

METAL OBJECT DETECTING DEVICE

BACKGROUND OF THE INVENTION:

The present invention relates to a detecting device which uses a coil for detecting metals.

5 Presently, there are three representative methods for detecting metals by using coils.

In a first prior-art method, an AC current is continuously applied to a coil for detecting metals. When an object to be examined is positioned on the coil, the
10 inductance of the coil changes. As a result, the current and, consequently, the voltage of the coil changes. The change in the AC voltage is detected and utilized for detecting a metal.

In a second prior-art method, a transmitting coil and
15 a receiving coil are placed adjacently to each other. When an object to be examined is positioned on the coils, the signal to be induced at the receiving coil changes. By detecting the change in the signal, a metal can be detected.

In a third prior-art method, a reference oscillator
20 circuit, a detection oscillator circuit, and a detection coil which is coupled to the detection oscillator circuit are used. When an object to be examined is positioned on the coil, the oscillation frequency for detection changes. By comparing the changed detection oscillation frequency and
25 the reference oscillation frequency, a metal can be detected.

Also, a microcomputer is sometimes used in the above methods for stabilizing detection operations.

In all of the above methods, detection of a metal is

achieved by utilizing the phenomenon that the impedance of a coil changes when a metal comes close to the coil to which an AC current is supplied. Therefore, it is necessary to continuously supply an AC current to the coil of the

5 detecting device. Also, it is necessary to include an oscillator circuit in the detecting device for generating an alternate current. As a result, the number of parts of the detecting device increases.

Also, in the prior-art metal object detecting device,
10 it is necessary to continuously drive its oscillator circuit. Therefore, the consumption of electric power is high. Also, since the electric power consumption is high, it is difficult to miniaturize the device to be able to be driven by a small-size battery.

15 Also, in the prior-art metal object detecting device, it is necessary to construct the oscillator circuit unstable, for increasing the detection sensitivity of the detecting device. In other words, it is necessary to construct the oscillator circuit in the manner that the oscillator circuit
20 is easily influenced from outside. However, by destabilizing the oscillator circuit, the operation of the metal object detecting device becomes unstable. For example, the operation of the metal object detecting device which was installed in summer becomes unstable in winter. Similarly,
25 the operation of the metal object detecting device which was installed in winter becomes unstable in summer. That is, when the detection sensitivity of the metal object detecting device is increased, the metal object detecting device is

easily influenced by environmental factors.

Also, in the prior-art metal object detecting device, if an AC oscillator which generates a frequency which is close to that of the detecting device is placed near the
5 detecting device, the detecting device receives the signal from the AC oscillator and amplifies it. Therefore, the metal object detecting device of the prior art cannot be used in a place where an AC oscillator which generates a frequency is close to that of the nearby metal object
10 detecting device.

Also, by adding a microcomputer to the metal object detecting device for stabilizing its operation, the costs for constructing the detecting device increases.

SUMMARY OF THE INVENTION

15 The object of the present invention is to provide a metal object detecting device which obviates the above drawbacks.

Also, the object of the present invention is to provide a metal object detecting device comprising a circuit
20 which comprises a coil for detection and a resistor which are connected in series, but does not comprise a capacitance element (capacitor), wherein a metal object is detected based on a transient phenomenon which occurs when an DC voltage is applied to the above circuit.

25 A detecting device of the present invention comprises an RL series circuit which comprises

a coil (L) for detecting an object of examination, wherein said coil is positioned to be able to place near an

object which is to be examined and may comprise said object of examination, and

a resistor (R) which is connected to said coil in series; and

5 a processing circuit (W,T,G) which,

based on a reference characteristic of a transient phenomenon of said RL circuit, detects a change in a characteristic of a transient phenomenon which occurs when a DC voltage is applied to said RL circuit, and

10 based on the detection result, outputs an examination result which indicates whether or not said object of examination exists.

A detecting device of the present invention comprises an RL series circuit which comprises

15 a coil (L) for detecting an object of examination, wherein said coil is positioned so that it can be placed near an object which is to be examined and may comprise said object of examination, and

a resistor (R) which is connected to said coil in series;

a control means (S) for controlling supply of a DC voltage from a power source (E) to said RL series circuit;

a detection circuit (W) which, based on a transient phenomenon which occurs when a DC voltage is applied to said RL circuit, outputs a detection signal which corresponds to the time constant of said RL series circuit; and

25 a processing circuit (T,G) which,

based on said detection signal and a reference

signal which corresponds to a predetermined reference time constant of said RL series circuit, detects change in the time constant of said RL series circuit, and

based on the change in the time constant,
5 generates a signal which indicates whether or not said object of examination exists.

