



Study on the Analysis of Main Components of Aluminum Alloy by XRF (X-Ray Fluorescence Analysis) Method

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Abstract

Aluminum alloy has low density, good plasticity, and high strength. It has a large number of applications in many fields. The performance of aluminum alloy is closely related to its alloy composition. The rapid and accurate determination of the content of various elements in aluminum alloy is important for its production and processing. The experiment is based on the energy dispersive X-ray fluorescence analysis method, and analyzes the main elements in the aluminum alloy samples with different composition. The best working mode and the best measurement time of different elements are determined among the partitions. The data measured in the experiment were compared and analyzed by using one-variable, two-variable, and three-variable fitting methods, and the best multiple fitting method for different elements was determined. After ternary fitting, the average absolute errors for Al, Mg, and Si are 0.040%, 0.027%, and 0.007%, respectively, and the average relative errors are 0.040%, 2.111%, and 0.469%, respectively; after binary fitting, the average absolute errors for Cu and Zn are 0.001% and 0.001%, and the average relative errors are 0.061% and 0.070%. The average absolute errors of Zn are 0.001% and 0.001%, and the average relative errors are 0.061% and 0.070%, respectively. The experimental results prove that the XRF method can be applied to the accurate measurement of the main components of aluminum alloy.

Subject Areas

Nuclear Technology and Application

Keywords

XRF, Aluminum Alloy, Matrix Effect, Multiple Regression Method

1. Introduction

With the rapid development of the global market economy in recent years, aluminum and its polymer alloy materials have been used in aerospace, vehicle manufacturing, mechanical processing, electronic appliances and other fields with their excellent properties such as oxidation resistance, easy repeat processing, and recyclability. It has been widely used in the world and has developed into the world's second-largest metal material in use after steel. The utilization rate is increasing year by year. At present, my country has become the world's largest aluminum alloy producer and consumer.

The physical and chemical properties of aluminum alloys are closely related to the material composition of the alloys. The accurate quantitative analysis of its composition, structure, and properties plays an important role in guiding the production and processing of aluminum alloys. Compared with the classical chemical methods commonly used in alloy composition analysis, the XRF analysis method has the characteristics of fast and accurate, and can realize on-site non-destructive analysis. The experiment uses the XRF method to analyze the main elements in the aluminum alloy and achieves better results. It is expected to provide reference for XRF method in rapid detection of aluminum alloy industrial production.

2. Basic principles

According to Moseley's law, the square of the atomic number is proportional to the energy of the characteristic ray [1] [2]. If the atomic number is different, the characteristic ray generated after being excited will be different. The purpose of the X-ray fluorescence quantitative analysis method is to calculate the content of the element to be measured in the sample through the count rate obtained by the measurement. Therefore, one can first determine the material composition of the sample, calculate the proportional coefficient, and then calculate the content of the element to be measured according to the counting rate:

$$W_k = \frac{\mu_0 + \mu_k}{KI_0} \cdot I_k. \quad (1)$$

3. Apparatus and Sample Preparation

3.1. Abbreviations and Acronyms

The instrument used in this experiment is the desktop integrated XRF energy spectrum analyzer Epsilon 1 produced by Malvern PANalytical, the Netherlands. It adopts X-ray tube with maximum voltage of 50 kV and maximum current of 500 μ A, Ag anode, and SDD (Silicon Drift Semiconductor Detector). The measurement element range is Na-Am, the resolution is 135 eV (Mg-K α), and the detection limit is 1 ppm-100%. Use USB and network connections to use standard computer peripherals for extended use, application development, and fixed operators.

The main analysis elements in this experiment are Al, Si, Mg, Cu, Zn, so it is

established after selecting the elements, so the Na-Si mode (applicable elements range from Na to Si) and Ni-Mo mode are established after selecting the elements on the instrument (The applicable elements range from Ni to Mo), and then the best tube pressure, tube flow and best time are measured for different modes [3].

According to previous experiments, the optimal tube pressure of Na-Si mode is 17 kV, the best tube flow is 75 μ A, the best measurement time is 600 s, the best filter is AL200; the best tube pressure of Ni-Mo mode is 46 kV, The best tube flow is 98 μ A, the best measurement time is 1200 s, and the best filter is AL200 (Built in the instrument).

All relevant parameters of the instrument are obtained from the same series of pre experiments, due to space constraints, only the final results are listed here.

