SAFETY DEVICE FOR CRANE

A safety device for a crane comprises apparatus for detecting a work length of the crane, a device for determining a safety or rated load corresponding to the detected work length, an instrument for detecting a load actually lifted, and apparatus for comparing the lifted load with the rated load to produce an output signal for operating an alarm device or stopping the crane when the lifted load is equal to or more than the rated load. The safety device employs elements which produce electric signals, corresponding to rated and lifted loads, which are compared.

10 Claims, 4 Drawing Figures
FIG. 1.

BOOM LENGTH DETECTING MEANS
WORK RADIUS DETECTING MEANS
RATED LOAD DETERMINING MEANS
NEG. FEEDBACK AMP.
AMPLIFIER
LIFTED LOAD DETECTING MEANS
DIFF. AMP.
RELAY & CONTACTS
ALARM DEVICE
COMPARATOR MEANS

FIG. 2.

\[ W_0 - WL \leq 0 \]
\[ W_0 = f(R) \]

\( W_0 \quad W_1 \quad W_2 \quad W_3 \quad W_4 \)
\( R_1 \quad R_2 \quad R_3 \quad R_4 \)

\( L \cos \theta = R \)
FIG. 3.

FIG. 4.
1 SAFETY DEVICE FOR CRANE

BACKGROUND OF THE INVENTION

1. Field of the Invention
This invention relates to a safety device for a crane adapted to always monitor an excessive load lifted by the operating crane over a safety load associated with a length of a boom and hence a work radius of the crane.

2. Description of the Prior Art
Recently, there has been a tendency for cranes to become larger and therefore the operator's delayed judgement and false operation are important problems to solve. These factors may cause serious accidents particularly in large type cranes.

To avoid such accidents, it is necessary to monitor an unexpected excessive load over a safety load of a crane to obtain correct data for safety.

In the prior art, there have been cranes equipped with alarm devices which warn of abnormal conditions on a single matter such as overloading or instability in a horizontal plane. In other more primitive cases, operators have determined the safety condition with reference to rated curves of the cranes in comparison with individual values of measured boom inclination angles, boom lengths and lifted loads. In these procedures, the recognition of dangerous conditions or the confirmation of safety cannot be made continuously so that operational efficiency may remain at a relatively low level.

There also are prior art cranes, equipped with means for continuously measuring a boom inclination angle and a load at a constant boom length. That is, a pressure value at a derrick crane and a pressure value under its rated load are converted into appropriate voltage values in a stepwise manner to provide an automatic determination of the safety of the crane. In the arrangement, however, it is necessary to adjust the means whenever the boom length varies during the crane operation, so that the arrangement does not contribute to a good improvement in efficiency.

SUMMARY OF THE INVENTION

The present invention is intended to overcome the above disadvantages in the prior art. One of its purposes is the provision of a safety device for a crane comprising boom length detecting means for detecting boom length as an electric signal, work radius detecting means for receiving said boom length signal and generating directly an electric signal corresponding to work radius, a product of said boom length signal and a cosine signal which is obtained by converting a boom inclination angle into an electric signal, lifted load detecting means for detecting a lifted load as an electric signal, rated load determining means for converting said work radius electrical signal received therein to a signal indicating a rated load corresponding to said work radius, and comparator means for comparing said signal indicating said rated load with said signal indicating said lifted load to produce an output signal for stopping the crane operation or operating an alarm device when said lifted load is equal to or more than said rated load.

The term "rated load" used herein is intended to mean a safety load corresponding to the length of a boom of a crane actually used and hence a work radius of the crane.

2 An object of the invention is to provide an improved safety device for a crane which is provided with a simplified circuit arrangement, and capable of automatically continuously checking for safe crane operation even if the length of the crane varies and preventing any false operation thereby improving the efficiency in the crane operation.

Another object of the invention is to provide a safety device for a crane capable of automatically continuously checking for safe crane operation by comparison of a load actually lifted with a rated load to meet the work radius obtained from a boom length and a boom inclination angle.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing the principle of the safety device according to the invention;

FIG. 2 is a diagram showing one example of a rated load curve;

FIG. 3 is a diagrammatical elevation of a truck crane employing the safety device according to the invention; and

FIG. 4 is a circuit arrangement showing one embodiment of a rated load determining means employed in the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the invention will be explained in detail hereinafter with reference to the drawings.

