project description

Uncertainty analysis (and more) in WANDA

assignment

WANDA, the pipeline software from WL | Delft Hydraulics, is the reference simulation environment for the evaluation of steady and transient flow conditions in pipe systems. WANDA is used worldwide by many consultants and production companies in the water, process, and oil and gas industries.

The increasing trend towards the risk-based design of pipe systems requires simulation tools that support uncertainty analyses of transient scenarios in the most flexible way. Many input parameters for transient models include some degree of uncertainty, and this leads in turn to uncertainty in extreme internal pressures. These output uncertainties have to be assessed in a risk-based design approach.

This R&D project developed a powerful script interpreter that enables the user to:

- run uncertainty analyses,
- perform a sensitivity analysis and
- generate a list of “child” cases from a “parent” case.

The new functionality has been explored and tested in several test-cases. An uncertainty analysis test-case is elaborated in this brochure.

The parameter script interpreter will be fully integrated in WANDA 3.60, which will be released in March 2007.

client

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period

February – December 2006

Unanticipated fluid transients may cause severe damage

H4402.20

WL | delft hydraulics

uncertainties in extreme pressure

Maximum and minimum pressures during critical transient scenarios, such as a full pump trip caused by power failure, are the key results for any surge analysis.

The standard design procedure to find the extreme transient system pressures is to select the *conservative* combination of input parameters that results in extreme values of the output parameters. Typical uncertain input parameters are the wall roughness, initial suction level, initial air vessel level and system boundaries. Unfortunately this standard procedure applies to simple straightforward systems only; i.e. a single transmission pipeline. The relation between parameter values and simulation results is not available a priori for more complex systems. Therefore multiple simulations must be performed for complex systems to quantify the sensitivity and uncertainty of the simulation results.

The parameter script functionality in WANDA supports this activity and automates the time-consuming work, associated with setting-up all model variations and extracting key results from the simulations.

The user only has to specify three data-items in a script-file to start the parameter script run:

- definition of input parameter groups that contain uncertainty,
- definition of key results,
- tabular specification of parameter values for the sensitivity or uncertainty analysis.

An example of a WANDA Parameter Script file is listed below.

```
* Parameter definition
5
'TIP_H','Pressure head at t = 0 [s]'
'SUCT_H','Pressure head at t = 0 [s]'
'DN1800','Wall roughness'
'Rough_wall','Wall roughness'
'Normal_pipes','Wall roughness'
*Output definition
5
'SAVEALL'
'pump','Pump speed','MAX'
'Normal_pipes','Pressure','MIN'
'pump_header','Pressure','MIN'
'pump_header','Discharge','MIN'
* Table of uncertain input parameters
6 !The number of parameter combinations is much larger in
reality
'01',20.9958,1.7992,0.8861,7.9118,0.3797
'02',21.3795,0.4311,0.4732,4.2254,0.2028
'03',21.6728,0.1740,0.6125,5.4691,0.2625
'04',29.7453,2.2243,0.9582,8.5560,0.4106
'05',23.9113,0.6529,0.5730,5.1166,0.2455
'06',25.9643,0.0336,0.3554,3.1732,0.1523
```

uncertainty analysis application

A concise sensitivity analysis and uncertainty analysis has been performed for a full pump trip scenario of a large treated sewage water outfall pipeline (15 km, ∅ DN1800), that is being upgraded. This outfall line includes a third party tie-in with known flow rate, but unknown pump data. Therefore the head-flow relation of this boundary is uncertain. Furthermore the wall roughness of the outfall pipeline may rise significantly between two consecutive pigging operations. Finally the static head of the system is marginal and therefore the suction level variation between the minimum and maximum allowable water level may affect the results. The example parameter script file above shows the input parameter definition, the output definition and part of the uncertainty table.

With 3 different input parameters and 4 selected outputs, the individual parameter variation identifies 12 (3 x 4) input-output relations. As an example, Figure 1 shows the minimum flow at the discharge side of the pumping station. If the suction level prior to pump trip is lower than 1 m NAP, then a temporary negative flow develops through the damped check valves.

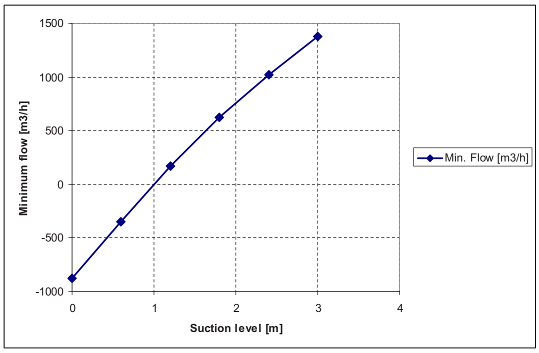

Figure 1: Temporary negative flows develop, if the pump failure occurs at suction levels below 1.0 m NAP

The uncertainty analysis has been carried out with a triangluar distribution of the wall roughness and uniform distributions of the other parameters. The correlation coefficients between the input parameters and the minimum system pressure immediately shows that the suction level explains most of the variation in the minimum pressure; this correlation coefficient, R, is 0.96 (see figure 2), while the other coefficients are less than 0.3.

The resulting uncertainties in the minimum pressure in terms of average and standard deviation and possibly other statistical quantities can be used in a quantitative risk assessment or probability based (re)design of the pipeline system.

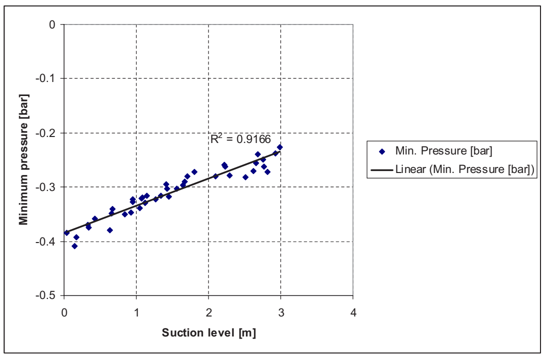

Figure 2: Minimum pressure variations are highly correlated with suction level uncertainties

This application demonstrates the practical relevance of the parameter script functionality for pipeline design studies.

WL | Delft Hydraulics

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