MODELLING VORTEX FLOW CONTROL DEVICES

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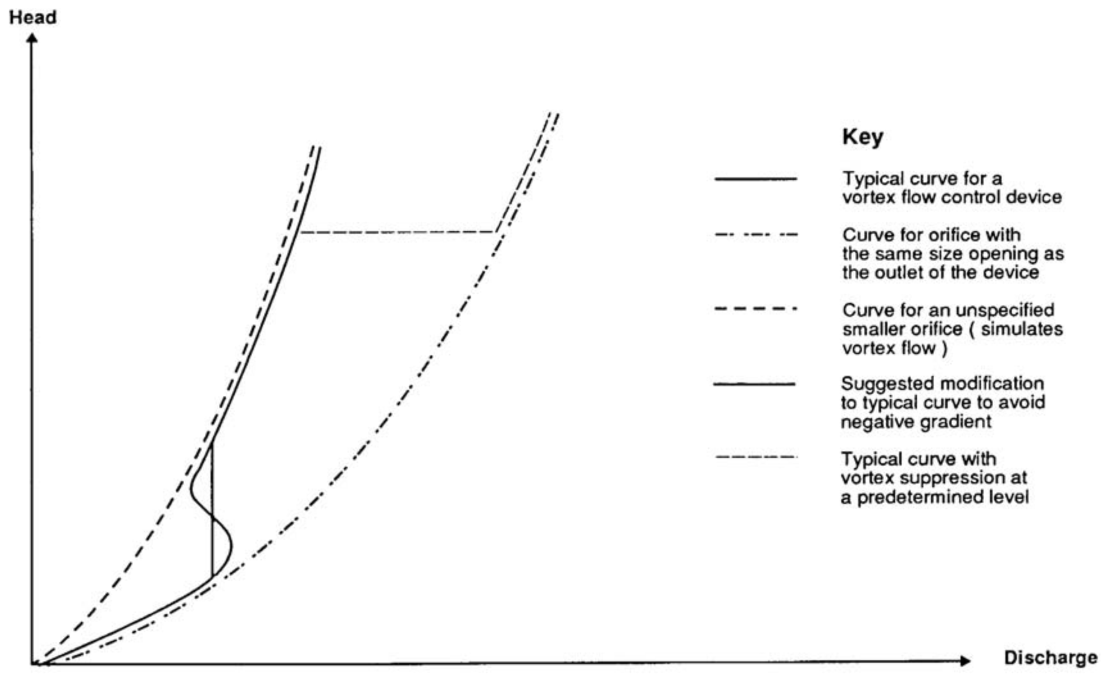
1. INTRODUCTION

Vortex flow control devices (e.g. the Hydrobrake ®) are a relatively recent development. They generally consist of a stainless steel unit with no moving parts and operate by directing the flow to rotate inside a cylindrical vessel towards a central outlet. This generates a vortex with an air filled core which allows the openings to be larger than the equivalent conventional orifice, reducing the likelihood of blockages.

At low flows, before the vortex is initiated, the discharge characteristic follows that for an orifice with the same area as the opening in the device. As the head increases the vortex initiates, and after a period of instability the discharge characteristic follows the curve for an orifice of a smaller area. Producing a 'kickback' on the curve (see Fig 1). An optional feature allows the vortex to be suppressed at a predetermined level. When this occurs, the discharge characteristic will revert to that of the larger orifice. This feature may be useful to increase flow downstream just before the onset of upstream flooding or when a tank is full.

If the outlet from the device becomes drowned downstream then this will affect the performance. If the depth downstream is less than 1.2 times the outlet diameter it is claimed (Ref 1) that there is no effect on the discharge characteristic as the air filled core of the vortex still vents to atmospheric pressure.



Above this level the effect on the characteristic is dependant on the head upstream of the device. At low heads the vortex will collapse and the characteristic will revert to that of the larger orifice. This will also occur if there is a negative head across the device. With high heads upstream of the device the vortex remains but with increased air pressures inside the core. This reduces the operating head to the differential head across the unit.

