

## DESCRIPTION

### TITLE OF THE INVENTION: CONDITION MONITORING SYSTEM FOR METAL RECOVERY DEVICE

#### TECHNICAL FIELD

[0001]

The present invention relates to a system for monitoring the condition of a metal recovery device.

#### BACKGROUND ART

[0002]

Various waste liquids, such as treated liquids discharged from factories, etc., and solutions obtained by dissolving waste, contain valuable metals such as Au, Ag, Pt, Ni, Cu, and Co. The metals to be recovered are recovered, for example, by electrolysis of the waste liquids. For example, various metal recovery devices as shown in Patent Literatures 1 to 4 are conventionally used as a metal recovery device using electrolysis.

[0003]

The metal recovery device requires maintenance since the operating efficiency decreases due to deterioration of electrodes or the like or wiring and a facility deteriorate as the operating time becomes longer. However, the time when maintenance of the metal recovery device becomes required depends on the type of an electrolyte, treatment conditions, etc., so that it is difficult to predict when maintenance of the metal recovery device will be required. Therefore, the condition of the metal recovery device is checked periodically, but this involves stopping the metal recovery device, which reduces the efficiency of metal recovery and causes a large workload.

#### CITATION LIST

##### PATENT LITERATURE

[0004]

- [PTL 1] Japanese Laid-Open Patent Publication No. 2017-155343
- [PTL 2] International Publication No. WO2008/153001
- [PTL 3] Japanese Laid-Open Patent Publication No. 2007-002310
- [PTL 4] Japanese Laid-Open Patent Publication No. S61-104096

#### SUMMARY OF THE INVENTION

## PROBLEMS TO BE SOLVED BY THE INVENTION

[0005]

The present invention has been made in view of the above problem, and is to provide a system for monitoring the condition of a metal recovery device.

## SOLUTION TO THE PROBLEMS

[0006]

A condition monitoring system of the present invention, which can solve the above problem, has the following configuration.

[1] A condition monitoring system for a metal recovery device, wherein the condition monitoring system, comprising:

- a metal recovery device; and
- a control device;

wherein the metal recovery device includes

- a voltage measuring unit measuring a voltage between an anode and a cathode;

wherein the control device includes

- a data calculation unit processing voltage data received from the voltage measuring unit;

wherein the data calculation unit calculates first-order differential value or second-order differential value as a feature amount based on the voltage data, and

diagnoses the metal recovery device as requiring maintenance when the feature amount is equal to or greater than the threshold value by comparing the feature amount with a predetermined threshold value.

[0007]

[2] The condition monitoring system wherein the system notifies a diagnostic result obtained by comparing the featured amount with the predetermined threshold value to a management terminal via a telecommunication line is also a preferable embodiment.

[0008]

[3] The condition monitoring system wherein the anode comprises a target for the requiring maintenance is an anode coated with an electrode catalyst is also a preferable embodiment.

## ADVANTAGEOUS EFFECTS OF THE INVENTION

[0009]

According to the present invention, it is possible to provide a system for monitoring the condition of a metal recovery device. In particular, the system of the present

invention grasps the condition of the metal recovery device by monitoring the voltage of the metal recovery device, thereby making it possible to perform maintenance on the metal recovery device at an appropriate time.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

[FIG. 1] FIG. 1 is a schematic configuration diagram of the entire configuration of a monitoring system for a metal recovery device of the present invention.

[FIG. 2] FIG. 2 is a schematic configuration diagram of a metal recovery device.

[FIG. 3] FIG. 3 is a block diagram showing the configuration of a monitoring system according to an embodiment of the present invention.

[FIG. 4] FIG. 4 illustrates the structure of a database.

[FIG. 5] FIG. 5 is a flowchart showing an example of data processing.

[FIG. 6] FIG. 6 is a graph in which values obtained by first-order differentiation on the basis of voltage data are plotted.

[FIG. 7] FIG. 7 is a graph in which values obtained by second-order differentiation on the basis of voltage data are plotted.

## DESCRIPTION OF EMBODIMENTS

[0011]

[Entire configuration of monitoring system]

FIG. 1 is a schematic configuration diagram showing an example of the entire configuration of a condition monitoring system for a metal recovery device (hereinafter, referred to as condition monitoring system) of the present invention.