The block diagram of FIG. 1 illustrates the principle of the device according to the invention. In the diagram, boom length detecting means 1 converts a boom length (L) into an electric signal L for detecting the boom length and work radius detecting means 2 converts a boom inclination angle (θ) into an electric signal cosθ and extracts an electric signal L cosθ as a product of the signal cosθ and the signal L of the boom length produced in the boom length detecting means 1. The signal L cosθ indicates a work radius R of a crane.

Rated load determining means 3 in FIG. 1 extracts a rated load W₀ = f(R) in the form of an electric voltage corresponding to the length of the crane work radius L cosθ = R received as an input in the rated load determining means. Lifted load detecting means 4 converts the load actually lifted into an electric signal Wₜ which is transmitted together with the rated load signal W₀ to comparator means 5 which discriminates the positive or negative value of the difference W₀-Wₜ. In case the load signal Wₜ is equal to or more than the rated load signal W₀, that is W₀-Wₜ ≤ 0, the comparator means 5 produces an output signal which operates alarm device or crane operation stopping means 6.

In the event the load signal Wₜ is less than the rated load signal W₀ that is W₀-Wₜ > 0, the comparator means 5 does not produce any output signal because the alarm device or crane operation stopping means 6 need not be operated.

While the safety device according to the invention can be applied to any crane of fixed or adjustable length boom, the invention will be specifically explained hereinafter with reference to a truck crane incorporating the safety device.

Referring to FIG. 3, a truck 7 is equipped with a swivel slide 8, pivotal points 9 for a boom, luffing cylin-
a load cell 11 for detecting a load, a cord reel 12, a potentiometer 13 for measuring the boom length, the main boom 14 and a hook 15.

In the embodiment, the boom length detecting means 1 shown in FIG. 1 consists of the cord reel 12 adapted to extend and retract a cord according to the boom length, the helical potentiometer 13 which converts the boom length to an electric resistance with the aid of the cord reel 12, and a negative feedback amplifier circuit (FIG. 1) which converts the electric resistance to an electric voltage signal. With the arrangement, the boom length detected by the cord reel 12 is converted into the electric signal as electric voltage L. The work radius detecting means 2 consists of a potentiometer (FIG. 3) mounted on the pivotal point 9, the resistance winding of which is wound in a cosine manner and a slider of which is interlocked with the main boom 14 such that a turned angle of the slider is proportional to a boom inclination angle (θ). When the output voltage L from the boom length detecting means 1 is applied to the end of the resistance winding of the potentiometer, it produces a signal L cosθ illustrating the work radius which has been converted from the turning angle of the slider.

The lifted load detecting means 4 comprises the conventional load cell 11 in which a real stress acting on a wire rope for lifting is converted into an electric signal which is applied to an amplifier (not shown) to obtain a signal of electric voltage Wt corresponding to the load.

The rated load determining means 3 comprises a circuit as shown in FIG. 4 to obtain a load curve Wt=f(R) such for example as the curve shown in FIG. 2 having an abscissa R (work radius) and an ordinate Wt (rated load). The voltage amplifier circuit shown in FIG. 4 is provided with an operational amplifier circuit and diode switches for changing over amplification factors according to the input voltage L cosθ=R. As can be seen from FIG. 2, the amplification factor within the range of the work radius from zero to R1 is zero because the load signal W1 is constant and equal to the rated load signal Wt and the amplification factors within the ranges from R1 to R2, R2 to R3 and R3 to R4 are \((Wt-W1)/(R2-R1)\), \((Wt-W2)/(R3-R2)\) and \((Wt-W3)/(R4-R3)\), respectively.

