The Modelling of Chugging Loads in Pressure Suppression Systems

W. Schweiger
Gesellschaft für Technisch-Wissenschaftliche Datenverarbeitung mbH, Am Mühlanger 81,
D-8039 Puchheim, Germany

B. Schwinges
Gesellschaft für Reaktorsicherheit (GRS) mbH, Glockengasse 2, D-5000 Köln 1, Germany

Summary

Chugging occuring during a later period of a LOCA blowdown stems from collapsing steam volums within the pool. It is supposed that chugging produces high impact loads on the containment structure. Thus for evaluating the structural response one has to know the pressure-time history of such an impact. This paper is concerned with the description of the chugging model KSWING. It is believed that a thermodynamic instability, called spontaneons condensation initializes the chugging event. Comparison between KSWING-results and two different experimental results show good agreement in frequency content and pressure time history.

1. Introduction

The socalled pressure suppression system is an important part of the safety concept of boiling water reactor plants. In case of a loss of coolant accident (LOCA) this device will prevent an increasing pressure due to steam release within the containment. This is achieved by leading the steam via vent pipes into a wetwell, where an essential condensation process takes place.

During the blowdown which is the first and the shortest period of the whole LOCA event basically three different types of dynamic loads acting on the containment structure can be distinguished. In this sequence they are caused by vent pipe clearing and pool swell, by condensation oscillations and by chugging. It is believed that chugging produces the most severe loading conditions on the containment structure and therefore only this type will be discussed furtheron.

In searching for the response of the containment walls caused by chugging loads one is faced with two fundamental problems. Primarely one has to deal with a fluid - structure - interaction (FSI) problem and secondly one has to evaluate an appropriate load time history. Chugging loads are characterized by high pressure peaks in the pool due to collapsing steam bubbles in the vicinity of the vent pipe outlets. There are three typical frequencies associated with chugging phenomena, namely a slow periodic motion of the pool water, the socalled vent acoustic and a characteristic eigenfrequency of the fluid filled structure (which is normally the lowest one).

While the FSI problem commonly is attacked with wellknown numerical methods /1/, the treatment of the processes at the steam pool interface are either handled as a field problem /2/ or as a lumped parameter problem. The second way seems to be more economic, especially if one agress with the simplification that the resulting pressure from chugging is used as an external load, located in the vent pipe outlet and thereby neglecting the motion of the pool fluid (partially decoupled problem, /3/). This paper is concerned with the description of a lumped parameter modal for the according load evaluation due to chugging.

2. Description of the Chugging Model

The basic concept of the chugging model KSWING is a lumped parameter description using four nodes, namely the drywell, the vent pipe plus attached bubble, the pool fluid and the wetwell. The fundamental equations describing the model are the well known volume averaged nodal balances of mass and energy and a one-dimensionalized equation of motion for the pool fluid (modified RAYLEIGH equation). This equation of motion is responsible for one of the characteristic frequencies, the socalled chugging period. To account for the vent acoustic - another characteristic frequncy - the motion of the steam through the vent pipe is modelled by means of an unsteady BERNOULLIs equation.

The steam is considered to be in a thermodynamic equilibrium with the exception of the effect of spontaneons condensation which is described below. The essential condensation of the steam takes place at the steam-pool-interface by means of a very complicated thermohydraulic process. In the model this process is roughly approximated by using a simple heat transfer equation with an exponential increase of interface area to account for the chaotic behavior of this process.

It is believed that this chaotic hydrodynamic unstable process is initialized by a thermodynamic instability called spontaneons condensation (WILSON effect) /4/, /5/. When the steam is allowed to depart from equilibrium within a short duration which means that it behaves like an ideal gas in the thermostatic two phase region it is said to be in a supersaturated state. In this unstable state the spontaneons formation rate of condensation nuclei depends in an extremely sensitive manner upon the supersaturation of the steam. After reaching a critical supersaturation spontaneons nucleation occurs and a new saturated states is found within less than 0.1 /ms/. In KSWING this effect is modelled by allowing the steam to randomly depart from equilibrium within a certain time window after the steam-pool-interface has left the vent pipe outlet and to control the critical nucleation rate. A simple iteration process leads to a new thermodynamic equilibrium.

With the above described model (the full analytic description is given elsewhere /6/) one can calculate time-histories of the pressure at the steam-pool-interface, which can be used as external-forces in FSI-codes to evaluate the structural response. For this computation step a 3d-field description rather than a lumped parameter concept will be the adaequate tool.

