신경회로망을 이용한 용접 Root Gap 검출과 모니터링에 관한 연구

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A Study on Detecting and Monitoring of Weld Root Gap using Neural Networks

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요 약

일반적으로 용접 Root 갭은 여러 가지 용접 결함들 중에 용접 품질을 저하시키는 중요한 요인 중의 하나이다. Gas metal arc welding (GMAW)에서 root 갭은 용접 전류, 아크 전압, 용적률 등과 같은 여러 가지 용접 파라미터들에 영향을 미친다. 그러나 용접 공정의 비선형성 때문에 root 갭과 많은 용접 파라미터들 사이의 관계를 분석하기가 힘들다. 그리고 아크센서를 사용하였을 경우, 감지된 신호에 대한 신호처리가 어렵지만 가격이 저렴하고 자동화하기가 쉬우므로 현재의 산업공정에서 대부분 아크센서가 사용되고 있다.

지금까지 언급된 여러 가지 어려운 문제점과 아크센서의 특징 때문에 본 논문에서는 GMAW에서 root 갭을 검출할 수 있는 적당한 용접 파라미터들을 선정하고, root 갭과 선정된 파라미터들의 관계를 인식할 수 있는 신경회로망을 이용하여 root 갭 검출 시스템을 설계하였다.

또한, 용접 품질의 검사에 용접 비드형상이 중요한 요인이다. 따라서 본 논문에서는 신경회로망으로 용접 파라미터와 용접 비드형상과의 관계를 인식하여, 용접 품질을 추정하고 용접 파라미터들의 효과를 분석할 수 있는 용접 비드 형상의 실시간 모니터링 시스템을 제안하여 여러 실험 데이터들을 기반으로 한 시뮬레이션을 통해 제안된 시스템이 root갭을 검출하고 또한 용접 비드 형상을 실시간으로 모니터링이 가능함 보여준다.

ABSTRACT

Weld root gap is a important fact of a falling-off weld quality in various kind of weld defect. The welding quality can be controlled by monitoring important parameters, such as, the Arc voltage, welding current and welding speed during the welding process. Welding systems use either a vision sensor or an Arc sensor, both of which are unable to control these parameters directly. Therefore, it is difficult to obtain necessary bead geometry without automatically controlling the welding parameters through the sensors. In this paper we propose a novel approach using neural networks for detecting and monitoring of weld root gap and bead shape. Through experiments we demonstrate that the proposed system can be used for real welding processes. The results demonstrate that the system can efficiently estimate the weld bead shape and detect the welding defects.

키워드

Neural network, Functional link network, Weld root gap, Weld bead shape

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Ⅰ. Introduction

Welding is a process in manufacturing for a range of industrial components from large-scale structures such as ships, bridges or heavy construction machinery to complex structures, such as aircraft engines, cars or miniature components for microelectronic applications. Phenomena occurring in the Gas metal arc welding(GMAW) process are very complex and highly non-linear. Thus, the analyses of physical phenomena in horizontal fillet welding are helpful in predicting weld quality according to specific welding conditions such as welding current, arc voltage and welding speed[1]. Therefore, it is important to know how the formation of weld defects result from welding conditions. Among the various welding conditions, root gaps can be induced through the cutting process which makes the workpiece unstable. And root gap instability during this process can lead to poor bead shape, causing lower weld quality[2]. In spite of its importance, it is difficult to detect root gaps using sensors in the weld process unlikely other defect factors. To achieve a satisfactory weld bead shape with no weld defects, it is necessary to study the effects of welding conditions on the weld bead shape. Furthermore, we implemented neural networks based on a back-propagation algorithm as well as an optimum design based on feasible direction in order to accurately estimate root gaps. We further suggest that the weld bead shape be estimated in real-time using a neural network.

Ⅱ. Neural Networks

Artificial neural networks(ANN) have gained prominence recently among researchers of non linear systems. As the name implies, these networks are computer models of the process and mechanisms that constitute biological nerve systems, to the extent that they are understood by researchers.

2.1 Multilayer Neural Networks

Multilayer neural networks was used as basic structure for the applications discussed here. Fig.1 shows multilayer neural networks.