The rated load Wt is determined as a function of the work radius R = Lcosθ by the use of the circuit as shown in FIG. 4. The polygonal line function generator in FIG. 4, which consists of diodes, resistances and an arithmetic unit, operates in a manner known by those skilled in the art and disclosed in various electric engineering reference books. The theory and technique of constructing such polygonal line function generators are set forth in "Electronic Analog Computers" by Korn et al., McGraw-Hill, 1956, pages 290–297 and "Operational Amplifiers, Design and Applications" by Graeme et al., McGraw-Hill, 1971, pages 250–253. The function generator is so constructed that when it receives as an input a voltage corresponding to \(R = L\cos \theta\), it will generate an output voltage corresponding to the rated load \(W_t\).

Voltages corresponding to the maximum rates load \(W_t\) and work radii \(R_1\), \(R_2\) and \(R_3\) are \((r/r_1)E\) and \((r_2/r_3)E\) respectively. Rated loads corresponding to \(R_1\), \(R_2\) and \(R_3\) are \(W_1\), \(W_2\) and \(W_3\). Moreover, there are following relationships, \((Wt-W1)/(R2-R1) = -(r/r_1)\), \((Wt-W2)/(R3-R2) = -(r_2/r_3)\).

Owing to the smoothing effect of the diodes, the polygonal line is changed into a smooth curve to improve the accuracy of approximate values.

The comparator means 5 consists of, for example, a differential amplifier, to both input terminals of which the signals \(W_t\) and \(W_a\) are supplied to discriminate the positive or negative value of the difference between the signals. When the load signal \(W_t\) is equal to or more than the rated load signal \(W_a\), that is, \(W_t - W_a \leq 0\), an output from the differential amplifier causes a relay of the crane operation stopping means 6 to be operated to close its contacts, so that an alarm lamp is lighted, an alarm buzzer is energized or the operation of the crane is stopped. In the event of \(W_t - W_a < 0\), the comparator means does not produce any output to make the alarm device operate or stop the operation of the crane.

As above described, the safety device according to the invention can always continuously monitor any excessive load more than a rated load meeting a work radius of the crane over the wide ranges of the boom length, the boom inclination angle and the lifted load without using a complicated electronic circuit, so that a crane operator can be absorbed in the crane operation without consuming time to consider the safety of the crane. Therefore, the efficiency in crane operation can be considerably improved.

Furthermore, the problem of delayed judgement of the operator, which is encountered in the prior art in any dangerous condition, can be solved and when an operator falsely operates a crane, it is automatically brought into an inoperative state so that any dangerous condition caused by the malfunction can be avoided. Moreover, the safety device according to the invention can be advantageously applied to any kind of cranes having fixed or adjustable length booms.

While the present invention has been shown and described in a certain form only, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various changes and modifications without departing from the spirit and scope thereof.

What is claimed is:

1. A safety device for a crane comprising boom length detecting means for detecting a boom length including means for generating a first electric signal corresponding to boom length, work radius detecting means for receiving said first signal and for generating a second electric signal corresponding to work radius, said second signal being a product of said first signal and a third cosine signal corresponding to a boom inclination angle, said cosine signal being generated in said work radius detecting means, lifted load detecting means for detecting a lifted load including means for generating a fourth electric signal corresponding to the lifted load, a rated load determining means including means for converting said second signal received therein to a fifth electric signal indicating a rated load corresponding to said work radius, said rated load determining means including a polygonal line function generator having an operational amplifier circuit and diode switches for changing over amplification factors according to said second signal, and comparator means for comparing said fifth signal with said fourth signal to produce a sixth output signal providing...
information concerning safe crane operation when said lifted load is equal to or more than said rated load.

2. A safety device as set forth in claim 1, wherein said boom length detecting means (1) comprises a cord reel (12) adapted to extend and retract a cord according to a boom length, a helical potentiometer (13) responsive to the movement of said cord to convert the boom length to an electric resistance, and a negative feedback amplifier circuit connected to the electric resistance for providing an electric voltage signal comprising said first signal.