Also, in the above detecting device, said detection circuit comprises a means (W) for generating and outputting said detection signal as a pulse which has a time-length
10 corresponding to said time constant.

Also, in the above detecting device, said processing circuit comprises

a constant time pulse signal generating circuit (T) which generates, as said reference signal, a reference
15 pulse which has a predetermined time-length corresponding to said reference time constant, and

a means (G) for generating, based on said pulse which is outputted from said detection circuit and said reference pulse which is outputted from said constant time
20 pulse signal generating circuit, a signal which indicates whether or not said object of examination is detected.

Also, in the above detecting device, in a different embodiment, said processing circuit comprises

a means for storing and outputting, as said
25 reference signal, the value of said reference time constant,

a pulse time measuring circuit which measures the time-length of said pulse outputted from said detection circuit and outputs a signal representing the time-length of

said pulse, and

a means for generating, based on said time-length of said pulse and said value of said reference time constant, a signal which indicates whether or not said object of examination is detected.

Also, in the above detecting device, said reference time constant has the value which is equal to the time constant of said RL series circuit which is obtained when an electromagnetically affecting object does not exist near said coil, or said reference time constant has a value which is a little shorter than said time constant.

Also, in the above detecting device, said object of examination is a metal.

Also, in the above detecting device, said time constant of said RL series circuit is derived from a signal waveform which represents a characteristic of the transient phenomenon of said RL series circuit.

Also, in the above detecting device, said signal waveform which represents a characteristic of the transient phenomenon is a signal waveform which represents change in voltage.

Also, in the above detecting device, said control means comprises a switch (S) which turns on and off the supply of said DC voltage, based on a predetermined time interval based on said reference time constant.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a drawing for explaining the fundamental of the present invention.

Fig. 2 is a diagram which shows the voltage of the circuit shown in Fig. 1, relative to time; wherein (a) indicates the change in voltage between points A and C of Fig. 1, and (b) indicates the change in voltage between
5 points B and C of Fig. 1.

Fig. 3 is a drawing which shows an embodiment of a metal object detecting device of the present invention.

Fig. 4 is a diagram which shows the relations between time and signal waveforms of some points of the metal object
10 detecting device of Fig. 3, wherein the waveforms of signals which are generated when no metal object is placed near the coil, and the waveforms of signals which are generated when a metal object is placed near the coil are shown.

DETAILED DESCRIPTION OF THE INVENTION

15 In the present invention, the change in the inductance of a metal detection coil is detected by utilizing the transient phenomenon. The result of the detection is then analyzed, converted to a signal, and outputted.

Fig. 1 is a drawing for explaining the fundamental of
20 the present invention, and it indicates an RL circuit. In Fig. 1, L denotes a coil for detection (detection coil), R a resistor, S a switch, and E a power source. These elements are serially connected as shown in Fig. 1. A, B and C in Fig. 1 indicate the points for measuring the voltage of this
25 circuit. Also, it is assumed that the inductance value of the coil L is L(H, henry), the resistance value is R(Ω , ohm), and the voltage value of the power source is E(V, volts).

Fig. 2 is a diagram which shows the voltage of the circuit shown in Fig. 1, relative to time. Fig. 2 (a) shows the change in voltage between points A and C of Fig. 1, and Fig. 2 (b) shows the change in voltage between points B and C of Fig. 1.

When the switch S of the circuit of Fig. 1 is turned on to apply a DC voltage $E(V)$ between points A and C, a waveform as shown in Fig. 2 (b) which represents a transient phenomenon appears across the coil L, that is, the signal waveform appears between points B and C. In this waveform, the time τ (that is, the time constant τ) that the voltage drops from $E(V)$ to $0.368E(V)$ (i.e., $(1-0.632)E(V)$) can be represented by the equation $\tau = L/R$. From this equation, it can be understood that the width of the signal, consequently, the magnitude of the time constant τ is proportional to the inductance value L.

When an object which has an influence on the magnetic field of the coil L, for example, a metal object, is placed near the coil L, the inductance value of the coil L changes. As the inductance value changes, the time constant of the RL circuit changes.

With the RL circuit, for example, a constant time pulse signal generating circuit (a circuit for generating a pulse which has a predetermined time-length (i.e., length of time), which is known, is combined. By comparing the measured time constant (which is represented in a pulse form) and the length of the pulse generated at the constant time pulse signal generating circuit, it is possible to

detect the existence of a metal object.

Alternatively, with the RL circuit, a pulse time measuring circuit (a circuit for measuring the time-length (length in time) of a pulse) is combined. By measuring a
5 time constant by the pulse time measuring circuit, it is possible to detect the existence of a metal object. In other words, by comparing the measured time constant and a reference time constant (for example, the time constant of the RL circuit which is obtained when no metal object is
10 placed near the coil), the existence of a metal object can be detected.