3. Results and Comparison with Experiments

The model was tested against two different experiments namely the GKSS-Pressure Suppression Test M1 and the KWU-GKM-II Test 21 (details are given in /6/). It was found that KSWING shows good agreement with these tests both in frequency content and in pressure time history (see fig. 1 - 4). It is not surprising that the axisymmetric GKM test rig leads to better coincidence between theory and experiment than the GKSS rig shape. The reason for this seems to be mainly due tothe simplified description of the interface motion.
(There is a calibration error in pressure PRM of fig. 4).

References

/1/ ZIENKIEWICZ, O. C., BETTESS, P., "Fluid-Structure Dynamic Interaction and Wave Forces. An Introduction to Numerical Treatment," Int'l J. Num. Meth. Eng., Vol. 13, 1-16 (1978).

/2/ LANDRAM, C. S., McMASTER, W. H., GONG, E. Y., "Steam Chugging Calculations with the Pele-IC Code," UCRL - 86207, Preprint, (Oct., 1981).

/3/ MAYR, M., SCHWEIGER, W., "Dynamische Druckbelastung flüssigkeitsgefüllter Schalen," Forsch. Ing. Wes. 44, Nr. 2, 42-46 (1978).

/4/ SAITO, T., et al, "On the unsteady Phenomena relating to Vapor Suppression," ASME Publ. 74-WA/HT-47 (1974).

/5/ HA-VAN, L., SCHWEIGER, W., "Contribution to the Analytical Treatment of Steam Chugging," Heat Transfer in Nuclear Reactor Safety, Hemisphere Publ. Corp. (1982).

/6/ SCHWEIGER, W., "Analytische Beschreibung des Chugging-Modells KSWING-V," (Final Report, in prep. f. BMFT).