3.2. Sample Preparation

The solid samples are cylindrical and the size is: $\Phi 40$ mm \times 20 mm (height). Since the surface finish of the metal sample directly affects the X-ray fluorescence intensity, this effect is related to the element to be measured, so when measuring, the end of the sample without characters is polished with a lathe and then wiped clean with medical cotton.

4. Experimental Results and Analysis

There are different series of aluminum alloys, and each series of aluminum alloys contains other elements besides aluminum [4] [5]. In addition to the analysis of Al, this experiment mainly analyzes the elements of Si, Mg, Cu, and Zn in the aluminum alloy. The K absorption limit energy and $K\alpha$ characteristic energy of each element are shown in **Table 1**.

In order to weaken the influence of the matrix effect, the five main elements of Al, Si, Mg, Cu, and Zn were fitted with one element, two elements and three elements respectively [6] [7] [8]. Aiming at the characteristics that the characteristic energies of Al, Mg, and Si are close to the absorption limit energy and will affect each other, the Al-Mg-Si ternary fitting calculation results with better correction effects are selected. The results and analysis are shown in **Table 2-4**.

For Cu and Zn, considering the influence of the higher content of Al in the sample, the Al-Cu and Al-Zn binary fitting calculation results with better correction effect are selected. The results and analysis are shown in **Table 5**.

Table 1. Absorption limit energy of each main element in aluminum alloy.

element	K absorption limit energy (E/keV)	$K\alpha$ characteristic energy (E/keV)
Mg	1.303	1.254
Al	1.559	1.487
Si	1.838	1.740
Cu	8.980	8.047
Zn	9.660	8.638

Table 2. Ternary fitting results of Al.

Al				
Serial number	Recommended value	Analysis value	Absolute error	Relative error (%)
A3	90.086	98.062	0.079	0.080
A9	96.060	94.494	-0.016	-0.010
A13	96.275	97.873	0.017	0.010
A17	87.699	82.849	-0.055	-0.060
Ave	95.084	98.840	0.040	0.040

Table 3. Ternary fitting results of Mg.

Mg				
Serial number	Recommended value	Analysis value	Absolute error	Relative error (%)
A3	1.202	1.269	0.056	4.650
A9	2.269	2.246	-0.010	-0.440
A13	1.096	1.110	0.012	1.120
A17	1.571	1.571	-0.038	-2.300
Ave	1.293	1.293	0.027	2.111

Table 4. Ternary fitting results of Si.

Si				
Serial number	Recommended value	Analysis value	Absolute error	Relative error (%)
A1	1.702	1.690	-0.007	-0.410
A4	2.839	2.848	0.003	0.110
A5	1.328	1.328	-0.010	-0.710
A6	1.383	1.395	0.009	0.620
Ave	1.567	1.579	0.007	0.469

Table 5. The binary fitting results of Cu and Zn.

Serial number	Cu				Zn			
	Recommended value	Analysis value	Absolute error	Relative error (%)	Recommended value	Analysis value	Absolute error	Relative error (%)
A1	4.371	4.372	0.000	0.000	0.039	0.039	0.001	1.400
A2	0.081	0.081	0.001	0.980	0.005	0.005	-0.000	-2.680
A3	0.081	0.081	-0.002	-1.790	0.004	0.004	-0.000	-5.570
A5	0.260	0.260	0.001	0.390	0.100	0.010	-0.003	-2.750
A6	1.777	1.776	-0.001	-0.030	5.792	5.792	0.000	0.000
Ave	1.314	1.315	0.001	0.061	0.994	1.000	0.001	0.070

5. Conclusions

The experiment uses an energy dispersive X-ray fluorescence instrument to analyze the five main elements of Al, Si, Mg, Cu, and Zn in aluminum alloys. The experimental measurement is carried out by setting the measurement mode between different regions of the absorption limit energy of different elements, and obtains the following results:

- 1) Considering the peak-to-back ratio, counting rate and measurement time, the relevant parameters of the Na-Si mode and Ni-Mo mode are determined.
- 2) The basic mathematical models of X-ray fluorescence for five elements of Al, Mg, Si, Cu and Zn have been established.
- 3) Using the multiple regression method to establish matrix effect correction formulas for Al and Mg, Si, Cu, and Zn, and compare the calculation results of different parameters, it is concluded that the ternary fitting is used for Al. It is concluded that the correction effect of Mg and Si is better, and the correction effect of the binary fitting is better for Cu and Zn.

Energy dispersive X-ray fluorescence instrument has the advantages of fast, non-destructive, convenient, and high sensitivity, and can be competent for the analysis of aluminum alloy samples.

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Conflicts of Interest

The authors declare no conflicts of interest.

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