters. The filter set will be constructed to isolate the three main spectra of infra, audible and ultra sound (FIG.2). Although priority is given to the audible range consideration will be given to the possible influences of frequencies present in the infra and ultra sound ranges. The analysis of the ultra sound will be limited by the ADC sampling rate which for this case will be 1MHz providing a practical frequency limitation of circa 200kHz.

As human hearing deteriorates towards the extremes of the audible range this spectrum if further filtered by eight passbands in a Normal Distribution.

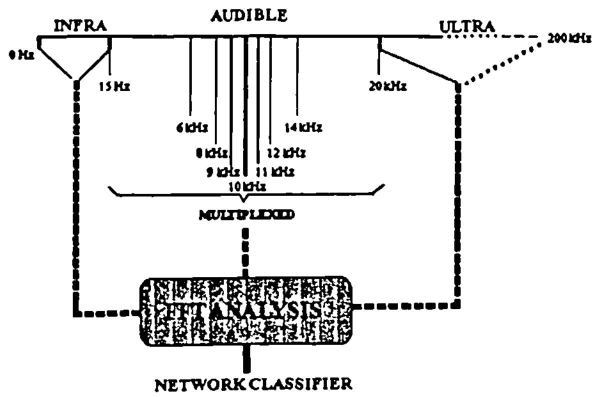


Figure.2 Audio Frequency Spectrum

The final array of passbands are multiplexed for optimum flexibility, to enable each bandpass to be isolated or used as stopbands.

Each bandpass is then subjected to an FFT analysis to isolate salient features within the frequency domain, when subjected to intentionally unstable inputs. Future developments will involve the filtration and isolation of such usable frequencies by hardware.

Isolated signals will then be digitised at a frequency of 1MHz and a resolution of 8 bits and downloaded to a PC for analysis by the software simulated ANN. The output of the analysis will interface with the controlling software of the welding parameters

The proposed experimental set up is shown in Figure 3.

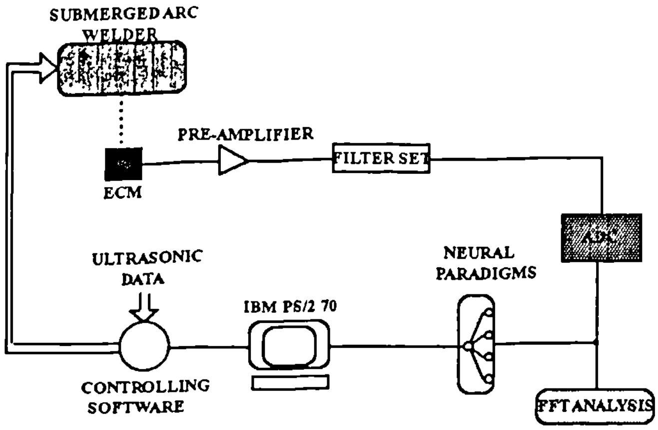
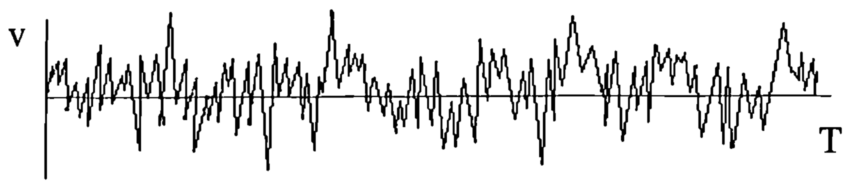


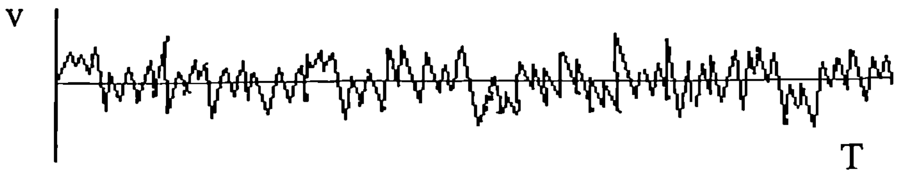
Figure 3. Experimental Set-up

APPLICATION OF NEURAL NETWORK PARADIGMS

Preliminary analysis of raw acoustic emissions yield signals typical of Figure 4. An amplitude degradation is evident, however, for use in real time control a signal processing system is required to isolate the transition band, detect its onset and consequently determine the point of instability of the weld parameter. This would involve the fast processing of noise affected data as well as the recognition of transition band characteristics associated with each weld parameter.



a) Optimum weld emission



b) Flux blockage signal

Figure 4. Acoustic Emissions

ANNs have been successfully utilised in the high speed signal processing of noisy or erratic data where conventional signal processing has failed [1,2,3,10]. Advantages of networks are enhanced by their ability to generalise and have been used in systems requiring predictive assessment of data. [11]

The general trend in ANN application has been towards the development of hybrid and multi-architectural systems[12,13]. In this way characteristics of certain network topologies are used in parallel or series with each other and/or expert systems.

