Investigation of Hydraulic Effects on Pipe Wall Thinning at Orifice Downstream in Piping System

Background

Pipe wall thinning is an important problem for the integrity of piping system in nuclear and thermal power plants. Among several wall thinning phenomena, Flow Accelerated Corrosion (FAC) requires considerable care since it has the potential for catastrophic pipe rupture. FAC is often observed at typical elements where turbulence is generated, such as orifice downstream or elbows (Fig.1). However, detail profile of turbulence in those elements or correlation of hydraulic factors and FAC are not presented clearly in previous studies. Quantitative prediction of FAC susceptible regions and hydraulic effects on FAC would help establishing effective FAC measures and appropriate pipe wall thinning inspection.

Objectives

To investigate FAC susceptible regions, where considerable care is required, and hydraulic effects on FAC; Orifice downstream region is the present target as a typical FAC susceptible element in piping system of power plants.

Principal Results

1. Evaluation of FAC susceptible region

Visualization experiments and numerical calculations were conducted for the pipe flow through orifice with contraction area ratio of 0.37. The following findings were obtained by comparing the experimental and numerical results with actual pipe wall thinning data of PWR power plant [*1].

(1) Numerical results showed good agreement with the experimental results of averaged flow features in the pipe and statistic turbulence profile in near-wall region. Consequently, the numerical calculation method was confirmed to be applicable to the flow in actual plant piping system (Fig.2).

(2) From results of the present studies and external experiment [*2], reattachment point of the flow separation in the orifice system showed a slight shift towards the downstream side with the increase of Reynolds number. The reattachment point was estimated to be about 2.5 times of the pipe diameter from the orifice, at the utmost, in the actual plant piping condition (Fig.3).

(3) By referring the actual plant pipe thinning data, the most susceptible region to FAC in the orifice downstream seems to be limited within the flow separation region. Therefore, conservative pipe thinning management will be possible by inspecting the region within 3 times of the pipe diameter from the orifice, as regulated in the current JSME (The Japan Society of Mechanical Engineers) code [*3].

2. Investigation of hydraulic factors affecting FAC

(1) Turbulent kinetic energy is, presumably, an important factor affecting FAC, since its profile along the wall agrees with that of the actual plant pipe thinning data by FAC (Fig.4).

(2) Maximum wall shear stress along the FAC susceptible area was predicted less than 10 Pa (Fig.4). This fact clearly describes that FAC is a totally different phenomena from erosion that represents mechanical failure of pipe walls by fluid impact. This finding contributed to establishing technical materials [*4] which supplemented the JSME code.

Future Developments

Turbulent properties in piping elements will be investigated, heading for the establishment of quantitative evaluation method for pipe wall thinning by FAC.

Main Researchers: Kimitoshi Yoneda, Ryo Morita, Ph. D.,
Research Scientist, Nuclear Power Generation Technology Sector, Nuclear Technology Research Laboratory

Reference

K. Yoneda and R. Morita, 2006, “Investigation of Flow Characteristics Affecting on Pipe Wall Thinning (Part 1) -Turbulent Properties at Orifice Downstream in Single-Phase Flow- ”, CRIEPI Report L05007 (in Japanese)

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*1：Data from ruptured condensate piping of Mihama 3 power plant (METI (Ministry of Economy, Trade and Industry), Aug. 2004)
*2：Experiment conducted by Kansai Electric Power co. ltd., imitating ruptured condensate piping of Mihama 3 (METI, Sep. 2004)
*3：Codes for Power Generation Facilities -Rules on Pipe Wall Thinning Management- (JSME, Mar. 2005)
*4：State of the art of Technical Knowledge about Pipe Wall Thinning (JSME, Sep. 2005)