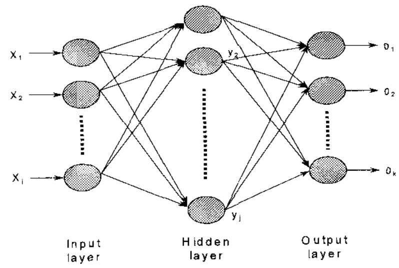


그림 1. 다층 신경회로망
Fig. 1. Multilayer neural networks

The backpropagation training algorithm allows experiential acquisition of input/output mapping knowledge within multilayer neural networks.

2.2 Functional Link Networks

Functional link networks are single-layer network. Generally, the hidden layer of neurons provides an appropriate pattern to image transformation, and the output layer yields the final mapping in multilayer networks. Instead of carrying out a two-stage transformation, input/output mapping can also be achieved through an artificially augmented single-layer network. The separating hyperplanes generated by such a network are defined in the extended input space.

The key idea of the method is to find a suitably enhanced representation of the input data. Additional input data that are used in the scheme incorporate higher order effects and artificially increase the dimension of the input space[3][4]. Fig. 2 shows the structure of functional link networks.

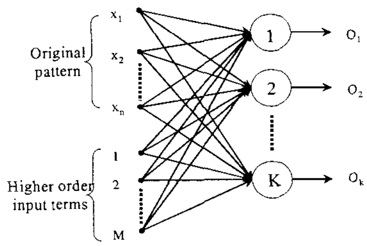


그림 2. 기능적 링크 네트워크
Fig. 2. Functional link network

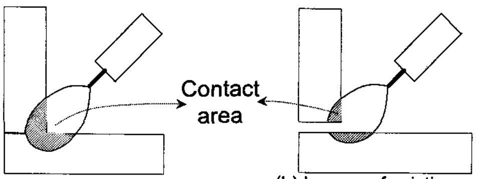
Ⅲ. GMAW Process

Gas Metal Arc Welding(GMAW) process are non-linear and very complex to analyze because of physical phenomena. Physical phenomena of welding process is described by various welding parameters such as welding current, arc voltage, welding speed and so on. Among the various welding parameters, root gap is a important fact of a falling-off weld quality in various kind of weld defect.

But it is difficult to detect root gap by arc sensor in welding process. Droplet-rate is related to root gap other than various welding parameters measured by arc sensor.

When filler metal is deposited from the electrode to the workpiece, generally droplet rate is the number of the transferred droplet per second.

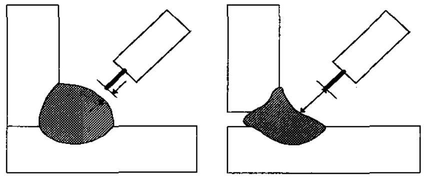
As mentioned, droplet rate is a important fact in various welding parameters that estimate root gap. The more expanded root gap is, the more decreased average of droplet rate is. The reason by which phenomena between root gap and droplet rate are occurred is as follows; In case that root gap exist on workpiece such as Fig. 3, the contact area between arc and workpiece is decreased by root gap, and then droplet rate is decreased by increased resistance[5].



(a) In case of no gap (b) In case of existing gap

그림 3. 아크와 workpiece 사이의 접촉영역
Fig. 3. The contact area between arc and workpiece

Also, Fig. 4 shows the other reason that droplet rate is decreased as root gap exist. In contrast to no gap workpiece, the height of bead in Fig.4-(b) becomes lower, because of root gap.



(a) In case of no gap (b) In case of existing gap

그림 4 비드 높이
Fig. 4. Bead height

Ⅳ. Simulation results and discussion

In automation of welding processes, many attempts were implemented to improve weld quality: weld joint test, estimate of optimal welding condition, proper welding process, selection of welding materials, examination of welding defect and trouble and so on. Among these many attempts, root gap is a important factor of a falling-off weld quality. Also we can appreciate weld quality by means of analyzing weld bead shape.

However, it is difficult to detect root gap, to estimate weld bead shape in real-time using current welding processes equipment. Therefore, in this chapter, it is suggested that root gap detecting system and monitoring system using neural networks. Fig. 5 shows the structure of the total system when the proposed systems apply to real processing

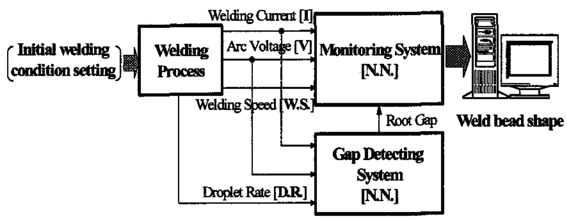


그림 5 전체 시스템 구성도
Fig. 5. the structure of the total system

4.1 Modeling of root gap detecting system

There are many welding parameters which influence root gap such as the welding current, arc voltage, droplet-rate and so on. Generally, many welding parameters are coupled with each other but not directly connected with root gap individually.

