SAFETY ANALYSIS ON A PRISMATIC BODY UNDERGOING FLOW-INDUCED VIBRATION USING 'DECISION TREE'

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1. INTRODUCTION

Aerodynamic characteristics of a square section without and with interference are important from the practical point of view. Investigations by Gowda and Ajith Kumar [1], Takeuchi and Matsumoto [2] and Schneider and Farge [3] reveal some of the interesting features of interference excitation. In the present analysis, the available literature data [4] on interference effects on the flow-induced oscillations of a square section cylinder (test cylinder, side dimension B) due to another square cylinder (interfering cylinder, side dimension b) have been analyzed using a data mining tool called 'Decision Tree' (hereafter referred to as DT) to assess the structural safety. The data utilized pertains to interference studies on the test cylinder for various relative positions of the interfering cylinder (L/B,T/B;Fig.(1)) and for four different size ratios (b/B=0.5, 1.0, 1.5 and 2.0; Fig.(1)). All the data were gathered at a single value of reduced velocity (=10.0) and at a single value of Scruton number (=3.2). In structures which could be subjected to large wind-induced oscillations (especially inhabited by human beings), public comfort and safety deserve prime consideration. This paper is primarily intended to contribute information on structural safety utilizing a square section cylinder to represent a typical building structure. Such an attempt could not be seen in the previous studies.

2. RESULTS AND DISCUSSION

The results are presented in Figs. (3)-(6). From these plots, the input data points for the DT are extracted and analyzed. Figure 2 shows the DT generated using the J48 algorithm, A WEKA implementation of C4.5 algorithm [5]. In Figs.(3)-(6), only the maximum amplitude values are plotted (a/B, where 'a' is the maximum amplitude).

2.1 Classification of vibratory amplitude:

For the purpose of data analysis using DT in an attempt to assess the safety of the structure, the amplitude of vibration has been arbitrarily classified as given in Table 1. However, in practical situations, the classification of amplitude needs more practical consideration with respect to the specific application. In this study, safety of the structure is assessed only with respect to the vibratory amplitude.

Table1: **Classification of amplitudes and structural safety conditions.**

Sl. No.	**Class of Amplitude**	**Structural safety**	**Range of a/B**
1	Low (L)	Safest	$a/B \leq 0.25$
2	Intermediate (I)	Safe	$0.25 < a/B \leq 0.325$
3	Higher (H)	Marginally Safe	$0.325 < a/B \leq 0.38$

4	Critical (C)	Unsafe (critical)	a/B > 0.38

In the DT (Fig.(2)), the nomenclature shown (b/B, L/B and T/B) carry the same meaning as those shown in Fig.(1); letters ‘L’, ‘I’, ‘H’ and ‘C’ appearing in the leaves of the Tree indicate Low, Intermediate, High and Critical amplitudes (Table 1). Based on the data given as input, DT gives more or less a generalized decision and hence, suggests the strongest possibility of its occurrence. The root of the DT (Fig.(2)) is constituted by the parameter L/B as it posses the highest Gain ratio [5], indicating that it is the most prominent parameter influencing the structural vibrations, followed by T/B and b/B. Parametric combinations for various structural safety conditions (Table 1) are discussed in the subsequent sections. Most of the results presented here pertains to b/B>1.0 (the b/B≤1.0 cases are not presented except for ‘Safest structural conditions’, due to space restrictions).

2.2 Safest structural conditions

In real life applications, the severity of structural condition is mainly determined by the maximum amplitude of vibration which has to be suppressed or at least brought down to acceptable limits for safety reasons, by providing (planning) a suitable structural environment. In this context, based on the data analysis, the safest structural conditions are arrived as follows:

For b/B≤ 1.0, it could be seen that (Fig.(2)), when the cylinders are very close (L/B≤1.0, T/B≤0.25), the upstream structure could be assured of safety (typically see the results at Fig.(3) for b/B=1.0). For b/B>1.0, DT gives two parametric combinations to ensure a safe structural environment (i) when the cylinders are sufficiently close to each other with L/B≤2.5 and T/B≤2.0 (see Fig.(4); b/B=1.5, 2.0) (ii) when the cylinders are farther apart with 5.0<L/B≤7.5 and T/B≤3.25 (see Fig.(3); b/B=2.0). From the results, it could be inferred that, when the structures are situated very close to each other (L/B≤1.0, T/B≤0.25), the structure could be assured of safety irrespective of the size ratio (b/B).