The above equation of the time constant can be applied to both a differentiating circuit and an integrating circuit. In the following, an embodiment of the present invention
15 will be explained with reference to a circuit which comprises a circuit of a differentiating-type in which one end of the detection circuit can be connected to zero electric potential.

Fig. 3 is a drawing which shows an embodiment of a
20 metal object detecting device of the present invention.

In Fig. 3, L denotes a detection coil and R denotes a resistor. S denotes a switch, and E denotes a driving power source for the coil L and the resistor R. One end of the coil L is coupled to a ground and the other end is coupled
25 to one end of the resistor R. The other end of the resistor R is coupled to the switch S. The switch S turns on and off the supply of the electric power to be applied from the power source E to the resistor R and the coil L. Also, it

is assumed that the inductance value of the coil L is $L(H)$, the resistance value is $R(\Omega)$, and the voltage value of the power source is $E(V)$.

W denotes a wave-shaping circuit which converts a
5 waveform of a signal detected from the coil L to a rectangular wave. In other words, based on a waveform detected from the coil L, the wave-shaping circuit W generates a rectangular wave which has the same time-length (i.e., width) as the time that the voltage of the coil L
10 changes from $E(V)$ to $0.368E(V)$. I denotes an inverter which is coupled to an output side of the wave-shaping circuit W. The inverter I inverts the polarity of a rectangular wave which is outputted from the wave-shaping circuit W.

T denotes a time pulse generator. The time pulse
15 generator T generates a pulse which has the same time-length (i.e., width) as the time constant of the RL circuit which can be obtained when no metal object is placed near the coil L, or it generates a pulse which has a length which is a little shorter than the time constant. By using the width
20 of the pulse as a reference, it is determined whether or not a metal object exists near the coil L.

D is a driving signal which is coupled to the switch S and the time pulse generator T. The switch S and the time pulse generator T operate when the driving signal D is
25 supplied.

G denotes a gate circuit. One input of the gate circuit G is coupled to an output side of the time pulse generator T, and the other input is coupled to an output

side of the inverter I. The gate circuit G compares a signal which is outputted from the time pulse generator T with a signal which is outputted from the wave-shaping circuit W and inverted by the inverter I. O denotes an
5 output signal of the gate circuit G. The signal O represents the difference between the signal which is outputted from the time pulse generator T and the signal which is outputted from the inverter I.

Also, arrows indicated in Fig. 3 show flowing
10 directions of signals.

Next, an operation of the metal object detecting device indicated in Fig. 3 will be explained.

When the driving signal D is supplied to the switch S and the time pulse generator T, both of them are driven.

15 Upon receiving the driving signal D, the switch S changes its state from an off state to an on state, and couples the power source E to the resistor R and the coil L. Then, a current flows from the power source E to the resistor R and the coil L. At this time, a transient
20 phenomenon appears at the resistor R and coil L. The wave-shaping circuit W detects a waveform which appears at the time of the transient phenomenon and represents the change in voltage of the coil L.

It is noted that the length (in time) of a waveform,
25 that is, the width of a signal, which is detected when a metal object exists near the coil L, and the length of a waveform which is detected when a metal object does not exist near the coil L are different.

The wave-shaping circuit W generates and outputs a rectangular wave which has the same time-length as the time that the voltage value of the detected waveform changes from $E(V)$ to $0.368E(V)$. The rectangular wave outputted from the wave-shaping circuit W is inverted by the inverter I and
5 supplied to the gate circuit G.

On the other hand, the time pulse generator T supplies a signal which is in the form of a pulse and has a predetermined length. The predetermined length is equal to the time
10 constant which can be calculated based on the equation $\tau = L/R$, or it is a little shorter than the calculated time constant.

The gate circuit G compares the signal which is outputted from the time pulse generator T with the signal
15 which is outputted from the inverter I, and outputs a signal O which represents the difference in length between these two signals. Based on the signal O, it is judged whether or not a metal object exists.

If the time (length) of the output signal O is not
20 long enough and cannot be used for further processing, the signal O can be processed by a microcomputer or can be extended to a desired length by a single shot multivibrator to be used for further processing.

Also, it is possible to continuously perform the
25 detection operation by periodically applying a DC voltage to the resistor R and the coil L. To this end, the switch S may be turned on and off in accordance with a predetermined cycle. Also, it may be possible to use a pulse generator as

a power supply. The time to supply a DC voltage is, for example, equal to the period of a transient phenomenon (i.e., from the beginning to the end of a transient phenomenon) which occurs when a voltage is applied to the RL circuit under the condition that no metal object affects the coil L, or a little longer than the period of the transient phenomenon. The time to stop supplying a DC voltage is equal to the period of a transient phenomenon which occurs when a voltage applied to the RL circuit is turned off.

