A comparison between two ways of blocked pump losses prediction: correlations and one dimensional CATHARE pump model

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Long Abstract

Introduction

For design and safety purposes, the CEA is currently working on Sodium Fast breeder Reactor (SFR) thermal-hydraulics. A SFR is a complex system designed to both produce electricity and minimize nuclear waste generation compared to the current Pressurized Water Reactor technology. SFRs are composed of three circuits: a primary circuit full with liquid metal sodium and designed with a “pool” geometry, a secondary circuit mainly composed of sodium pipes and a third circuit where another fluid is flowing (water or gas) which permits converting thermal energy into electricity. The primary circuit is composed of huge components such as primary pumps, which are about fifteen meters high and hang from a concrete plate into the sodium pool. As an illustration, figure 1 describes a typical SFR pump.

Primary pumps play a great role in transient dynamics. During Loss of Flow and Failure of a pump - grid plate connection pipe transients, at least one pump is supposed to stop on inertia or to get stuck. In this case, transient calculations are sensitive to blocked pump losses.

At the CEA, the CATHARE code is used for many SFR thermal-hydraulic calculations [1]. CATHARE 3 is a two-phase flow system-scale code based on three transport equations per phase: mass, energy and momentum [2]. Most often 6 equations representing continuous liquid and continuous gas are used, but some applications need to model a third field, such as droplets flowing in the continuous gas field (or bubbles in the continuous liquid phase). In this case, 9 equations are resolved. CATHARE is owned by 4 institutions (AREVA, CEA, EDF, IRSN) and mainly developed at the CEA for more than 30 years. This system code is able of describing the behavior of various fluids including light and heavy water, sodium, and non-condensable gases (helium, nitrogen, hydrogen…).

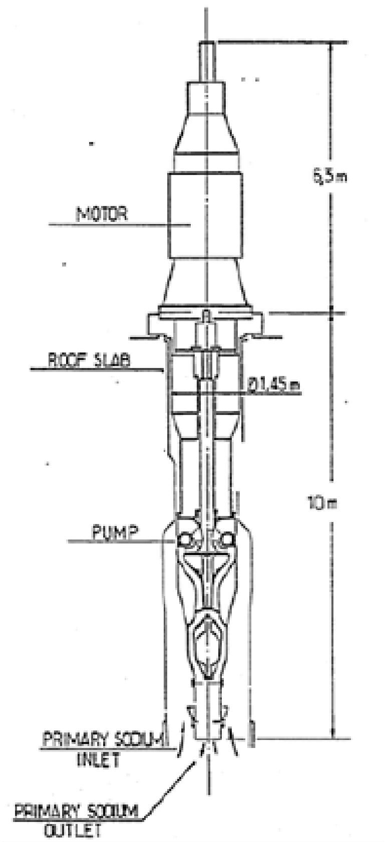

Figure 1: SFR primary pump

There are two ways to estimate blocked pump losses: a correlative way and a modelling way which permits the prediction of pump characteristics. In this article, both are used and compared together.

Blocked pump losses correlations in both direct and reverse flow have been developed by the CEA in the three last years. These correlations are based on losses values coming from 20 pumps for the direct flow and from 19 pumps for the reverse flow. The aim of the present article is to illustrate a comparison between the results obtained with theses correlations and those obtained with the recently implemented one dimensional pump model described below.

As it is really difficult and rare to have access to complete or degraded pump performance characteristics (4 quadrants, cavitation) the CATHARE development team recently chose to implement a one dimensional pump model in CATHARE 3. This model could become a great alternative when there is a lack of data coming from pump manufacturer. The computer development and validation of this model are part of a multiannual project supported by industrial companies. The one dimensional pump model contents is first based on the De Crecy 1983 proposition [3], whose aim was to predict light water reactor pump behavior when two-phase flow is entering the pump suction. The source terms involved in momentum and energy equations are the following: losses due to shocks, variable section, pre and post-rotation. Currently, the aim is not only to be able to model these last situations but also to describe the cavitation phenomena for centrifugal pumps and in particular liquid sodium fast reactor primary pumps.

Firstly, a sensibility study to blocked pump losses is presented. Two different SFR transients are calculated:

- Failure of a pump – grid plate connection pipe
- Loss Of Flow

Blocked pump losses in the two directions (direct and reverse flow) are modified in order to visualize the impact on the cladding maximal temperature.

Secondly, the recently implemented CATHARE one dimensional pump model is presented and calculations are analyzed.

Finally, the two blocked pump correlations (direct flow and reverse flow) are presented and results are compared to CATHARE one dimensional pump model calculations.

References

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