The condition monitoring system of the present invention monitors the condition of a voltage used in a metal recovery device 1. The condition monitoring system includes the metal recovery device 1 and a control device 20.

The metal recovery device 1 has an anode and a voltage measuring unit 10 which measures a voltage between the anode and a cathode.

The control device 20 has a data calculation unit which processes voltage data received from the voltage measuring unit 10.

The control device 20 includes a data calculation unit which is a central processing unit represented by a CPU or the like, a storage unit for various data, and a data input/output unit, and is, for example, a computer, such as a general purpose computer, a personal computer, and a server, which includes a processor such as a CPU, a memory such as a

ROM, a storage medium such as an HDD, and a communication function for transmitting and receiving data.

The control device 20 is connected via a wire or wirelessly to an output portion of the voltage measuring unit 10 provided to the metal recovery device 1, and is configured to be able to acquire voltage data during operation of the metal recovery device.

Furthermore, the condition monitoring system may optionally include a management terminal 40. The results obtained by processing the voltage data by the data processing unit of the control device 20 may be notified to the management terminal 40 via a telecommunication line if necessary.

[0012]

[Configuration of metal recovery device]

FIG. 2 is a schematic configuration diagram showing an example of the metal recovery device 1. The outline of the metal recovery device 1 will be described with reference to FIG. 2. However, the present invention is not limited to the illustrated example, and the system of the present invention can be applied to various known metal recovery devices for recovering metals from waste liquids by using electrolysis.

The condition monitoring system of the present invention can be used without changing the configuration of an existing metal recovery device.

The metal recovery device 1 has an electrolytic tank 2 which contains a waste liquid 6 containing metal ions (hereinafter, referred to as metal ion-containing solution), and an anode 3 and a cathode 4 which are required for electrolysis.

The size, shape, and material of the electrolytic tank 2 can be selected as appropriate according to the purpose.

The material of the anode 3 is an insoluble material. Various known electrode substrates can be used for the anode 3, and, for example, metals having corrosion resistance, such as titanium, niobium, zirconium, and various alloys including these metals as base materials, are preferable. An anode having an electrode substrate covered with an electrode catalyst is also preferably used in the metal recovery device that is to be a target of the present invention. Examples of the electrode catalyst for covering the anode substrate include oxides of platinum group metals such as ruthenium, rhodium, palladium, platinum, and iridium.

The present invention can be applied to the anodes of existing metal recovery devices, and thus can be applied thereto without changing the sizes, shapes, number, or materials of the anodes.

[0013]

The material of the cathode 4 can be selected as appropriate according to the type

of the metal ion-containing solution 6 and the metal to be recovered, and examples thereof include iron, nickel, stainless steel, aluminum, titanium, and alloys including these metals as base materials.

In the illustrated example, a tubular cathode 4 is used, but the present invention can be applied to existing metal recovery devices, and thus can be applied thereto without changing the material, size, shape, structure, etc., of the cathode.

A drive unit 5 is provided to the cathode 4, and the cathode 4 is configured to rotate by the drive unit 5. The cathode 4 rotates in a circumferential direction about a shaft 14 by operation of the drive unit 5. Examples of the drive unit 5 include, but are not limited to, power sources such as a motor.

[0014]

The anode 3 and the cathode 4 are connected to a power supply unit 7 having a rectifier and an AC power supply, and are configured to generate an electric potential between the anode 3 and the cathode 4 in the electrolytic tank 2.

The power supply unit 7 rectifies the AC power supply and supplies a predetermined DC current to the electrodes 3 and 4. When the power is supplied, electrolysis of the metal ion-containing solution 6 is performed in the electrolytic tank 2, and valuable metals are deposited on the cathode 4.

In the present invention, the voltage measuring unit 10 is installed on the metal recovery device 1 in order to measure the voltage of the current supplied to the electrodes. The voltage measuring unit 10 has a voltage measuring sensor 8 such as a voltmeter, a voltage measuring terminal 9, and a measured value output portion 11. The voltage measuring terminal 9 is connected at any position between the power supply unit 7 and the anode 3 and between the power supply unit 7 and the cathode 4 such that the voltage of the electrode can be measured.