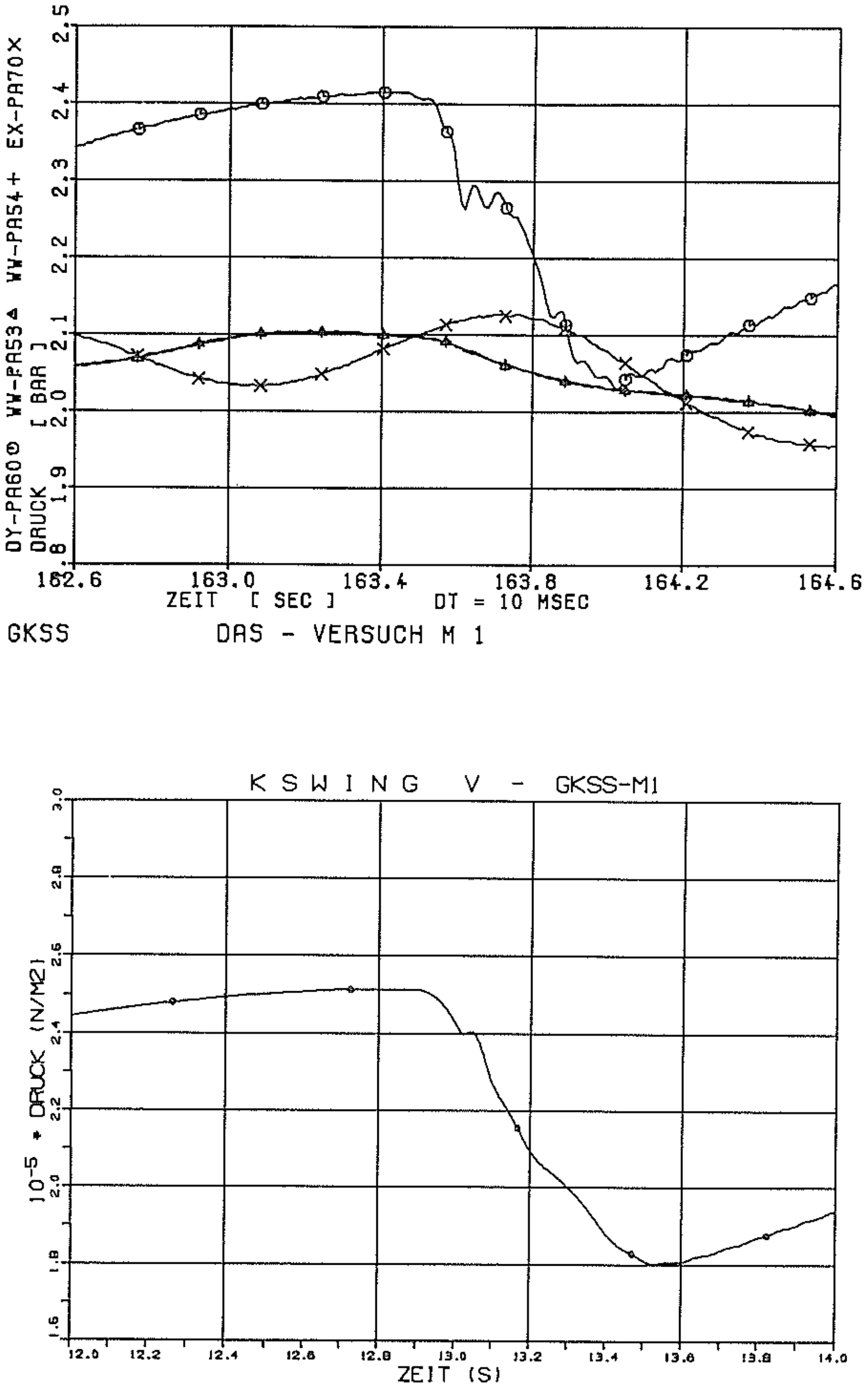


Fig. 1 Drywell Pressure PA60 of GKSS Test M1 compared with