Metal Identification Based on Laser-induced Breakdown Spectroscopy and BP Neural Network

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Keywords: LIBS, Scrap metal sorting, The BP neural network.

Abstract. For sorting scrap metal materials, the ultimate goal is to separate some scrap metal from other scrap metal materials completely. In this paper, Laser-Induced Breakdown Spectroscopy (LIBS) is used to take sample data from cooked aluminum, aluminum, magnesium, stainless steel, iron, copper, and zinc 7 metal samples seven scrap metal samplings with principal component analysis methods of data reduction. And BP neural network is used to the classification of aluminum and non-aluminum metals, Experiment results show that the classification accuracy up to 93.40% . These results provide a method for sorting scrap metal and reference data with BP neural network and LIBS technique, which make online scrap metal sorting get better result.

Introduction

With the gradual increase in the consumption of metal products, scrap metal is also growing increasingly. If the growing scrap metal is not classified to be reused, it must bound to cause great waste of resources. Thus the recycling markets created, but from a domestic perspective sorting scrap metal industry is still need to improve. There are many sorting methods, mainly including scrap metal sorting methods, the physical characteristics of the sorting method, eddy current separation technology, support vector machine method, etc. Among them, the manual sorting method has a large cost, and is easily prone to error with identify characteristics slowly. The physical characteristics of the sorting method is a new method based on the physical characteristics of the material differences in reflective, conductive, magnetic sorting and other characteristics, in order to achieve metal sorting. However, when sorting the materials, they must be arranged in rows on the conveyor belt sequentially to be test, and to implement sorting. Eddy current separation technology is based on the principle that when a metal material is in an alternating magnetic field which will produce eddy currents, and magnetic field metal band would generate eddy current magnetic Loren, depending on the density and conductivity of the metal, the metal material is subjected to a total force is different, which can be sorted. Comparing to the above sorting method, the LIBS technique can deal with the materials presented in the soil, air, seawater and many other substances and elements in real-time, on-line non-destructive testing and analysis with highly detection efficiency [1, 3]. Therefore, using the LIBS technology for sorting scrap metal material is a good choice.

At present, however due to the stability of laser induced breakdown spectroscopy is not too high and gradually applied to various fields, which makes the auxiliary method for laser induced breakdown spectroscopy fully applied in the actual industrial research become a hot spot. Guo Lianbo[4],etc., for example, the support vector machine algorithm assisted laser induced breakdown spectroscopy research of qualitative identification technology for a variety of plastic. Although he has performed well in such studies, but did not involve the classification of scrap metal in. And BP neural network can be used as classification, clustering, prediction, etc., the process is more simple, more than all the sorting method did not involve the use of BP neural network[5] in combined with sorting of LIBS technique. It is applied to a variety of scrap metal, so it is necessary to further study the sorting method. This paper is about the BP neural network combined with LIBS technology of
Al and non-Al online sorting in the samples. Study the BP algorithm of artificial neural analysis performance under different input parameters, discussed the experimental results, and verified the only reasonable design of experimental parameters, BP algorithm is to get a more ideal in metal sorting experimental results.

**Based on LIBS and BP Sample Data Extraction and Processing**

**LIBS Technology Introduction**

In this paper, the LIBS technique is a method with use of laser induced plasma as evaporation, atomization and excitation source atomic emission spectroscopy method. In the LIBS test sample, the high-power laser pulses are converged. The power density is usually the focal point reaches GW/cm² or more, and some part of the sample material at such a high power density, can be instantly excited by high temperature, high electron density plasma. In plasma, as the molecules accept outside energy consisting of matter, atoms or ions transition from a low energy state to a higher energy state, and then by the high-energy state transition back to a lower energy state, this process will also emit radiation at different wavelengths, and finally through the spectrometer collect different wavelength information.