[0015]

The metal ion-containing solution 6 is not particularly limited as long as the metal ion-containing solution 6 is a solution containing a valuable metal. The metal ion-containing solution 6 is, for example, a plating waste solution such as a plating stripping solution, a plating solution, and a cleaning solution for plated products, a solution obtained by dissolving a material containing a valuable metal, such as a printed circuit board, in an acid solution, or the like.

Examples of the valuable metal include, but are not limited to, gold, silver, copper, nickel, and platinum group elements, and the valuable metal is an arbitrary metal to be recovered.

[0016]

The metal ion-containing solution 6 is supplied, for example, from a discharge

source such as a factory via a supply tank 12 or the like provided as necessary, through a supply port provided in the electrolytic tank 2, to the electrolytic tank 2 in a batch or continuous manner. A liquid feeding means such as a pump 13 may be used as necessary for supplying the metal ion-containing solution 6. The operating conditions of the metal recovery device such as electrolysis conditions are set as appropriate according to the throughput of the metal recovery device 1 or the supply amount of the metal ion-containing solution 6. The present invention can employ the existing operating conditions of the metal recovery device 1.

A treated liquid resulting from treatment in the electrolytic tank 2 is fed to an arbitrary treatment process. In the illustrated example, the treated liquid discharged from the electrolytic tank 2 is returned to the supply tank 12 and supplied to the electrolytic tank 2 again. In the present invention, the process of treating the treated liquid is not particularly limited, and known processes can be employed. For example, the treated liquid may be fed to an arbitrary treatment process other than electrolysis.

[0017]

In the present specification, the case where the voltage varies due to depletion of the electrode catalyst coated on the anode is described as an example, but the condition monitoring system of the present invention is not limited to voltage variation based on the anode. Targets of the condition monitoring system of the present invention can also include accelerated voltage variation occurring on the basis of various failures. For example, when an abnormality occurs in the metal recovery device, such as when a wire connecting each electrode and the power supply unit deteriorates, the voltage may vary in an accelerated manner. In such a case as well, if a feature amount becomes equal to or larger than a threshold value, the management terminal 40 is notified. By this notification, it is recognized that the metal recovery device is in a condition where maintenance is required. If the condition of the anode checked on the basis of this notification is normal, it can be determined that there is a problem in another part such as the wire, for example. Therefore, on the basis of the notification, it is recognized that the metal recovery device is in a condition where maintenance is required.

[0018]

#### [Relationship between voltage change and anode deterioration]

If a metal recovery device uses an anode having an electrode substrate covered with an electrode catalyst such as a precious metal, the performance of the anode deteriorates as an electrolysis treatment period becomes longer. As a results, the electrolysis efficiency decreases, and maintenance of the anode becomes necessary.

As a result of a study by the present inventors, the present inventors have found that by measuring the voltage of the current supplied to the electrodes and comparing a feature

amount calculated from the measured value with a threshold value for determining the deterioration condition of the anode (hereinafter, referred to as threshold value), it is possible to determine an appropriate time for maintenance of the anode.

The present inventors have conducted studies, and as a result, have found that when depletion of the electrode catalyst coated on the anode proceeds due to electrolytic treatment and the area of the coated electrode catalyst decreases, a current is concentrated on the remaining electrode catalyst portion to accelerate the depletion of the electrode catalyst, and the voltage rises rapidly at this time.

When the voltage during electrolytic treatment is measured and the value thereof is plotted on a graph, the voltage rises as the depletion of the electrode catalyst on the anode proceeds and the anode begins to deteriorate, so that an inflection point at which the voltage curve changes appears. However, even if the amount of change in the voltage per unit time is observed, the voltage also changes depending on the treatment conditions such as the type of a solution to be treated and the concentration of metal ions. Therefore, if the change in the voltage is the target of detection, many detection errors occur, and it is impossible to determine whether or not maintenance is required.

[0019]

Therefore, the present inventors have further studied for reduction of detection errors, and as a result, the present inventors have found that when voltage measurement results are subjected to first-order differentiation or second-order differentiation and are plotted, an inflection point at which the voltage curve changes sharply from 0 to positive appears as shown in FIG. 6 or FIG. 7 (a part indicated by an arrow in the drawing), and when this first-order or second-order differential value becomes equal to or larger than a predetermined threshold value, it can be determined that maintenance of the anode is required.