KSWING Result

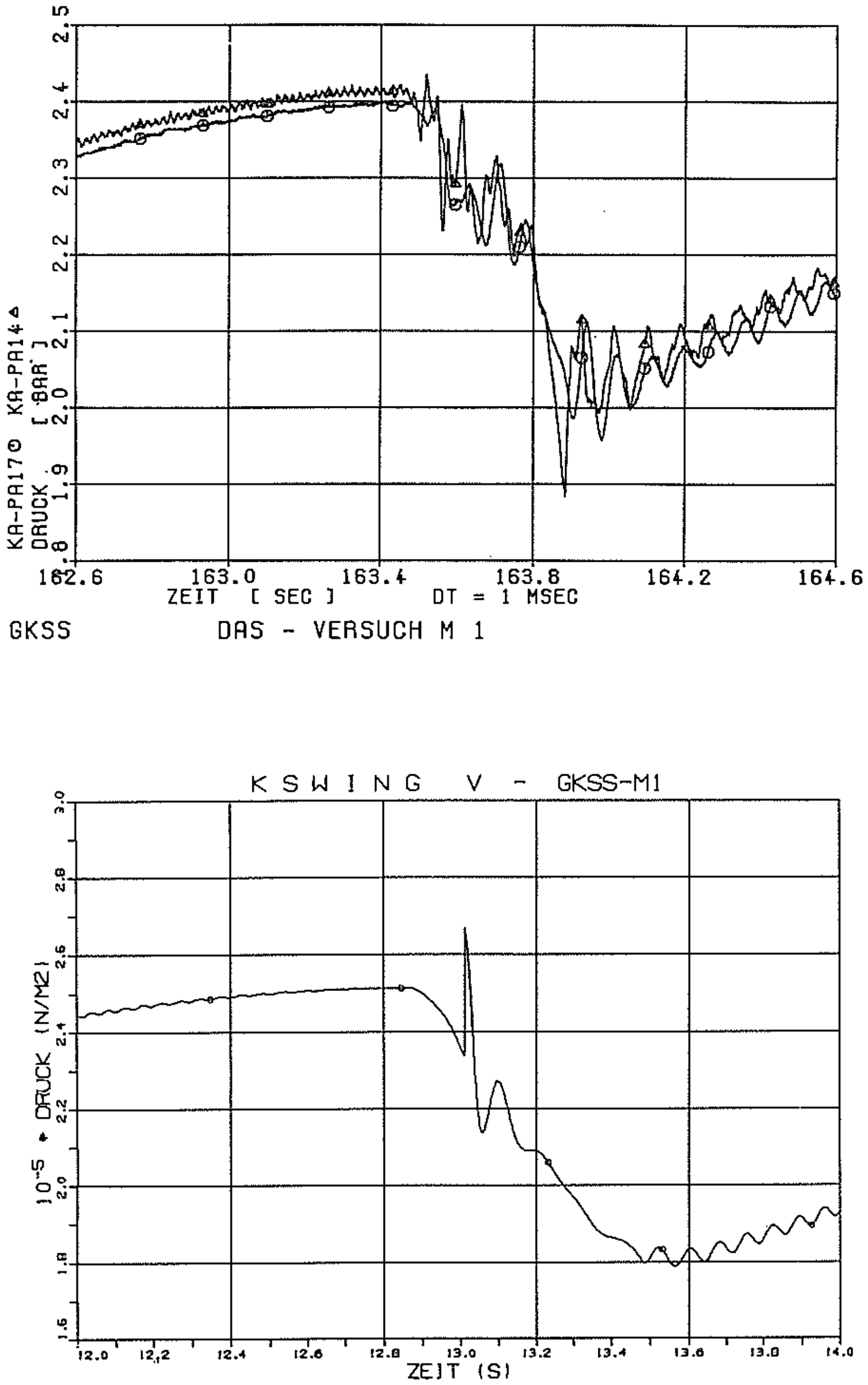
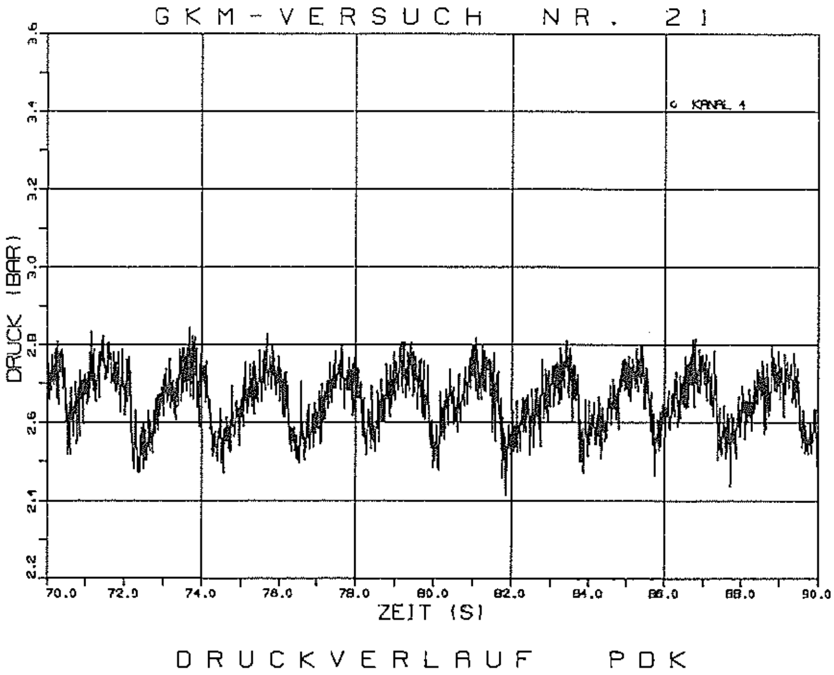