**Data Processing Based on BP**

The BP neural network imitate the human brain’s working and the reaction of external input data, the algorithm study is spread by positive and error back propagation of two process. As can be seen from the process BP neural network development, having a generalization capability, fault tolerance, non-linear mapping ability, self-learning and adaptive ability, etc., because of these advantages BP neural network, many research scholars at home and abroad have studied it, and using the network to solve many application problems.

Taking into account the efficiency of the experiment, if the data entered is too large BP is bound to make the training time is very long and after using the identification guide to sort sample inefficiently, the principal component analysis is adopted. Principal component analysis of the data obtained subtracting the mean, covariance matrix, a characteristic feature vectors and covariance matrices, vectors and mode selection component composition data obtained six new process, ignoring the redundant main element and suppressed some measurement noise, to the data reduction process so that the data processing speed faster.

**Experimental Study**

**Experiment Device and Data Extraction**

In this experiment the LIBS system structure of experiment device was shown in figure 1. With Beamtech China Nimma - 400 series laser single pulse energy about 200mJ, wavelength of 1064 nm, pulse width (FWHM) 9.5 ns, pulse repetition frequency of 1 – 10 Hz. Laser that through a flat convex lens 1 (plano convex lens 1) for the first time is 75 mm, the focal length is 500 mm, collection of light path in front of the fiber optic flat convex mirror 2 (plano convex lens 2) focal length is 70 mm, a diameter of 40mm.Probe detection delay 5 μs, due to the laser from the micro focusing on the effects of laser, and the laser converge in laboratory bench sample surface, and the purpose to prevent laser sample the air near the breakdown, so set the laser via flat on the surface of the convex lens 1 to sample distance 450 mm.
Collected by spectrometer LIBS technology cooked aluminum, aluminum, magnesium, stainless steel, iron, copper, and zinc 7 metal samples of raw data, by 200 points for each metal after averaging of data, get a plasma spectra in Fig 2(a) and Fig 2(b). As can be seen from the diagram data collected varies by the LIBS, detected wavelengths (174.3721-446.1414 nm) range, and has its own characteristic spectral lines.

Sample Recognition Based on Principal Component Analysis and BP

Although LIBS spectrum can find out the characteristic spectrum to distinguish it from other metals, each Spectra due to environmental differences are not the same so that directly using LIBS to the qualitative identification of the sample is very difficult in the metal sorting, so the experiment combined with BP network for the qualitative identification of the sample.

Data acquisition part is an important step in this experiment, due to the use of laser induced breakdown spectroscopy is a relatively large data, and the experimental data directly affects the experimental results. To solve this problem, the experimental data are in the same time, the same experiment set of experimental equipment at ambient temperature and all parameters under the same conditions, with 200mJ mono-pulse laser acquisition data of 7 class samples, each sample is to choose 5 pieces, 50 point collection (both the front and the acquisition of 25 points), and each point is collected by laser bombardment firstly. Experiments using MATLAB based on BP neural network algorithm have to process the data collected.

Due to the laboratory data collected by each point contains 2048 different wavelength information, and needs to quickly tell what belongs to the data collected scrap metal. Considering the real time experiment, experiment for data processing should be done. To achieve this goal, the experiment in the data processing based on the principal component analysis. Finally, the experiment will be collected data from 1400 points for the BP neural network training, training results as shown in table 1. This study collected the rest of the data is used to BP network’s validation, the experimental results show that the BP network can be timely and accurately determine the already collected data belongs to the kind of metal, which is in order to timely in the
course of industrial production will feedback the data to the computer, the control of a conveyor belt separate scrap metal through one of the most important process.

Table 1. Sample data and BP identify output results.