Therefore, in the present invention, measured voltage data (raw data) is not used as it is, but a value obtained by first-order differentiation or second-order differentiation thereof (hereinafter, sometimes referred to collectively as differential value) is used as a feature amount, and whether or not maintenance of the anode is required is determined by comparing the feature amount with the threshold value.

The method of the first-order differentiation is, for example, dividing the amount of change in the voltage by time, but is not limited thereto. Also, the method of the second-order differentiation is, for example, dividing the amount of change in the first-order differential value by time, but is not limited thereto.

[0020]

The threshold value can be determined from the electrolysis conditions such as the

type of liquid to be electrolyzed, voltage, and current, past data, data of similar devices, etc., by referring to values at which maintenance of the anode becomes required.

An arbitrary voltage may be set as a threshold value, and when a feature amount has reached the threshold value, it may be determined that the present condition is a condition where maintenance is required. However, the voltage may significantly vary after the start of operation, which may result in erroneous detection. From the viewpoint of reducing a rate of erroneous detection that occurs in the early stage of operation, for example, (1) the average value of differential values after a predetermined time elapses from the start of electrolysis may be calculated, a value that is twice the average value may be set as a threshold value, a differential value collected at a predetermined interval may be compared with this threshold value, and when the differential value becomes equal to or larger than the threshold value once or successively an arbitrary number of times equal to or larger than 2, it may be determined that the present condition is a condition where maintenance is required.

Alternatively, (2) differential values calculated after a predetermined time elapses from the start of electrolysis and the moving average value of the respective differential values may be compared, and when the moving average value becomes equal to or larger than the threshold value, it may be determined that the present condition is a condition where maintenance is required.

The reason why the differential values are calculated after the predetermined time elapses is that the voltage tends to increase or decrease immediately after the start of electrolysis, and thus it is preferable to collect data after the voltage becomes stabilized, such as after 30 hours elapse from the start of electrolysis, for example.

Moreover, the comparison between the differential value and the threshold value is preferably performed at a fixed interval, and, for example, when an electrolyzer is operated continuously for 24 hours, the comparison may be performed at a fixed interval such as every 12 hours or every 24 hours or at an arbitrary interval (hereinafter, collectively referred to as predetermined interval). Also, when the electrolyzer is operated for shorter than 24 hours, the comparison may be performed at a predetermined interval during the operation.

As for the moving average value as well, an average value may be obtained every arbitrary fixed interval, and, for example, 100 hours may be set as appropriate as the fixed interval.

[0021]

Still alternatively, (3) setting a threshold value as follows is a preferable embodiment.

Feature amounts are calculated from acquired voltage data, the average value and

the standard deviation ( $1\sigma$ ) of the feature amounts are obtained, and the average value +  $n\sigma$  ( $n$  is an arbitrarily set value) is set as a threshold value. The threshold value and the feature amount are compared, and when the feature amount becomes equal to or larger than the threshold value, it is determined that the present condition is a condition where maintenance is required.

For example, in Table 1, a threshold value is set as follows, and the condition of the anode can be monitored. Table 1 is data corresponding to FIG. 7.

[0022]

[Table 1]

|    | Accumulated time<br>(hr) | Current (A/cm <sup>2</sup> ) | Feature amount<br>Voltage (second-order<br>differential value) | Average value | Standard deviation<br>( $1\sigma$ ) | Threshold value<br>Average + $3\sigma$ |
|----|--------------------------|------------------------------|----------------------------------------------------------------|---------------|-------------------------------------|----------------------------------------|
| 1  | 0                        | 1.5                          |                                                                |               |                                     |                                        |
| 2  | 24                       | 1.5                          |                                                                |               |                                     |                                        |
| 3  | 48                       | 1.5                          | 0.00052                                                        |               |                                     |                                        |
| 4  | 72                       | 1.5                          | 0.00122                                                        | 0.00087       | 0.00035                             | 0.00191                                |
| 5  | 96                       | 1.5                          | -0.00139                                                       | 0.00012       | 0.00110                             | 0.00342                                |
| 6  | 105                      | 1.5                          | 0.00401                                                        | 0.00109       | 0.00194                             | 0.00690                                |
| 7  | 113                      | 1.5                          | -0.00399                                                       | 0.00007       | 0.00267                             | 0.00809                                |
| 8  | 129                      | 1.5                          | 0.01641                                                        | 0.00280       | 0.00099                             | 0.00576                                |
| 9  | 131                      | 1.5                          | 0.66250                                                        | 0.09704       | 0.03581                             | 0.20446                                |
| 10 | 133                      | 1.5                          | -0.35000                                                       | 0.04116       | 0.03421                             | 0.14380                                |