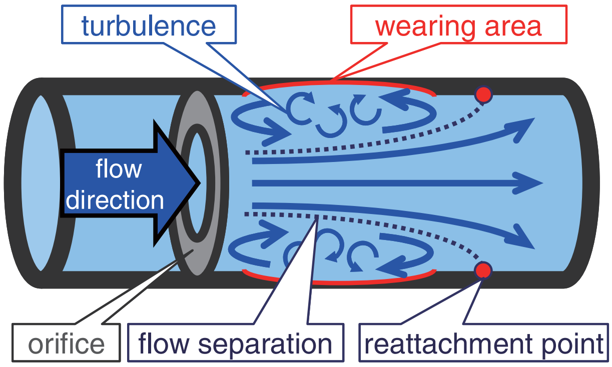

Fig.1 Typical flow field in orifice downstream and wearing tendency by FAC

Contracted stream jet from the orifice creates separation region with inverse flow along the wall. The point on the wall surface, where the flow direction switches from backward to forward, is so-called reattachment point.

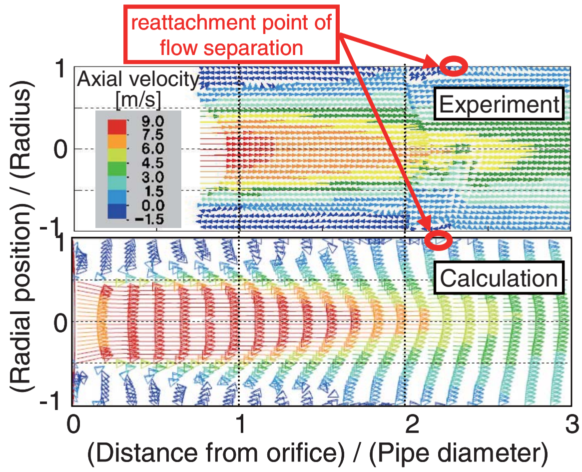

Fig.2 Average axial velocity profile in orifice downstream

Experiments were conducted with acrylic transparent pipe of 100mm in diameter, and the flow was visualized and measured by PIV (Particle Image Velocimetry) method.

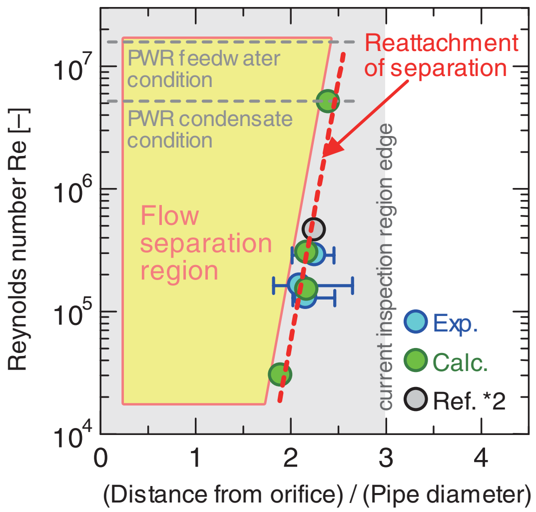

Fig.3 Profile of reattachment point of flow separation in orifice downstream

Reynolds number (Re) was defined as follows:
Re = (pipe diameter) x (average velocity in the pipe) / (kinetic viscosity of water)

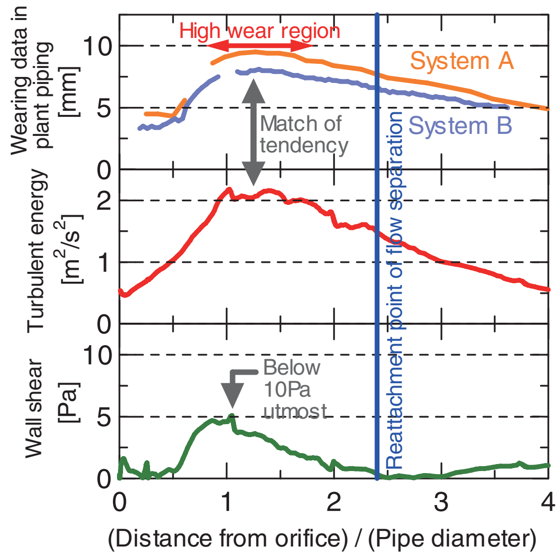

Fig.4 Comparison of actual FAC wearing data to calculated turbulent energy and wall shear

Numerical calculations were conducted with actual PWR plant condition of temperature and pressure.