<table>
<thead>
<tr>
<th>Sample data</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrought Al data</td>
<td>1</td>
</tr>
<tr>
<td>Al</td>
<td>1</td>
</tr>
<tr>
<td>Mg</td>
<td>2</td>
</tr>
<tr>
<td>Sus</td>
<td>2</td>
</tr>
<tr>
<td>Fe</td>
<td>2</td>
</tr>
<tr>
<td>Cu</td>
<td>2</td>
</tr>
<tr>
<td>Zn</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>3</td>
</tr>
</tbody>
</table>

(1: On behalf of the aluminum, 2: On behalf of other metals, 3: On behalf of not this experiment metal)

**Experimental Results and Analysis**

In order to separate scrap metal smoothly, the experiment using BP neural network combined with LIBS technology analysis the metal samples’ qualitative, in order to easily distinguish between metal belong to categories, with 1 representing the results of the training and aluminum, with 2 on behalf of the aluminum scrap metal training and validation results. BP neural network have collected 1400 training data, the error threshold is set to 0.2, the training results are shown in figure 3 below, the actual results allowed error range includes 1357 data, there are 25 data that can't classification, 21 data that error classified. The correct classification accuracy of 96.90%, the classification accuracy can satisfy the verification of the experimental data.

![BP Network Model To Predict The Output Curve (Validation Sample)](image)

![BP Network Model To Predict The Output Curve (Verify Sample)](image)

(a) BP data training results  
(b) BP data validation results

Figure 3. Training and validation results.

This experiment is a part of many kinds of scrap metal sorting experiments, so it is very important to the BP neural network to verify and validate the accuracy of the result. It directly affect a variety of scrap metal is separated completely. Figure 3 is the result of this experiment data validation, there are 350 data points involved in the validation, in the range of the threshold error 331 points were classified correctly, 10 data points can't classification, 9 digits are taken by error classification accuracy of 94.60%, from the above data can see the results of the experiments can be used as a sorting experiment all the former part.

Fig.3 (a) and Fig.3 (b) shows the experimental results, this paper analyzes the factors that influence the accuracy of the experimental results is as follows.

A. Using laser induced breakdown spectroscopy to experiment on scrap metal collecting the data, the environment is not stable, such as temperature, scrap metal material surface cleanliness, etc. Especially scrap metal material surface cleanliness has much effected on the experimental results, if the surface cleanliness is different, every time the collected data is not completely the same, even some of the data may not gather the data of the metal.
B. Because of the large experimental data in the experiment using principal component analysis was performed on the data collected, although after dealing with the principal component analysis, the data can replace most of original data information, but after BP training, every time the training set of parameters such as weights and threshold value is different, so the loss of part of principal component analysis information is also the cause of the results accuracy. At the same time, the same experiment samples collected data is not identical. Combined with the experiment to principal component analysis for data processing, it can also lead to the same metal used in the validation and training data can make a big difference, when the training data and test the results compared to verify the accuracy of different.

C. Best LIBS signal acquisition time and laser light source for sorting result has a certain influence. When the time interval of detection time delay is short, plasma radiation has a strong background in a row, interfere with the data. As plasma produced by laser excitation energy, the stability of the laser light source will cause the laser and the coupling effect between metal material is different, so the state of the plasma is not the same, then experiments, collect samples of the same data will not be exactly the same, so the laser light source is also affect the accuracy of experimental results for one reason.

**Conclusion**

This experiment is in the scrap metal sorting quickly identify laser LIBS technology research and application of the test a total of seven different types of samples in data collection, and the data is divided into two parts- aluminum and non-aluminum, and then the data as the input of the BP neural network algorithm, and finally set up the experimental parameters, and maintain the stability of the experiment environment, experimental results show that the aluminum and the non-aluminum sorting recognition results can reach very high accuracy, although the identification precision of BP neural network can meet the requirements of the experiment of metal sorting, but the disadvantage of this experiment is sorting to identify species too little, just to determine the aluminum. The class of scrap metal materials apart from each other more will be the next research direction. To optimize the BP neural network algorithm and other algorithms, the focus of the research will do some experiments. In short, it has good prospects for the BP neural network algorithm combines with the LIBS technique is applied to scrap metal sorting.

**References**