[0023]

In Table 1, the average value +  $3\sigma$  is set as a threshold value, and at an accumulated time of 129 hours at which the feature amount exceeds the threshold value, it can be determined that the present condition is a condition where maintenance is required.

[0024]

[Configuration of condition monitoring system]

FIG. 3 is a block diagram showing the configuration of a condition monitoring system according to an embodiment of the present invention.

The control device 20 has a data acquisition unit 22, a storage unit 23, a data calculation unit 24, and an output unit 25. The control device 20 preferably further has an A/D converter 21 which converts voltage data acquired by the voltage measuring unit 10 into digital data.

[0025]

FIG. 5 is a flowchart showing an example of processing of the data calculation unit 24 of the control system 20.

[0026]

The voltage measuring unit 10 measures the voltage of the current supplied to the electrodes, with the voltage measuring sensor 8 during operation of the metal recovery device 1. The interval of measurement with the voltage measuring sensor 8 can be set arbitrarily, and setting may be made, for example, such that the voltage is measured at a fixed interval or continuously. The obtained voltage data (voltage measurement values) is transmitted to the control device 20 via the measured value output portion 11. Preferably, the voltage data is transmitted to the A/D converter 21. The measured value output portion 11 and the control device 20 are connected via a wired LAN, a wireless LAN, WiFi, a telecommunication line such as a telephone communication line, or an arbitrary communication means such as a data transfer cable, and are configured to be able to transmit the voltage data.

[0027]

The A/D converter 21 converts an analog signal received from the voltage measuring unit 10, into a digital signal.

[0028]

The data acquisition unit 22 receives voltage data from the voltage measuring unit 10 or the A/D converter 21. The received voltage data is stored in the storage unit 23 and transmitted to the data calculation unit 24. The received voltage data may be transmitted from the data acquisition unit 22 directly to the data calculation unit 24, or may be stored in the storage unit 23 from the data acquisition unit 22, then read from the storage unit 23, and

transmitted to the data calculation unit 24. Preferably, the voltage data is stored in association with acquisition time information.

[0029]

The data calculation unit 24 calculates a feature amount (a value obtained by first-order differentiation and/or second-order differentiation) from the acquired voltage data. The obtained differential value is stored as a feature amount in the storage unit 23.

[0030]

Moreover, the data calculation unit 24 determines the condition of the anode by comparing the feature amount with a threshold value. The determination result is stored in the storage unit 23. The determination result may be stored in the storage unit 23 with additional information, such as a symbol, a numerical value, and a character, added thereto. Examples of the additional information include information for distinguishing between being equal to or larger than the threshold value and being less than the threshold value, and the difference value between the feature amount and the threshold value.

[0031]

The data calculation unit 24 determines whether or not an event such as notification is required, according to the determination result, and transmits the determination result from the output unit 25 to the management terminal 40 if necessary. For example, when the determination result meets a necessary condition, such as being equal to or larger than the threshold value, execution of the event is triggered, and the determination result is notified from the output unit 25 via a telecommunication line to the management terminal 40. The content of the notification can be information set as appropriate, such as a predetermined determination result, various acquired data, and a fixed sentence. For example, notification information may be generated by adding a fixed sentence prepared in advance in the storage unit 23, the above determination result, the voltage data, etc.

[0032]

The output unit 25 communicates with the management terminal 40 via a communication line. For example, when the output unit 25 receives a determination result from the data calculation unit 24, the output unit 25 transmits this information to the management terminal 40. The information transmitted to the management terminal 40 and the date and time when the information is transmitted may be stored in the storage unit 23.