Neural networks are used in root gap detecting to overcome non-linearity of welding process. root gap detecting system using neural networks is shown Fig. 6.

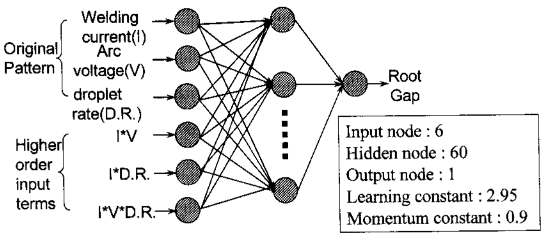


그림 6. root gap 검출 시스템에서 사용된 다층 신경회로망

Fig. 6. Multilayer neural networks used for root gap detecting system

Welding parameters such as welding current, arc current, droplet-rate is used in input parameters of neural networks and output parameters is root gap.

A good performance could not be obtained using general multilayer neural networks due to highly non-linear characteristic in welding process. Therefore, to solve these problems, the proposed neural networks as shown Fig. 6 has higher order input terms that used functional link networks. Although no new information is explicitly inserted into the process, additional input data that are used in higher order input terms artificially increase the dimension of the input space. Thus the proposed neural networks can represent the non-linear relationship between the input and output parameters by means of the extended input space.

The training data used learning was selected 174 patterns, and the test data was used in 145 patterns. The train and test data was derived by experiment which get droplet rate, when root gap was artificially created in workpiece. The test results from this algorithm are shown Fig. 7, Fig. 8. Each of artificially created gap was estimated by the proposed root gap detecting system.

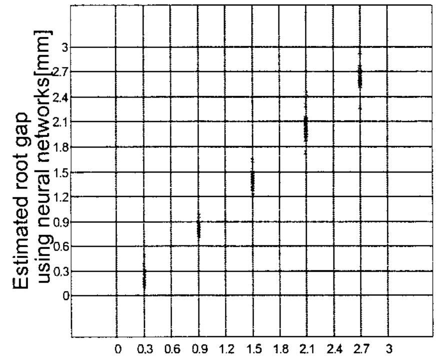


그림 7 학습에 사용된 데이터의 root gap 측정값과 추정값의 비교

Fig. 7. Comparison between measured and estimated root gap for training data

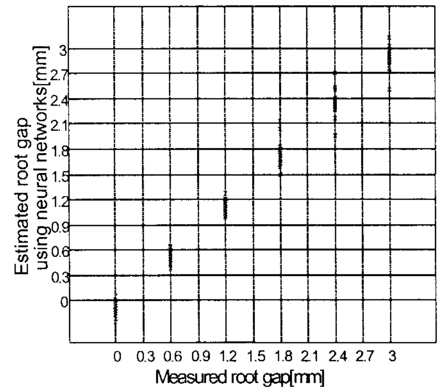


그림 8. 테스트용 데이터의 root gap 측정값과 추정값의 비교

Fig. 8. Comparison between measured and estimated root gap for test data

4.2 Modeling of Monitoring System

Weld bead shape is helpful to predict the weld quality according to certain welding parameters such as welding current, arc voltage, welding speed, root gap and so on. In order to estimate weld bead shape, it is necessary to derive a mathematical relationship between weld bead shape and welding parameters. but the approach to the mathematical modeling is to deepen the understanding of the basic phenomena involved in the process. Therefore, weld bead shape be monitored using neural networks which can learn a mathematical relationship between weld bead shape and welding parameters[6][7][8]. Parameters that represent bead shape is shown Fig. 9.

Training input parameters used learning of neural networks are welding current, arc voltage, welding speed, root gap. Output parameters is selected by fifteen points that represent geometry of weld bead shape, including vertical and horizontal leg lengths, penetration, throat thickness, reinforcement height.

