



Failure analysis on speed reducer shaft of sluice gate in nuclear power plant



Tong-Tong Bi, Zhen-Guo Yang*

Department of Materials Science, Fudan University, Shanghai 200433, PR China

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ABSTRACT

Irradiated fuels of nuclear power plants are usually preserved and cooled in specific water pools containing boric acid solution in nuclear power plants because of residual radioactivity and radiated heat. A sluice gate between two storage pools is used for isolation and connection of irradiated fuels. However, suddenly happened an abnormal fracture of a speed reducer shaft for driving sluice gate in a nuclear power plant with 650 MW capacity in the southern part of China, which could cause potential risk for storage safety of the fuel assemblies. Therefore, comprehensive analysis and investigation on the fractured shaft were carefully carried out in this study. The analysis results revealed that hydrogen embrittlement and temper brittleness induced during carburization and heat treatment were the root causes for the unexpected fracture of the shaft. Countermeasures and recommendations were then proposed and proved effective after implementation.

1. Introduction

It is known that irradiated fuels of nuclear power plant are generally preserved and cooled in specific water pools containing boric acid solution because of residual radioactivity and radiated heat. For the isolation between the irradiated fuel pools as well as the control of the amount of boric acid solution under different circumstances, the sluice gate in a nuclear power plant with 650 MW capacity in southern part of China is driven by speed reducer, which is installed at 20-m-high platform from the bottom of water pool, as shown in Fig. 1. Fig. 1(a) shows the external appearance of the sluice gate, and Fig. 1(b) illustrates schematic diagram of the structural components in the irradiated fuel pool. The sluice gate, which is manually driven through output end of speed reducer, is open on-off 10 times per year. The input end of the speed reducer is connected with 2.5-m-long shaft with a manual handle and its more detailed parameters are listed in Table 1.

In June 2015, when the nuclear power plant was undertaken routine inspection, one of the speed reducer shafts was found fractured during disassembling inspection. It would obviously affect the normal opening on-off of the sluice gate and storage safety of the irradiated fuel matters in neighboring pools was at risk. In a normal condition, the design lifetime of the speed reducer shaft is forty years, unfortunately, the abnormal fracture of the rotating shaft suddenly occurred less than twelve years. Although its failure factors might be ascribed to one or more of many aspects, such as material selection, mechanical property, manufacture process, operational manner, maintaining way, service environment, etc. The primary factor should to be confirmed to as to ascertain safety operation of the nuclear power equipment.

Indeed, some failure incidents and researches about relevant shafts have been reported [1–8], showing that improper heat-treatment, stress fatigue, materials brittleness and external corrosion were main causes. But the failure of speed reducer shaft on the

* Corresponding author.

E-mail address: zgyang@fudan.edu.cn (Z.-G. Yang).

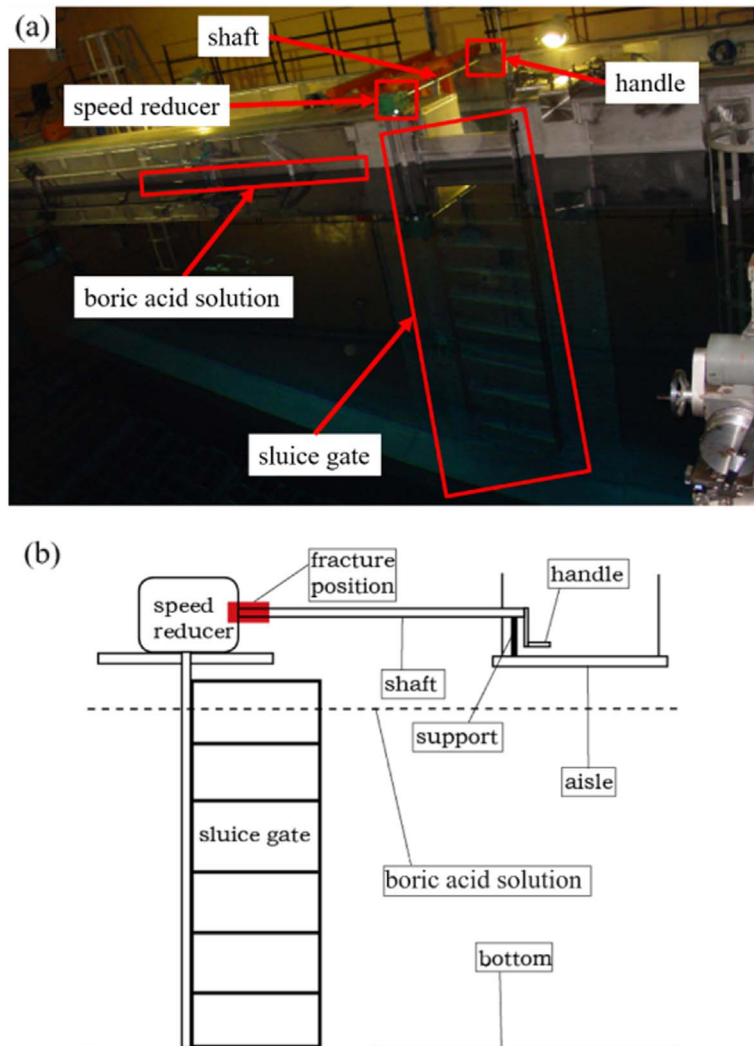


Fig. 1. Appearance and structure of irradiated fuel pool: (a) overall structure and (b) schematic diagram.

sluice gate of irradiated fuel pools in the nuclear power plant has not been reported. Furthermore, the unexpected failure of the shaft, which occurred under normal condition at low stress and less corrosive medium, was seldom disclosed.

To this end, by means of various characterization methods, comprehensive analyses were carefully performed on the fractured speed reducer shaft. Then, some countermeasures and suggestions were proposed so as to prevent the recurrence of the similar incident, based on our previous experiences on the failure analysis [9–20]. Achievement of this study would not only ensure safe operation of the nuclear power plant, but also provide reference values for the safety of similar shafts used in other industrial fields.

Table 1
Operation parameters of speed reducer.

Parameters	Model	Weight	Transmission ratio	Manual force	Product manufacturer
Speed reducer	1PKC140N	35 Kg	45	100 N	SEW transmission equipment (Tianjin) Co., Ltd.

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