3. A safety device as set forth in claim 1, wherein said work radius detecting means (2) comprises a potentiometer, the resistance winding of which is wound in a cosine manner and a slider interlocked with a main boom (14) wherein a turned angle of the slider is proportional to a boom inclination angle (θ), an output voltage signal (L) from said boom length detecting means (1) being applied to the ends of said resistance winding of said potentiometer for producing a signal (L cosθ), corresponding to a work radius, which is generated from the turning angle of the slider, said signal (L) comprising said first signal and said signal (L cosθ) comprising said second signal.

4. A safety device as set forth in claim 1, wherein said lifted load detecting means (4) comprises a load cell (11) in which a real stress acting on a wire rope for lifting is converted into an electric signal which is applied to an amplifier to obtain a signal of electric voltage (W₁) corresponding to the lifted load, said voltage (W₁) comprising said fourth signal.

5. A safety device as set forth in claim 1, wherein said rated load determining means (3) comprises an operational amplifier circuit and diode switches for changing amplification factors according to an input voltage (L cosθ = R) comprising said second signal, said amplification factors being (W₂ - W₁)/(R₁ - R₂), (W₃ - W₂)/(R₃ - R₂), and (W₄ - W₃)/(R₄ - R₃) corresponding to respective ranges of work radii, wherein R₁ - R₂ are work radii and W₁ - W₄ are corresponding rate loads.

6. A safety device as set forth in claim 1, wherein said comparator means (5) comprises a differential amplifier, to the respective input terminals of which the fourth signal (W₄) and a rated load signal (W₄₀) comprising said fifth signal are supplied to discriminate the positive or negative value of the difference between the signals (W₄₀) and (W₄) wherein when the lifted load is equal to or more than the rated load, said differential amplifier produces an output signal comprising said sixth signal to operate an alarm device (6).

7. A safety device as set forth in claim 6, wherein said alarm device (6) comprises a relay adapted to be operated by said output signal from said differential amplifier to close its contacts so that an alarm buzzer sounds.

8. A safety device as set forth in claim 6, wherein said alarm device (6) comprises a relay adapted to be operated by said output signal from said differential amplifier to close its contacts so that an alarm lamp is lighted.

9. A safety device as set forth in claim 6, wherein said alarm device (6) comprises a relay adapted to be operated by said output signal from said differential amplifier to close its contacts so that an alarm lamp is lighted.

10. A safety device as a crane comprising boom length detecting means (1) comprising a cord reel (12) adapted to extend and retract a cord according to a boom length, a helical potentiometer (13) responsive to the movement of said cord to convert the boom length to an electric resistance, and a first negative feedback amplifier circuit, connected to the electric resistance, for providing a first electric output voltage signal (L), a work radius detecting means (2) including a second potentiometer, the resistance winding of which is wound in a cosine manner, and a slider interlocked with a main boom (14) wherein a turned angle of the slider is proportional to a boom inclination angle (θ), the output voltage signal (L) from said boom length detecting means (1) being applied to the ends of said resistance winding of said second potentiometer for producing a second signal (L cosθ), corresponding to work radius, which is generated from the turning angle of the slider, lifted load detecting means (4) including a load cell (11) in which a real stress acting on a wire rope for lifting is converted into a third electric signal which is applied to a first amplifier to obtain a fourth signal of electric voltage (W₄) corresponding to the lifted load, rated load determining means (3) including a second operational amplifier circuit and diode switches for changing amplification factors according to an input voltage (L cosθ = R) comprising said second signal to provide a fifth electric signal corresponding to a rated load signal (W₄₀), said amplification factors being (W₂ - W₁)/(R₁ - R₂), (W₃ - W₂)/(R₃ - R₂), and (W₄ - W₃)/(R₄ - R₃) corresponding to respective ranges of work radii, wherein R₁ - R₂ are work radii and W₁ - W₄ are corresponding rated loads, and comparator means (5) including a second differential amplifier, to the respective input terminals of which the fourth signal (W₄) and the fifth signal (W₄₀) are supplied to discriminate the positive or negative value of the difference between the signals (W₄₀) and (W₄) wherein when the lifted load is equal to or more than the rated load, said differential amplifier produces a sixth output signal to operate an alarm device (6), said alarm device including a relay adapted to be operated by said sixth output signal from said differential amplifier to close its contacts.