Fig. 2 Vent Pipe Pressure PA17 of GKSS Test M1 compared with KSWING Result



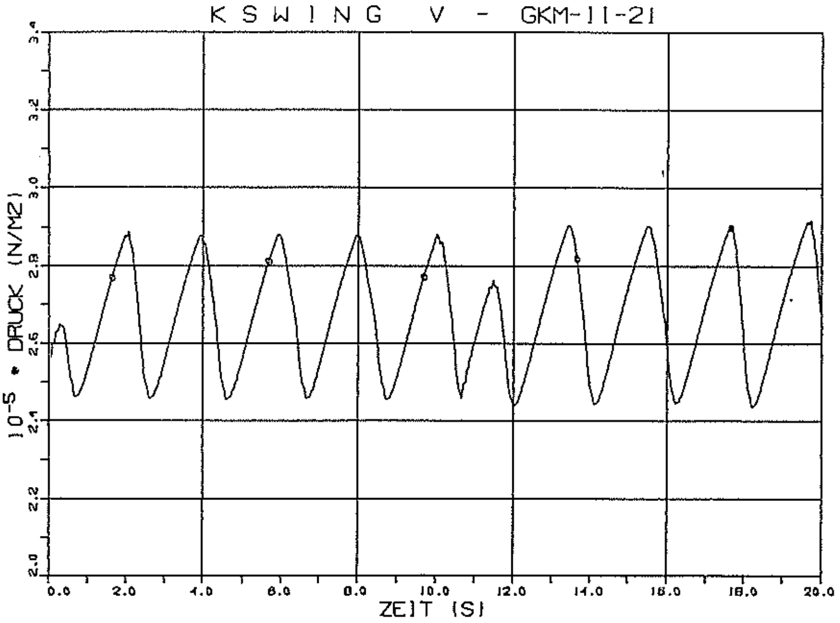


Fig. 3 Drywell Pressure of GKM-II Test 21 compared with KSWING Result

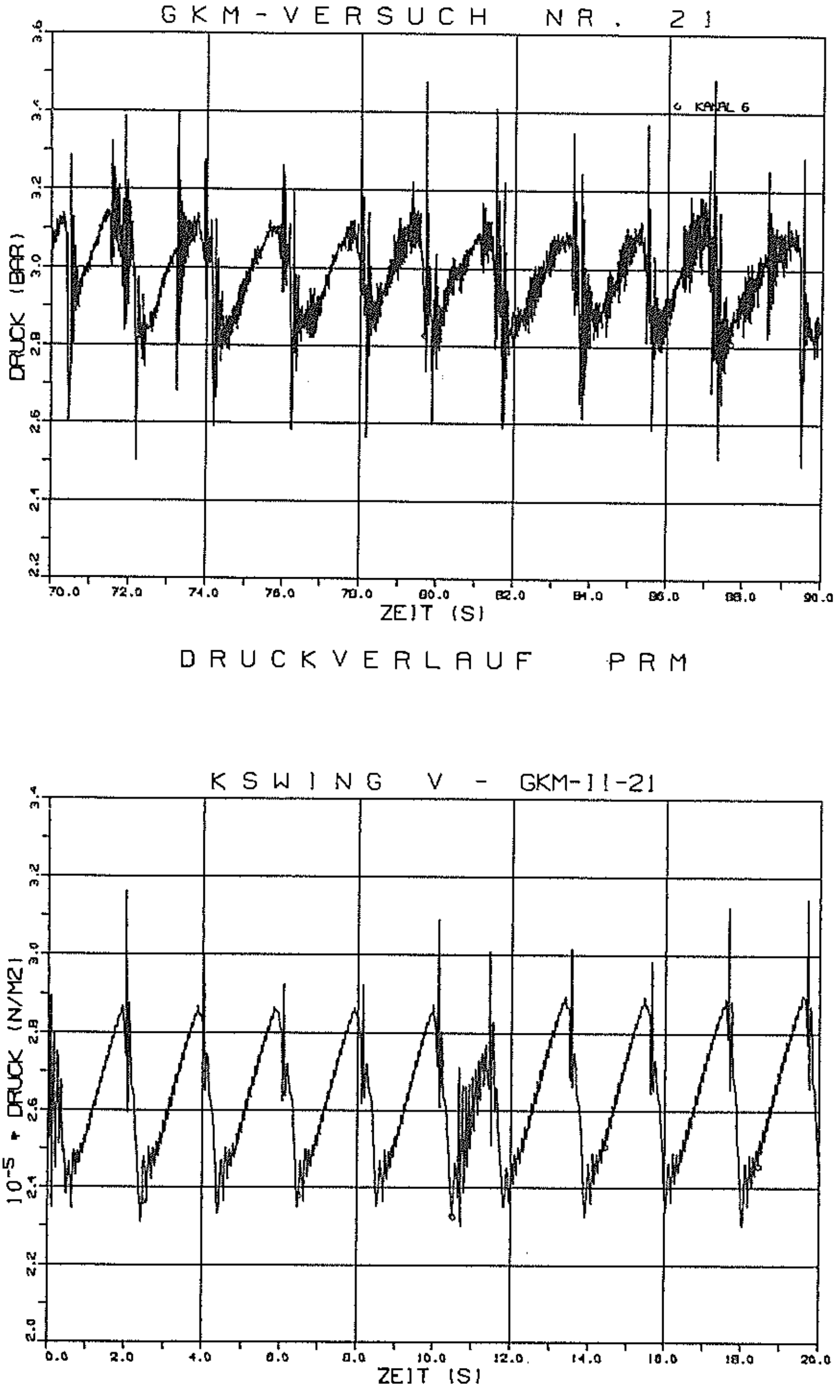


Fig. 4 Vent Pipe Pressure of GKM-II Test 21 compared with KSWING Result