AN ASSESSMENT OF RELAP5-3D USING THE EDWARDS-O’BRIEN BLOWDOWN PROBLEM

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AN ASSESSMENT OF RELAP5-3D USING THE EDWARDS-O'BRIEN BLOWDOWN PROBLEM

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Abstract

The RELAP5-3D (version bt) computer code was used to assess the United States Nuclear Regulatory Commission's Standard Problem 1 (Edwards-O'Brien Blowdown Test). The RELAP5-3D standard installation problem based on the Edwards-O'Brien Blowdown Test was modified to model the appropriate initial conditions and to represent the proper location of the instruments present in the experiment. The results obtained using the modified model are significantly different from the original calculation indicating the need to model accurately the experimental conditions if an accurate assessment of the calculational model is to be obtained.

Introduction

An important part of any computer code development effort is performing an assessment of the program's ability to predict measured data accurately. To aid in the assessment process, a series of standard problems based on experimental data has been established. One such problem, Standard Problem 1, is based on the Edwards-O'Brien Blowdown Test. [1]

Description of the Test

The Edwards-O'Brien experiments consisted of fluid depressurization studies in a straight pipe 4.096 m (13.44 ft.) long with an inside diameter of 0.073 m (2.88 in.). The pipe was filled with water and brought to initial conditions ranging from 3.55 MPa (500 psig) and 514.8°K (467°F) to 17.34 MPa (2500 psig) and 616.5°K (650°F). Standard Problem 1 was performed at nominal initial conditions of 7.00 MPa (1000 psig) and 513.7°K (465°F).

A glass disk at one end of the pipe was designed to rupture with a single shot from a pellet gun to initiate the depressurization phase of the transient. The time for the disk to fully open was estimated to be 1.0 ms. Following the experiment, a small amount of glass was observed around the circumference of the opening. Based on this, Standard Problem 1 stipulates that the break flow area be reduced by 13% from the pipe cross sectional area.

Fast response temperature and pressure measuring instruments were located along the length of the pipe. The instrument locations (gauge stations) were identified as GS-1 through GS-7 and were positioned as shown in Figure 1.

Data reported from the experiment included time dependent pressures at each of the gauge stations and temperature and void fraction information at GS-5. These parameters were measured for 600 ms. after the initiation of the depressurization.

Description of the Model

The calculational model used in this analysis was based on the edhtrk.i standard installation problem for RELAP5-3D. [2] The nodalization used in the installation problem consists of 20 volumes of equal length. The initial conditions are isothermal at 502.2°K (444.3°F) and 7.00 MPa (1000 psig). The flow area in the installation problem was approximately 6.7% less than the experimental value.

For this analysis, the nodalization was modified to model more accurately the geometry of the test, paying particular attention to the location of the installed instrumentation. The isothermal initial conditions were modified to reflect the actual enthalpy at the gauge stations as given by Hendrie. [3] The initial conditions for volumes between gauge stations were determined by linearly interpolating between the measured data. The
modified nodalization and initial conditions used in this
analysis are presented in Table 1 and shown graphically
in Figure 2. The pipe flow area was increased to model
faithfully the experiment.

The flow area at the rupture disk was taken to be 87% of
the pipe flow area. The abrupt area change option was
used to model the non-recoverable losses at the break.
The heat structures modeled in the installation problem were
removed as they were judged to have an insignificant
effect on the results owing to the extremely short
duration of the transient.

The semi-implicit time integration scheme was used for
all cases in this analysis. RELAP5-3D with no
developmental (Card 1) options was used in this
analysis. The Ransom-Trapp critical flow model with
the default discharge coefficients was used instead of the
Henry-Fauske model. [4]

Results

The RELAP5-3D calculations were performed using the
semi-implicit time integration scheme with a maximum
time step of 0.1 ms. The calculated pressures at each
gauge station using both the modified nodalization and
the installation problem nodalization are presented in
Figures 3 through 9 and compared with data. The
volume containing the gauge station (but not necessarily
at the volume center) was used in the installation
problem analysis. The calculated void fraction data at
each gauge station for each nodalization are presented in
Figures 10 through 16. A comparison of the calculated
void fraction and measured data at GS-5 is presented in
Figure 14.

