

B. Electrode Degradation Identification In Resistance Spot Welding By Intelligent Machine Learning

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Introduction

Resistance spot welding (RSW) is widely used in the automobile industry for its low cost, high speed, simple mechanism and applicability of automation. Welding quality of RSW is tightly related to the electrode conditions. Identification and classification of electrode degradation conditions is the key task for the successful control of this industrial process. Successful identification of the electrode conditions can help control algorithms to make necessary alterations to the welding schedules such as increasing welding current, redressing or replacing the electrodes to ensure the welding quality. This paper proposes an online electrode degradation-monitoring scheme that identifies electrode degradation conditions from the observed process variable in the perspective of intelligent machine learning. Touchdown force as non-intrusive pre-weld signal that is free from induced voltage during welding is selected as the process variable to monitor electrode degradation conditions.

Technical approach/procedure

Touch down force signals were acquired by a data acquisition system that conducts signal conditioning and data storage. Machine learning scheme consisting of feature extraction, feature selection and pattern recognition algorithms is implemented to identify the electrode degradation conditions. Wavelet transform and statistical analysis are performed to extract feature set from the acquired raw signal. An information theoretic approach of dimension reduction techniques, called MIFS (Mutual Information Feature Selection) that uses a mutual-information based heuristic to evaluate the worth of features in terms of classification discriminant ability, is used to select appropriate inputs to the pattern recognition algorithms. Pattern recognition algorithms of neural networks and statistical classifiers are applied to the features selected.

Results/Discussion

Five electrode life tests were conducted with variations of system conditions (cold and warm); time spans of day; types of electrodes; sheet material (steel and aluminum); welders (AC and DC pedestal welders); touchdown force presets and welding schedules. The datasets from the life tests are used to train and verify the machine learning algorithms. Data samples from electrode life tests were sectioned correlating electrode failure to electrode degradation in terms of the change in the electrode contact area and shear force strength. Three designated life stages belonging to new, halfway worn and completely worn electrodes are applied in this study indicating as classification labels. For the life tests conducted on AC and DC welder, one life test dataset is used to select the feature inputs to classifiers and establish classification models, the other life test datasets conducted with identical welder and welding material are used to examine the generality of the models. The key to make machine-learning algorithms work in practice is to choose right inputs to the classification models. Various feature extraction, dimension reduction and pattern recognition techniques are explored to find out the most efficient ones for this application. From the classification results of the features from different dimension reduction approaches, it is observed that the features selected by MIFS are the most efficient one to represent the electrode

degradation conditions. The joint probability density function and class specific feature distribution of the features selected by MIFS shows little overlap of the feature distribution which indicates that the features selected provide maximum separation likelihood for the pattern recognition algorithms. By validating from the data belonging to different life tests other than the training data, conclusion can be drawn that the MIFS based feature selection algorithm followed by Back-Propagation neural network is demonstrated to be an efficient machine learning scheme to monitor the electrode degradation with classification rates up to 90% for identical type electrodes and 82 % for different type electrodes.

Table 1. Results

Life Test Dataset No ^a .	ITL ^b	HMM ^b	Combined ^b (Max)	BP ^b	PARZEN ^b	KNN ^b
1 (Training)	98 %	96 %	98 %	97 %	97 %	94 %
2 (Validation)	93 %	94 %	91 %	92 %	87 %	84 %
3 (Validation)	88 %	90 %	87 %	83 %	77 %	80 %
4 (Training)	97 %	93 %	97 %	96 %	100 %	96 %
5 (Validation)	93 %	91 %	93 %	94 %	88 %	91 %

- a. Life Tests 1&2 were conducted with FB-25 Cu-Cr-Zr Domed coated electrodes and 0.7 mm thick Hot Dip Galvanized Steel on 250KVA single phase AC welder. Life Test 3 was conducted under similar situation except with uncoated electrodes. Life tests 4&5 were conducted with Class I (Cu-0.15% Zr) electrodes and 1.5 mm thick AA5182-H111 aluminum alloy on 170 KVA Medium Frequency Direct Current welder. Tests were conducted in different time spans of day and start from system warm or cold conditions.
- b. Pattern recognition results on features selected by MIFS, ITL: Information Theoretical Learning, HMM: Hidden Markov Model, BP: Backpropagation Network, Parzen: Parzen Window Classifier, KNN: K Nearest Neighborhood Classifier

Conclusions

Touchdown force has been found to be useful pre-weld information to identify electrode degradation. Wavelet coefficients reflecting time-frequency information and local ad hoc statistics are considered to be informative to detect the touchdown force variations along the electrode life. Mutual information based feature selection scheme is proved to be efficient to select the most informative features that are relevant to the electrode degradation and as irrelevant to other system variations as possible. Electrode life datasets from different operating conditions of the resistance spot welding process are used to validate the feasibility of the proposed approach. Successful identification rates verify that the machine-learning algorithm is practicable to properly identify the life stages of the electrodes and to predict the failure of electrodes due to degradation. Note that with electro-servo actuated welders, the motor voltage and current provide easily available substitutes for the force sensor.