A study on the stress cycle determination using an optimization technique

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1. Introduction

Monitoring for various transients is needed because they can cause the fatigue damage to nuclear components when transients are occurred by events such as plant heat-up/cool-down or reactor trip in the operating NPPs. Then, the Korea Institute of Nuclear Safety (KINS) developed a monitoring system. It was called as Computerized technical Advisory system for the Radiological Emergency (CARE). However, it is difficult to evaluate the fatigue damage by using the actual transient data. Because the amount of data is very much and these signals usually contain noises. So various methods, such as peaking counting, level crossing counting or simple range counting method, to determine the stress cycles were developed. In this paper, an engineering methodology which extracts stress cycles from the real-time transient data has been developed. To determine stress cycles, the racetrack counting and rainflow counting method were used, and an optimization technique was applied to implement the racetrack counting algorithm. Depending on the application of the racetrack method, the stress cycles counted by the rainflow method were compared. As a result, it was found that stress cycles smaller than a threshold value were discarded.

2. The cycle counting method

2.1 Racetrack counting method [1]

The racetrack counting method is originally called the ordered overall range method. Its objective is to condense and reveal significant events in a complex reversal history. It is based on an assumption that the highest peak to the lowest valley is the most important feature in the history. The second highest peak to the second lowest valley is the next most important feature in the history. Continuing this manner, all reversals can be counted or counting can be performed until a reversal range is less than a selected value. A procedure of the racetrack counting method is illustrated in Fig. 1. For this procedure, a racetrack width must be defined. Only reversal points at which a racer would have to change from upward to downward or vice versa are counted. It is obvious that the track width determines the number of counted reversals. Applying this method, the original complex history is condensed to a smoother history, and small amplitude ranges causing negligible fatigue damage are discarded.

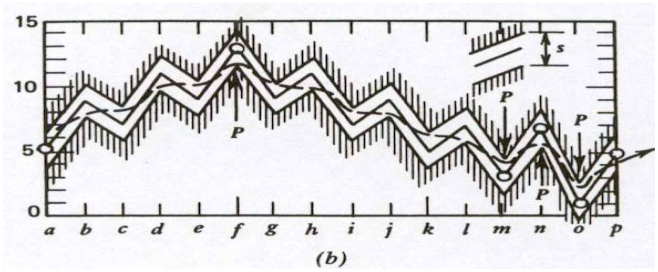
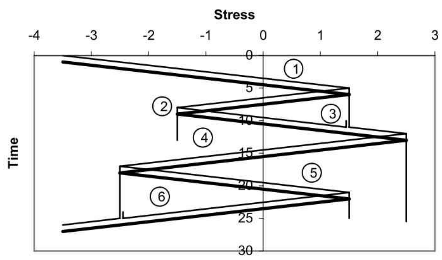


Fig. 1. The schematic of a racetrack counting method



Range Number	Stress Range
1	6
2	3
3	3
4	6
5	4
6	4

Fig. 2. The schematic of a rainflow counting method

2.2 Rainflow counting method [2]

The rainflow counting method was proposed by Matsuishi and Endo in 1968 to count the number of cycles of each stress range in a stress history. Based on an extensive series of axial strain controlled fatigue tests, Dowling demonstrated that the rainflow counting method accurately identified closed hysteresis loops in a variable amplitude histogram. It was concluded that counting methods other than range-pair and rainflow methods resulted in enormous differences in predicted and actual fatigue lives. To apply the rainflow counting method, a stress history has to be oriented vertically with positive time pointing downward. Then, the fall of rain from top of the stress history is used to facilitate the method. The rainflow paths are defined according to the following rules :

a) A rainflow path is started at each peak and trough.

b) When a rainflow path that started at a trough comes to the tip of a roof, the flow stops if the opposite trough is more negative than that at the start of the path under consideration. Conversely, a path that started at a peak is stopped by a peak which is more positive than that at the start of the rain path under consideration.

c) If the rain flowing down a roof intercepts flow from previous path the present path is stopped.

d) A path is not started until the path under consideration is stopped.

Fig. 2 illustrates an example of rainflow counting method.

3. An analysis of the random stress history

To implement the racetrack counting method, the optimization technique is used. The dotted line in the Fig. 1 is defined as the shortest path by which two end points are connected in the track, and inflection points of the dotted line are the reversal points. Therefore, determining the dotted line becomes an optimization problem to find the coefficients of polynomial equations minimizing the distance between two end points.