It has been envisaged that for the application to this research three neural networks could be employed

i) Back PropagationNetworks[14,15]
ii) Kohonen self organising feature maps [14]
iii) Weightless or Logical Neural networks [16]

Back error propagation has been successful in bandpass functions and the filtering of noisy data especially where ambient noise creates a problem [5,15].

Pattern recognition problems are relieved by the extraction of salient features on which a pattern classifying network can base its considerations. Back error propagation can identify usable features automatically. This, therefore, can be considered the pre-processing network and when optimally trained could remove the necessity of the more time consuming FFT analysis.

The Kohonen paradigm, when primed with a set of prominent features, can identify the organisational relationships and map the similarities of the input patterns. It is anticipated that this network can provide a complex pattern recognition system for the identification of features associated with signal transition bands. The signal transition is indicative of single or multiple weld parameter fluctuation and consequently of weld instability.

The Logical Neural Network (LNN) was a system jointly devised by Brunel University and Imperial College, London. It utilises conventional RAM technology to store responses to "learned" patterns. If a summing device is used to process the output responses of a number of RAMs it is possible to discriminate between novel and learned patterns. Manipulation of the neural threshold functions will ensure that similar input patterns provide similar responses and hence exhibit properties of generalisation. This technique is used in a system known as WISARD which operates on real time video data to distinguish between facial images [8].

It is envisaged that the LNN could discriminate between successive input patterns from the Kohonen network and finally identify which weld parameter is potentially unstable.

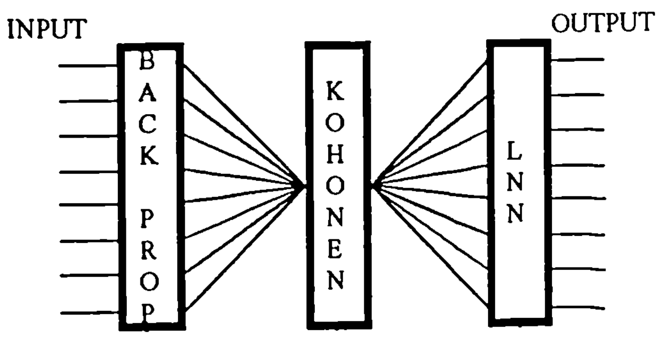


Figure 5. Neural System

The proposed neural system is summarised in Figure 5.

The ANNs are to be developed using either commercial software tools or custom compiled programs in 'C' and Prospero Pascal. The conventional RAM techniques utilised by LNNs provide ready adaptation to hardware.

CONCLUSIONS

ANNs have been successfully employed to interpret chaotic ultrasonic signals in real time and provide on line weld control [1,2,3].

Complex problems require the combination of knowledge based and neural computing techniques to reach an optimum solution.

It is feasible that a hybrid, multi-architectural system can interpret acoustic data in real time to predict the onset of weld parameter instability.

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

REFERENCES

[1] Stroud R.R., Harris T.J., Taylor Burge K.L., 'Neural Networks in Automated Weld Control', TWI, Gateshead, UK, 1991. Paper 22.

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

[3] 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.

[4] BRITE EuRam project-BREU 0415 BE-4006-90

[5] Mead C., 'Analog VLSI And Neural Systems', Addison-Wesley, Reading MA, 1989

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

[7] Nellis J., Stonham T.J, 'A Fully Integrated Hand-Printed Character Recognition System Using Artificial Neural Networks', IEE Second International Conference On Artificial Neural Networks, Conference Publication No. 349, Bournemouth, UK, November 1991. p219.

[8] Fukushima K., Imagawa T., 'Recognition And Segmentation Of Connected Characters In Cursive Handwriting With Selective Attention', ICANN-91, Espoo, Finland, June1991. Vol 1, p 105.

[9] Meyendorf N. *et al*, 'Monitoring of Pulsed Laser Welding by Acoustic Emissions', COMADEM '91, Southampton, July 1991. p515.

[10] 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.

[11] 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.

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

[13] Picton P.D., Johnson J.H., Hallam N.J. 'Neural Networks in Safety-Critical Systems', COMADEM '91, Southampton, July 1991. p17.

[14] Dayhoff J, 'Neural Network Architectures An Introduction', Van Nostrand Reinhold, 1990.

[15] Hecht-Nielson R., ' Neurocomputing', Addison-Wesley Publishing Company, 1991.

[16] Aleksander I., 'Connectionism Or Weightless Neurocomputing?', ICANN-91, Espoo, Finland, June 1991. Vol 2, p991.