10 Also, except for the resistor R and the coil L, it is possible to construct the circuit of the metal object detecting device of the present invention in a digital circuit form.

15 Also, it is possible to further stabilize the detection operation of the metal object detecting device of the present invention by combining the metal object detecting device with a computer, etc. Also, it is possible to manage the operation conditions of the metal object detecting device of the present invention by using a computer, etc.

20 According to the construction of the metal object detecting device of the present invention, the number of parts for constructing the metal object detecting device can be reduced.

25 Also, according to the construction of the metal object detecting device of the present invention, the metal object detecting device can stably operate without assistance of a microcomputer, etc.

 Also, according to the construction of the metal

object detecting device of the present invention, the electric power consumption of the metal object detecting device is lowered, and it becomes possible to miniaturize the metal object detecting device to be able to be driven by
5 a small-size battery.

Also, according to the construction of the metal object detecting device of the present invention, it is possible to use the metal object detecting device at a place where an AC oscillator which generates a frequency which is
10 the same or close to that of the metal object detecting device exists nearby.

Also, by forming the circuit, except for the resistor R and the coil L, of the metal object detecting device of the present invention in a digital circuit, it is possible
15 to reduce a drift due to temperature.



We claim:

1. A detecting device comprising;

an RL series circuit which comprises

a coil (L) for detecting an object of examination,

5 wherein said coil is positioned such that it can be placed
near an object which is to be examined and may comprise said
object of examination, and

a resistor (R) which is connected to said coil in
series; and

10 a processing circuit which,

based on a reference characteristic of a transient
phenomenon of said RL circuit, detects a change in a
characteristic of a transient phenomenon which occurs when a
DC voltage is applied to said RL circuit, and

15 based on the detection result, outputs an
examination result which indicates whether or not said
object of examination exists.

2. A detecting device comprising;

an RL series circuit which comprises

20 a coil (L) for detecting an object of examination,
wherein said coil is positioned such that it can be placed
near an object which is to be examined and may comprises
said object of examination, and

a resistor (R) which is connected to said coil in
25 series;

a control means (S) for controlling supply of a DC
voltage from a power source (E) to said RL series circuit;

a detection circuit (W) which, based on a transient



phenomenon which occurs when a DC voltage is applied to said RL circuit, outputs a detection signal which corresponds to the time constant of said RL series circuit; and

a processing circuit (T,G) which,

5 based on said detection signal and a reference signal which corresponds to a predetermined reference time constant of said RL series circuit, detects a change in the time constant of said RL series circuit, and

 based on the change in the time constant,
10 generates a signal which indicates whether or not said object of examination exists.

3. The detecting device as set forth in claim 2, wherein said detection circuit comprises a means (W) for generating and outputting said detection signal as a pulse which has a
15 time-length corresponding to said time constant.

4. The detecting device as set forth in claim 3, wherein said processing circuit comprises

 a constant time pulse signal generating circuit (T) which generates, as said reference signal, a reference
20 pulse which has a predetermined time-length corresponding to said reference time constant, and

 a means (G) for generating, based on said pulse which is outputted from said detection circuit and said reference pulse which is outputted from said constant time
25 pulse signal generating circuit, a signal which indicates whether or not said object of examination is detected.

5. The detecting device as set forth in claim 3, wherein said processing circuit comprises



a means for storing and outputting, as said reference signal, the value of said reference time constant,

a pulse time measuring circuit which measures the time-length of said pulse outputted from said detection
5 circuit and outputs a signal representing the time-length of said pulse, and

a means for generating, based on said time-length of said pulse and said value of said reference time constant, a signal which indicates whether or not said object of
10 examination is detected.

6. The detecting device as set forth in one of claims 2 to 5, wherein said reference time constant has the value which is equal to the time constant of said RL series circuit which is obtained when an electromagnetically
15 affecting object does not exist near said coil, or said reference time constant has the value which is a little shorter than said time constant.

7. The detecting device as set forth in one of claims 2 to 6, wherein said object of examination is a metal.

20 8. The detecting device as set forth in one of claims 2 to 7, wherein said time constant of said RL series circuit is derived from a signal waveform which represents a characteristic of the transient phenomenon of said RL series circuit.

25 9. The detecting device as set forth in claim 8, wherein said signal waveform which represents a characteristic of the transient phenomenon is a signal waveform which represents change in voltage.



10. The detecting device as set forth in one of claims 2 to 9, wherein said control means comprises a switch (S) which turns on and off the supply of said DC voltage, based on a predetermined time interval based on said reference
5 time constant.