Development and Application of On-line Monitor for the ZLW-1 Axis Cracks

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Development and Application of On-line Monitor for the ZLW-1 Axis Cracks

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Abstract. This article mainly introduces a method that uses acoustic emission techniques to achieve on-line monitor for the shaft cracks and crack growth. According to this method, axis crack monitor is produced by acoustic emission techniques. This instrument can apply to all the pressure vessels, pipelines and rotor machines that can bear buckling load. It has the online real-time monitoring, automatic recording, printing, sound and light alarm, collecting crack information function. After a series of tests in both laboratory and field, it shows that this instrument is very versatile and possesses broad prospects of development and application.

1. Introduction
For the high-speed rotating machinery, especially some large prime mover like steam turbine, it will cause serious accident if the shaft appears cracks. According to incomplete statistics, So far large steam turbine has happened hundreds of accidents in the world which caused by rotor cracks, and some caused huge losses. However, the instruments we use now cannot react crack extension, during the period that shaft appears cracks and cracks extension, the vibration signal nearly has no change, that is to say there is no shock character appearing.

According to the field experience, when the depth of shaft crack is greater than one-third of shaft diameter, the stiffness of the shaft will reduce, then vibration signal starts to change, we find it is too late if we depend on the change of the vibration signal.

Nowadays acoustic detection methods have great development, and acoustic emission testing is an important method of non-destructive testing [1]. Because acoustic emission testing is a dynamic and non-destructive testing methods, and acoustic emission signals comes from the crack itself, we can know the process that the crack appears expansion and monitor the security online all the time [2, 3].

The instrument this article introduces is based on the acoustic emission techniques [4]. Its main function is to monitor the crack initiation and extension of shaft and shaft parts online.

2. The principle and method of acoustic emission monitoring
The principle of using acoustic emission monitoring shaft and rotor blades crack is that when shaft or rotor blade cracks or crack propagation extends, it would produce elastic waves, and this wave spreads through the shaft, then sensor receives acoustic emission signals of cracks. The signal is passed to the processor by electromagnetic induction. In order to detect crack shaft correctly and eliminate the interference signal. We install a filter behind the preamplifier and adjust the band to crack band.
3. The composition of acoustic emission diagnostic instrument
This instrument includes three parts: acoustic emission transducers, preamplifier and signal processors.

Sensors are the eyes of the whole instrumentation, the sensitivity of monitoring instrument is
determined by it. We choose double-ended resonant piezoelectric sensor by comparison. This
instrument not only has strong anti-interference ability and it is easy to make, but the configuration of
secondary instrument is also very convenient.

We choose the voltage amplifier as preamplifier, this is exactly matched with the selected
piezoelectric transducer. In order to improve the sensitivity, we choose an operational amplifier which
has high input impedance, low drift, low noise, its magnification is 40dB.

Signal processor is the heart of the whole monitoring instrument. We choose SCM of MCS-51 type
to analyze signals and complete a variety of control functions. When signal is communicated to the
instrument, it will be enlarged 60dB. Compared with threshold voltage, we will get ringing pulse, then
starts pulse counter by Counter named 8031. The ringing pulses which are noted per second need to be
arranged, and we judge whether it has cracks or not. If it works properly, it will only show the current
ringing rate values of acoustic emission, if not, it will cause sound and light alarm and print to record the
time and acoustic emission count value. Operating personnels can call the data stored in the data storage,
then analyze the situation the rotor runs and the trend of crack extension.

The CPU this instrument uses is SCM belonging to the series of 8051, it uses modular structure on
the design, that is to say, This process which completes instrumentation functions will be divided into
several modules, then these modules need to be united organically. Because this instrument is applied to
monitor online, it cannot calculate too many data’s, all the procedures are written in assembly language
to improve the speed and occupy little space.

According to the function of this instrument, the monitoring program of this instrument can be
divided into the following modules:

The main program module. It is used to Initialize 8031 and 8255, and ensure the working status of
each port. Otherwise, it also includes system self-test, setting up various working conditions and calling
subroutines;

The data processing module; It is used to deal with the collected acoustic emission rate values to
ensure the working status of measured objects. If it works in danger, it will turn to sound and light alarm
and print to record the time; If it works well, it will turn to show the datas. Otherwise, it also has a
function to choose and store a representative value.

Interrupt service routine. It includes timer interrupt subroutine and out interrupt subroutine. Timer
interrupt subroutine is used to read the datas from the counter and reload timer initial value T0. We need
to judge whether it gets 1s or not, if it gets, the flag bit is 77H, if not, it will be interrupted and returned
The out interrupt subroutine is to judge which button is pressed, then carry out the function of the
module the button represents.

Digital tube display subroutine. Its function is to make the datas which have been treated display on
the LED digital tube. In order to facilitate operating personals to read meter, we take the method of
zero elimination, that is beginning to show from the first number that is not zero. If all the numbers are
zero, it will only display a zero in the end.

Print subroutine. It includes three parts: error print subroutine, curve print subroutine and data sheet
printing subroutine. They can help operating personals master the trend of crack growth.

The main program is combined with these modules, they control the instrument together. The main
program also need to complete initialization of the 8031 and 8255 chip, the status of timers and counters
need to be set, we also need to set the time constant of the timer, interrupt mode and so on. Its structure
is shown in figure 1.
4. The situation of practical application

4.1. The trial case in the laboratory

The acoustic emission monitoring instrument of ZLW-1 shaft crack runs well in the laboratory. In the trial operation, we do not find any trouble about the instrument. After that, we simulate the fracture experiments and test the sensitivity of the instrument.

In order to do the experiment, we take one specimen from the main steam pipe. Its material is 10CrMo910 steel. Firstly, we put it into a rectangular shape, in order to shorten the experimental time and get the experimental results as soon as possible, we make a crack in the middle. Secondly, we put the specimen on the hydraulic machine and load slowly. The sensor is coupled to the side of the specimen by magnet and turbine oil. At the beginning of the load, the specimen begins to change, but the instrument does not display obviously. When the crack of the specimen begins to expand (about 1mm), the instrument changes immediately, the digital tube shows 659(AE). We continue to load, the specimen cracks once again, it is about 2mm, the digital tube shows 643(AE), the third is 3mm and shows 1472(AE). Finally, the specimen fractures, and the digital tube shows 1881(AE).

4.2. The actual application in the scene

The acoustic emission monitoring instrument of ZLW-1 shaft crack has been installed in 1# feed pump in Tong Liao power plant. The instrument runs well in the field. Though the practical equipments do not have cracks, we can simulate axis cracks. When it has cracks, the instrument indicates a large value, then starts sound and light alarm and the printer prints the value at that moment. Through a series of analogs, it proves the instrument is applicable.
5. Conclusion
The shaft crack monitor instrument this article introduced can achieve to monitor rotor online all the time. In a series of laboratory tests, it detects the depth which is less than 1mm. However, the past diagnostic technique detects the cracks which has been extended 25%~40% depth of shaft diameter. Compared with the past, it has significant progress. These tests are basically close to the actual situation of the scene, so it can be directly transplanted to the turbine generator rotor and other non-rotating machinery.

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