In general the vortex control will pass forward greater flows before the vortex is initiated than an orifice set to pass forward the same flows at higher heads when the vortex has been initiated. In some cases this can result in considerable savings in the volume of upstream storage required.

2. MODELLING VORTEX FLOW CONTROL DEVICES

2.1 Introduction

Vortex flow control devices can be modelled as the continuation outlets on on-line or off-line tanks with the various simulation programs. They can be represented in one of four ways:

i) As an orifice with an area equivalent to the reduced flow area of the device. This gives a reasonable approximation over the working range of the device other than at very low heads (before the vortex is initiated) or when the vortex has collapsed. This method is an approximation which ignores any potential savings in upstream storage due to increased discharge before the vortex initiates,

ii) Using a limiting discharge downstream to design to a maximum flow. This method is even more of an approximation than the first method. This is very simplistic representation of the head discharge curve and may significantly underestimate the volume of storage required. For this reason this method is not recommended.

iii) By defining a head discharge relationship for the continuation or return pipe using a user defined head discharge relationship.

iv) By specifying the Hydro-Brake option in Win*Des* or Win*Dap*, giving the values of design head and the maximum flow for for that head.

For initial design or planning purposes it is suggested that method i) is used. If the reduced storage is not likely to be significant then this may suffice. The reductions in storage are unlikely to be significant where:

a) The device is to be designed to operate at high heads and low flows, or

b) where the required storage is small.

Where a more rigorous analysis is required then methods (iii) or (iv) should be used.

2.2 USE OF HEAD DISCHARGE CURVES

One limitation of most software is that it cannot simulate curves where there is a negative gradient (i.e. where the flow decreases for an increase in operating head). A modification has therefore to be made to the curve in the area where the vortex is initiated; (see Figure 1).

Users should note that the flows are calculated from the difference in head between the upstream and downstream sides of the device.

As usual when modelling tanks users should be careful to check the results for possible mathematical instabilities.

a) WALLRUS-SIM

When using this facility in WALLRUS the user should note that the program will potentially use both the user defined head discharge curve only after initialisation. During the initialisation the software uses orifice data. The continuation outlet from the tank should therefore be modelled as an orifice having the same area as the outlet from the vortex flow control device. A discharge coefficient in the range 0.65 to 0.7 (Ref 1), should be used together with an invert level such that the centre of the outlet is aligned with the centre of the pipe.

Details of the head discharge curve as a set of flow values for a fixed increment of depth. Values should be given for the whole range of likely operating heads as the software will calculate the discharge based on an extrapolation of the highest two values in the data series where the head goes outside the range of values specified. If it is desired to cause the vortex to collapse at a certain level then the values should increase rapidly above this level. The orifice plate information should be be entered in the tank as a negative number to signify that a head discharge curve is used. This is used during initialisation.

b) HydroWorks

Head discharge relationships in can be defined in HydroWorks. The control is physically located in the node.

Details of the head discharge curve as a set of flow values for a fixed increment of depth. Values should be given for the whole range of likely operating heads as the software will calculate the discharge based on the highest value in the data series where the head goes outside the range of values specified. If it is desired to cause the vortex to collapse at a certain level then the values should increase rapidly above this level.

c) MOUSE

Head discharge relationships in can be defined in MOUSE. The control is physically located at the first computational point (for flow) in the specified pipe.

A set of flow values (at the regulation point) versus depth (levels at the control node) define the curve. It is important that the specified values covers the range of possible depths. Errors can result if the range of depth values is insufficient.

d) MicroDrainage Win*Des*/Win*Dap*

Head discharge relationships can be defined in Win*Des* and Win*Dap.* The software requires values to be entered for the full range of likely heads up to a level 300mm above the cover level. In the unlikely event of the head exceeding this point, the software will extrapolate from the last two values.

3. REFERENCES

1. Smisson, R P M, 'The modelling of Hydro-Brake™ flow controls using WASSP'. WaPUG Spring Meeting 1987.