[0033]

Various types of processing in each processing unit of the control device 20 such as the data acquisition unit 22, the storage unit 23, the data calculation unit 24, and the output unit 25 are realized by a processor such as a CPU executing programs corresponding to the

respective types of processing. In addition, each program is stored in advance in a memory such as a ROM, and the processor executes necessary processing in each processing unit and operates, by reading the program from the memory and executing the program.

A storage medium such as a RAM may be provided to temporarily store data if necessary. By temporarily storing data in the RAM, the time required for the processor to acquire data from a storage medium such as an HDD can be shortened.

[0034]

The storage unit 23 may be a stationary storage medium such as an HDD or an SSD, or a portable storage medium such as an SD card or a USB memory.

In the present invention, preferably, a database (DBMS: database management system) area is provided in the storage unit 23, and each data received by the storage unit 23 is inputted and stored in an appropriate record in the database. For example, preferably, in a database of FIG. 4, records for storing data generated by the above processing, such as a unique primary key determined uniquely, a measurement date record (Day), a measurement time record (Time), an accumulated time record, a current data record, a voltage data record, a second-order differentiation record, an average value record, a standard deviation record, a threshold value record, and a determination result record, are created, and each data derived from the same voltage data is inputted and stored in each record in association with the same primary key. As necessary, the database may be provided with records that hold arbitrary information such as a status indicated by the above data, or an event and an action triggered by the above data.

[0035]

The output unit 25 is a functional unit that communicates with the control device 20 and the external management terminal 40, and is composed of, for example, a communication module that can be connected to a telecommunication line such as an LTE line or the Internet, or a communication module that can be connected to a wired LAN or the like.

[0036]

The number of management terminals 40 to be notified may be one or may be two or more. The management terminal 40 is a terminal capable of communicating with the control device 20, and examples thereof include mobile information terminals such as smartphones, tablets, PDAs, and mobile phones, and terminals including various communication modules such as mobile computers and desktop computers.

[0037]

The notification received by the management terminal 40 allows a manager to grasp the condition of the anode 3 and perform appropriate maintenance and management such as replacing the anode.

Moreover, the manager can check the data stored in the storage unit 23, by accessing the control device 20 through the telecommunication line, or through a terminal such as a personal computer connected optionally to the control device 20. At this time, the manager can easily check the condition of the anode by using a program for extracting and processing any record or data from the database. For example, a graph may be created using voltage information, thereby allowing monitoring of changes in voltage over time.

[0038]

This application claims priority to Japanese Patent Application No. 2020-176849 filed on October 21, 2020, the entire contents of which are incorporated herein by reference.

#### DESCRIPTION OF THE REFERENCE CHARACTERS

[0039]

- 1 metal recovery device
- 2 electrolytic tank
- 3 anode
- 4 cathode
- 5 drive unit
- 6 metal ion-containing solution
- 7 power supply unit
- 8 voltage measuring sensor
- 9 voltage measuring terminal
- 10 voltage measuring unit
- 11 measured value output portion
- 12 supply tank
- 13 pump
- 14 shaft
- 20 control device
- 21 A/D converter
- 22 data acquisition unit
- 23 storage unit
- 24 data calculation unit
- 25 output unit
- 40 management terminal

## CLAIMS

1. A condition monitoring system for a metal recovery device,  
wherein the condition monitoring system, comprising:
  - a metal recovery device; and
  - a control device;wherein the metal recovery device includes
  - a voltage measuring unit measuring a voltage between an anode and a cathode;wherein the control device includes
  - a data calculation unit processing voltage data received from the voltage measuring unit;wherein the data calculation unit calculates first-order differential value or second-order differential value as a feature amount based on the voltage data, and diagnoses the metal recovery device as requiring maintenance when the feature amount is equal to or greater than the threshold value by comparing the feature amount with a predetermined threshold value.
2. The condition monitoring system according to claim 1, wherein the condition monitoring system notifies a diagnostic result obtained by comparing the featured amount with the predetermined threshold value to a management terminal via a telecommunication line.
3. The condition monitoring system according to claim 1 or 2, wherein a target for the requiring maintenance is an anode coated with an electrode catalyst.