The modelling changes that had the greatest effect on
the results were modifying the nodalization to model
more accurately the location of the installed
instrumentation and modifying the initial conditions to
reflect the initial temperature variation within the pipe.
The calculated pressure was least affected by these
changes. The void fraction was markedly changed at
some locations, particularly near the break, Figures 10
through 12.

Another factor affecting the void fractions history near
the break was the break flow. The predicted break flow
was shown to be very sensitive to these changes,
Figure 17. An additional calculation was performed to
determine whether the re-nodalization or the modified
initial conditions led to the erratic break flow behavior.
An isothermal case using the modified nodalization was
run and the results are presented in Figure 17. These
results clearly indicate that the erratic behavior was due
entirely to the modified initial conditions. However, it
should be noted that the erratic behavior in the break
flow did not result in erratic behavior in either the
predicted pressure or void fraction at the gauge station
locations.

A third variation of the modified model was evaluated
using the Henry-Fauske critical flow model. The break
flow in this calculation showed much less sensitivity to
the initial temperature distribution in the test section,
Figure 17. The Henry-Fauske model also predicted a
higher break flow during the initial phase of the
blowdown. The effect of the higher break flow on the
predicted void fraction at GS-5 is presented in
Figure 14. No significant improvement was seen in the
void fraction prediction.

The effect of changing the flow area, critical flow model
and pipe roughness had only minor effects on the
results.

Conclusions

A model of the Edwards-O'Brien Blowdown Test has
been developed and used in the assessment of the
RELAP5-3D computer code. Unlike previous models
used in the assessment, this model faithfully represents
the locations of the installed instrumentation and the
actual initial conditions present in the test. The results of
this analysis indicate relatively good agreement with the
experimental data.

The Edwards-O'Brien test was designed specifically to
assess the critical flow models used in computer
programs. This analysis indicated that the predicted
break flow was very sensitive to the initial temperature
distribution and, to a lesser extent, the nodalization used
in the model. Therefore, particular attention must be
paid to modelling the location of instruments in
experiments and to the determination of the correct
initial conditions to be used in the evaluation of transient
test data if an accurate assessment of the calculational
model is to be obtained.

Since break flow was not measured directly in the
experiment and the prediction of the measured
parameters was shown to be relatively insensitive to the
break flow behavior, it is difficult to determine which of
the break flow models yield the correct prediction of the
break flow. However, the results of the various analyses
show that an inadequate representation of the experiment could lead to incorrect conclusions regarding the adequacy of the model being assessed.

References


Table 1: Modified Nodalization for the Edwards-O’Brien Blowdown Problem (Standard Problem 1)

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BREAK LOCATION
Concrete abutment

Additional thermocouples (7 of 7) to monitor initial water temperature

Electric heating bands

Dimension

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Pipe internal diameter 2.88 in (73 mm)

Solenoid operated pellet gun

1" thick toughened glass disc

To vacuum pump for removing air from pipe prior to filling with water

 Provision at each gauge station (GS 1-7) for transient pressure and temperature measurements

To reservoir and Hydropump

Pressurising valve

Additional facility at GS 1 and GS 5 for transient void fraction measurements

Figure 1: Edwards-O'Brien Blowdown Test (taken from [1])

Figure 2: Modified Initial Temperature Profile
Figure 3: Pressure as a Function of Time at GS-1

Figure 4: Pressure as a Function of Time at GS-2
Figure 5: Pressure as a Function of Time at GS-3

Figure 6: Pressure as a Function of Time at GS-4
Figure 7: Pressure as a Function of Time at GS-5

Figure 8: Pressure as a Function of Time at GS-6
Figure 9: Pressure as a Function of Time at GS-7

Figure 10: Void Fraction as a Function of Time at GS-1
Figure 11: Void Fraction as a Function of Time at GS-2

Figure 12: Void Fraction as a Function of Time at GS-3
Figure 13: Void Fraction as a Function of Time at GS-4

Figure 14: Void Fraction as a Function of Time at GS-5
Figure 15: Void Fraction as a Function of Time at GS-6

Figure 16: Void Fraction as a Function of Time at GS-7
Figure 17: Break Flow as a Function of Time