2.3 Critical structural conditions

Due to aerodynamic interference of structures, very large oscillations could also result [6]. If the oscillations build up beyond a limit (‘critical’), it could cause structural damage. The limiting value for critical condition is very complex to arrive at using the conventional techniques, mainly because the coupling between the oscillating body and the flow field around it is highly non-linear. It is found that DT (Fig.(2)) is capable of giving crucial information (critical conditions) contained in data as discussed in the following sections:

For b/B>1.0, in general, for these cases, the possibility of occurrence of critical condition is higher at L/B>3.0, as suggested by the DT. DT provides a quite interesting unsafe combination with 3.0 < L/B ≤ 5.0 and T/B≤ 3.25 for 1.0<b/B≤1.5 (Fig.(2)); typically, the results at Fig.(3) (for b/B=1.5) illustrates this finding of the Tree. It could be further observed in Fig.6 also where, for b/B=2.0, at L/B=8.0, for T/B ≤ 3.25, considerable vibratory amplitude persists.

2.4 Marginally safe conditions

All the structural conditions just below the ‘critical’ conditions are classified as ‘marginally safe’ conditions (Table 1). Accordingly, the parametric combinations are identified leading to ‘marginally safe’ conditions. At the upper limit of ‘marginally safe’ condition, the structure would start to become ‘unsafe’. Hence, ‘marginally safe’ structural condition could be considered as an ‘alert message’ for preventive actions. Only a few cases are presented here.

As the DT points out, for b/B>1.0, there is a higher possibility for the structure to experience ‘marginally safe’ conditions. At closer longitudinal spacing (L/B≤3.0) with 2.0 < T/B ≤ 3.25, structural environment could persist in ‘marginal safe’ conditions (Fig.(2)); results at Fig.(4) for b/B=1.5 and 2.0 indicates this possibility. Again, in the range of size ratio 1.0 < b/B ≤ 1.5, for the configurations with 5.0 < L/B ≤ 9.5 and 0.75 < T/B ≤ 3.25, the Tree points out that the structure would be in the 'alert' stage; results at Fig. (5) for b/B=1.5 (at L/B=5.5) clearly indicates this decision of the Tree.

Other parametric combinations for ensuring structural safety could be obtained from DT (but, not presented here due to space limitations).

3. CONCLUDING REMARKS

From the data analysis using Decision Tree, the following conclusions are drawn.

1. It has been found that among all the parameters affecting the severity of flow-induced oscillations (thus the structural safety), the tandem spacing ratio (L/B) is the most prominent one. In the order of importance as suggested by the DT, L/B is followed by T/B (transverse spacing ratio) and then, b/B (size ratio).
2. For L/B>3.0, the Tree indicates a higher possibility for the occurrence of critical (unsafe) conditions when compared to the cases with L/B≤3.0.
3. When the structures are situated very close to each other (L/B≤1.0, T/B≤0.25), the upstream structure could be assured of safety irrespective of the size ratio (b/B).

In practical conditions, factors such as change in the wind flow velocity, support conditions, change in the wind direction, any other structural modifications etc could influence the excitation of the structure which have not been considered in the present study. However, the same procedure (as adopted in the present study) could be used to analyse the data and to arrive at some key conclusions on structural safety, incorporating additional parameters. Accordingly, the structural environment could be better planned to ensure safety.

ACKNOWLEDGEMENTS

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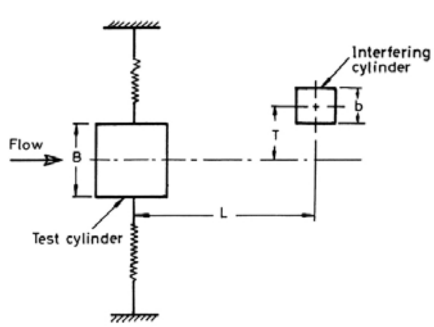