To solve this problem, aforementioned genetic algorithm (GA) concept is used. The GA is a search algorithm based on the principles of natural genetics and natural selection subject to Darwin's theory, "Survival of Fittest". It is also an efficient tool for solving the nonlinear optimization problems, especially when dealing with fairly complex problems where other standard nonlinear programming techniques are not able to offer fast and efficient solutions[3].

Fig. 3 shows a normalized stress transient. The stress cycles on this transient are determined by using the racetrack counting and rainflow counting method, and the width of the racetrack is 2. Table 1 represents the stress cycles counted by two counting method and Table 2 shows the stress cycles counted by only rainflow counting method. The stress cycles counted by two methods were compared with those counted by only rainflow method and found that stress cycles smaller than a threshold value were eliminated. As the application of the racetrack counting method, the original complex transient is condensed to a smoother transient, and small amplitude cycles causing negligible fatigue damage are discarded.

4. Conclusions

In this paper, an engineering methodology which extracts stress cycles from the real-time transient data has been developed. To determine stress cycles, the racetrack counting and rainflow counting method were used, and a GA concept was applied to implement the racetrack counting algorithm. The stress cycles counted by two methods were compared with those counted by only rainflow method and found that stress cycles smaller than a threshold value were eliminated. As the application of the racetrack counting method, the original complex transient is condensed to a smoother transient, and small amplitude cycles causing negligible fatigue damage are discarded.

Table 1 The stress cycles counted by the racetrack counting and rainflow counting methods

Stress Amplitude	4	8	12
Number of Cycles	1.5	0.5	0.5

Table 2 The stress cycles counted by the rainflow counting methods

Stress Amplitude	2	4	8	12
Number of Cycles	5	1.5	0.5	0.5

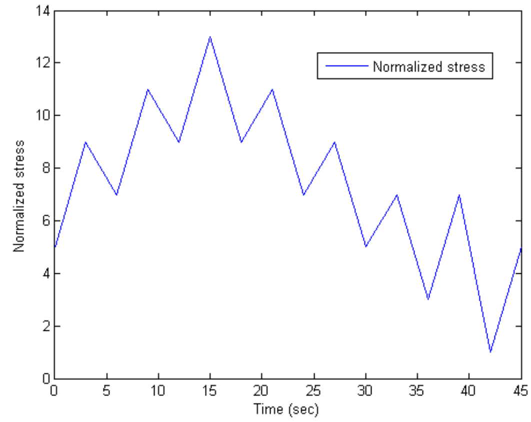


Fig. 3. The normalized stress transient

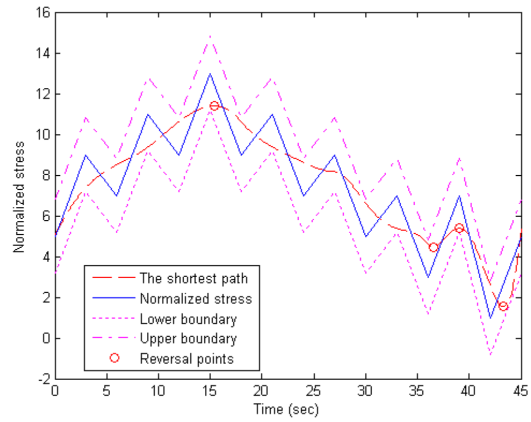


Fig. 4. The extraction of reversal points

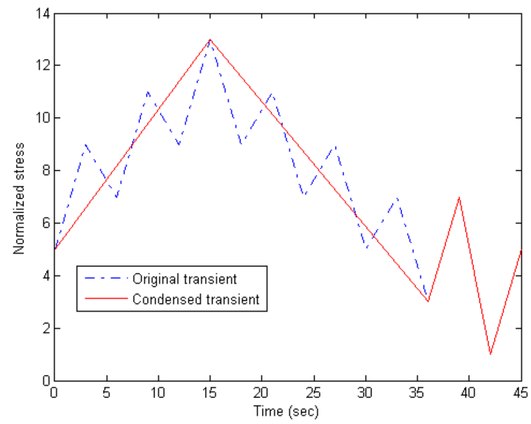


Fig. 5. The comparison between the original transient and the condensed transient

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