

Determination of Missile Impact Force on Turbine Generator of a Nuclear Power Plant

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Abstract
It is reported that when turbines over speed then it results in flying objects or missiles which travels at high velocities. These missiles can cause severe damage to equipment and can be a source of danger to public safety. This review work discusses the methodologies used to determine the velocity of missiles produced when there is fracture in turbine generator. Review of the available damage assessment models has been reported and review experimental work done in this area.
Keywords: turbine missile, high velocity, rupture, orientation, safety

INTRODUCTION

The turbine generators store large amounts of rotational kinetic energy in their rotors. In the unlikely event of a major mechanical failure, this energy may be transformed into fragments that may destroy the surrounding stationary parts. If the energy absorbing capability of these stationary turbine generator parts is insufficient, external missiles will be released [1]. The probability of missile generation requires evaluation to ensure that it does not in unacceptable damage to the safety related equipment and systems. The researchers [2,3] have studied the fractures in turbine wheels of a nuclear power plant and has reported data related flying objects from the fractures. The flying objects can range from small debris to very big size. The velocities of these objects could be well over 250 m/s. and they have the potential to cause severe mechanical damage. Usually the deterministic approach is used to provide physical protection from these missiles. Currently probabilistic approaches are also being employed to quantify the damage [4,5]. The physical separation principle originates against missiles is to provide safety systems system into different buildings which are separated by partition walls [6].

Fig. 1 shows the typical cross section of a turbine in a steam power plant and Fig. 2 represents the possible turbine missiles that can originate. The normal governing control system operates to ensure that the control(governing) valves are fully closed at three percent over speed, and that the mechanical hydraulic over speed trip system is set to operate at ten percent overs peed. Each system contains fully redundant and testable components, and the systems operate to ensure that the turbine cannot attain sufficient speed to cause any rotating component to fail, thereby generating missile-like pieces that might leave the turbine casing [7]. The assessment of missile protection resulting from steam turbine failure is based on the general guidelines provided in US NRC Regulatory Guide 1.115, "Protection Against Low-Trajectory Turbine Missiles".

The adequacy of missile protection is considered acceptable if the overall probability of unacceptable consequences is sufficiently low. This is determined based on any one or a combination of the following probabilities:

P1 = Probability of production and flying off from missiles;

P2 = Probability that a missile strikes a target of safety importance;

P3 = Probability that a missile damages a target.

Since the total combined probability of unacceptable missile damage is the product of P1, P2, and P3, then as far as practical, each of these individual factors is designed to be sufficiently small such that the total product is sufficiently low, and hence the probability of unacceptable consequences is sufficiently low. The overall goal of the US NRC guidelines is to maintain the value of the product of the above three probabilities at an acceptably low level, of the order of 1×10^{-7} [8]. Dynamic effects caused by impact, whenever required, are evaluated in order to make sure that they do not exceed other dynamic effects for which the structure or equipment has already been qualified (e.g., seismic effects). Impact loads are calculated, whenever applicable, by calculating both the impact force and its duration by the formulae [9].