Fig.1 Schematic sketch of the configuration tested

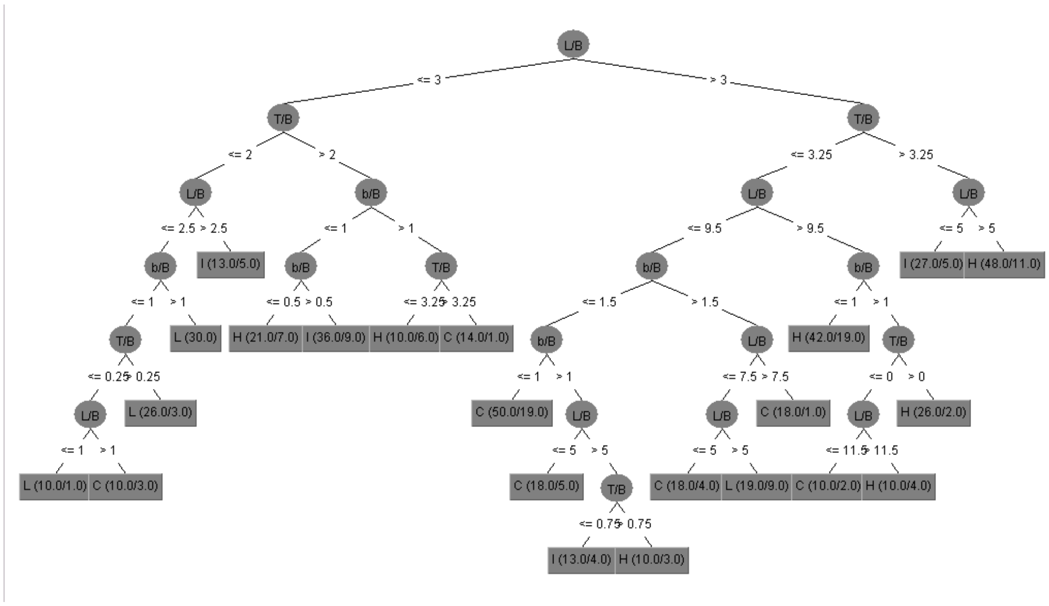

Fig.2 Decision Tree

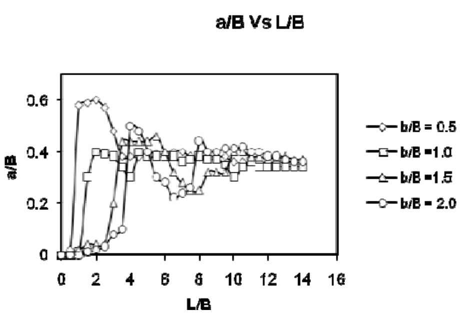

Figure.3 Results for tandem arrangement

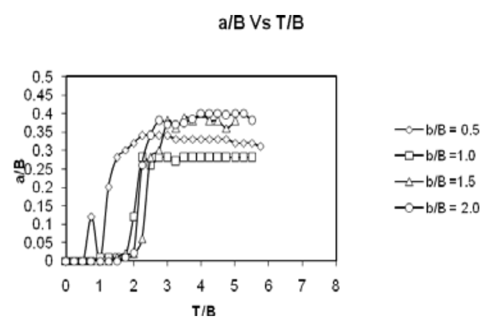

Figure 4 Results for side-by-side arrangement

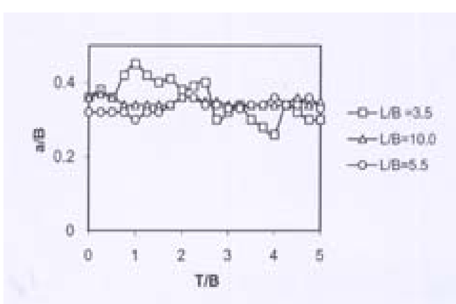

Figure 5 Results for staggered arrangement; b/B=1.5

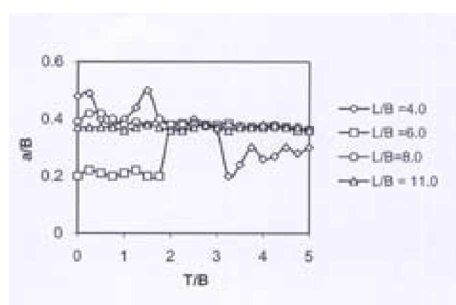

Figure 6 Results for staggered arrangement; b/B=2