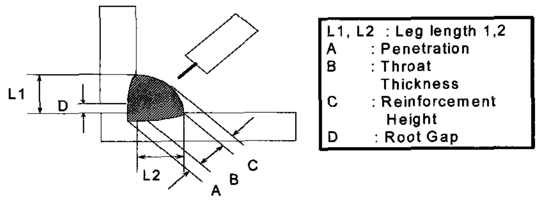


그림 9. 수평 필릿 용접의 용접 비드 형상의 단면
Fig. 9. Profile of weld bead shape in Horizontal Fillet Welding

Structure of neural networks used the proposed monitoring system is shown Fig. 10.

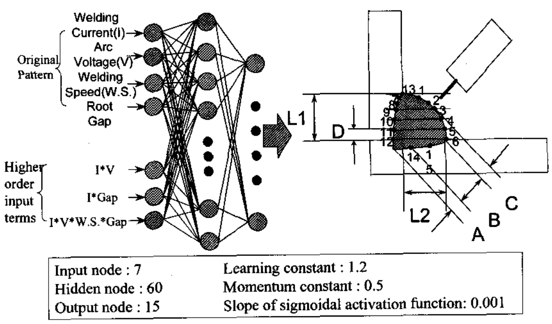


그림 10. 모니터링 시스템에 사용된 신경회로망
Fig. 10. Neural networks used for monitoring system

The proposed neural networks have higher order input terms like root gap detecting system and fifteen points that represent geometry selected output parameters. In welding parameters, welding current is the most interacting factor with other input parameters, Therefore, three higher order input terms interacted with each other, were selected among possible combinations, The number of the training data used neural networks is 198.

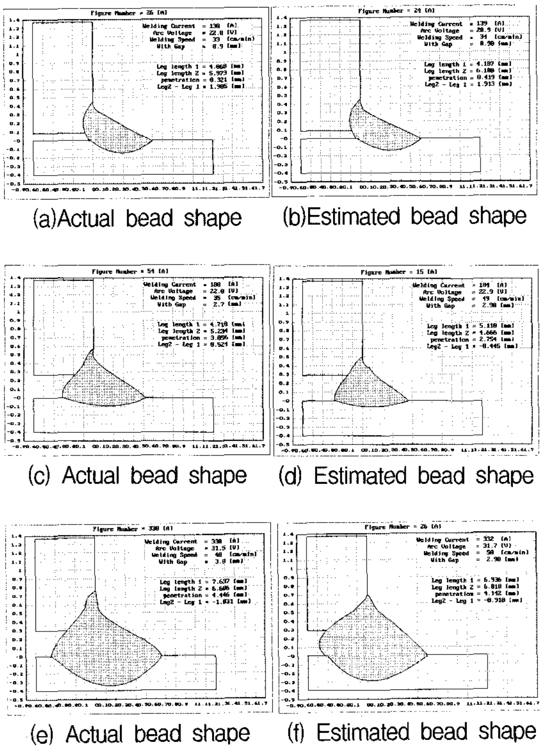


그림 11. 모니터링 시스템을 사용한 용접 비드 형상의 측정값과 추정값의 비교
Fig. 11. Comparison between the measured and estimated weld bead shape using monitoring system

The simulation result was shown Fig. 11. The actual surveyed weld bead shape was monitored as shown Fig. 11-(a),(c),(e) and the estimated weld bead shape was monitored as shown Fig. 11-(b)(d)(f). As compared with measured weld bead shape, the test results using the test input parameters could be acquired the satisfied and adaptive output due to generalization capability of neural networks.

V. Conclusion

The root gap detecting system and the weld bead shape monitoring system were introduced to estimate weld defects in real time using neural networks. Poor weld bead shape is excessively caused by root gaps among other various factors.

The above results show that the proposed root gap detecting system demonstrated adaptability in the test welding parameters except for the training data, which used learning. Accordingly, root gaps were satisfactorily estimated by the proposed system, and overcame the non-linear characteristics and complexities of the GMAW process. Also, the proposed monitoring system precisely predicted weld quality, and the cause of various defects could be induced in the GMAW process. If for example a vision sensor is used to measure weld bead shape, we might face a number of problems, i.e., complexity of image processing by the camera, considerable time and cost, improper environment and so on. With the proposed monitoring system using neural networks, we can easily overcome these problems, and weld bead shape can be precisely monitored in all welding conditions. We expect that the above proposed system can effectively improve welding quality, and reduce time-consuming work in the GMAW process due to decreased weld defects.

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