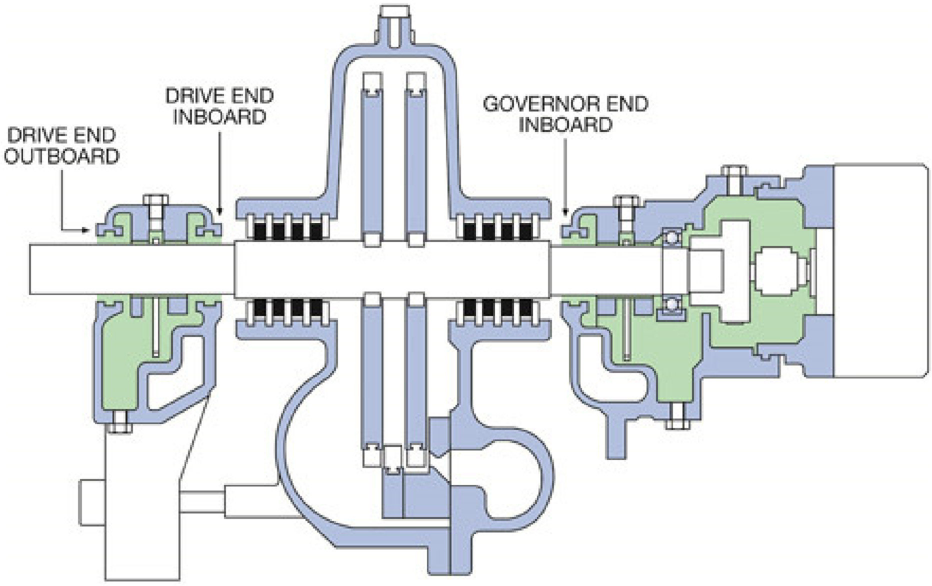

Fig. 1 Turbine Cross-section

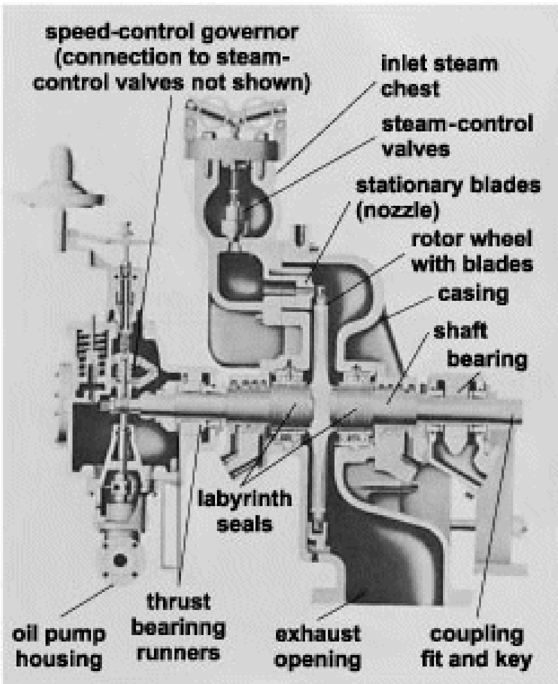

Fig. 2 Impact areas for turbine missiles.

DAMAGE ANALYSIS TECHNIQUE

A number of experimental as well as analytical research has been done to determine the volume of the debris. Kar [10] has suggested a formula in which the debris is taken as frustum of cone where the top diameter is considered to be equal to debris diameter is given below:

$$\theta = \left(\frac{D}{t^{1/3}}\right) 45^\circ \leq 60^\circ$$

Recht and Ipson Formula [11,12] is derived on the basis of conservation of energy and momentum. It forecasts the residual velocity of missile, V_r as

$$V_r = \left(\frac{W}{W + W_t}\right)(V_i^2 - V_p^2)^{0.5}$$

Where W is the missile mass, W_t is the mass of target material. The initial velocity is given by V_i and V_p is the missile's perforation threshold velocity [13]

The numbers of experiments were done on rigid cylindrical missiles and concrete targets by French and suggested a relationship as below:

$$V_r = \left(\frac{W}{W + W_t}\right)^{0.5}(V_i^2 - V_p^2)^{0.5}$$

Ballistic Research Laboratory (BRL)[14] has also determined a formula for steel targets where the equivalent thickness, t_{eq} is defined as

$$t_{eq} = t + 6.0\, t_{sp}^{0.5625}$$

Where t is thickness of the concrete barrier and t_{sp} the scab plate respectively. A typical view of the debris and missile orientation can be viewed from WTC event.

Fig. 3: WTC Debris orientation

CONCLUSIONS AND RECOMMENDATIONS

Undoubtedly, it is important that understanding of the orientation of the missile generated from a turbine generator is important from safety point of view of the other equipment. The typical analytical methods have been evolved from a number of practical turbine missile experiment.The typical values for various missile sizes may reach to about 100 m/s which can cause severe damage to the structures around Turbine Generator.

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