Measurement of the radiation impedance of a pipe with a circular flange

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Jean-Pierre Dalmont
Université du Maine

Measurements of the Radiation Impedance of a Pipe with a Circular Flange

Jean-Pierre Dalmont and Nicolas Joly

Institut d'Acoustique et de Mécanique de l'Université du Maine, 72085 Le Mans cedex 9

Abstract: This paper presents measurements and calculations of the radiation impedance of a tube ended in finite circular flanges. Both results are in a good agreement and show that the diffraction by the edges as a significant influence on this impedance.

INTRODUCTION

The theory of the radiation impedance of a circular pipe is well known for the case of an infinite flange (1) and the case of an unflanged pipe (2). As in practice a tube without thickness and an infinite flange can not be realized it is interesting to know how a finite flange behaves between these two limit cases. Our aim is to evaluate the radiation impedance, especially the equivalent length correction, of a circular pipe ended with different finite circular flanges. This has been done by both measurements and numerical calculation.

MEASUREMENTS

The experiment consists of a measurement of the input impedance of a tube of length $L = 85\text{mm}$ and radius $r = 10\text{mm}$ ended in a circular flange of thickness 20mm. This has been done with the sensor described in (3) using the calibration procedure described in (4). The radiation impedance Z_r is deduced from the measured input impedance Z_m by the relation:

$$Z_r = \frac{Z_m - Z_L}{1 - Z_m Z_L} \text{ with } Z_L = Z_c \mathrm{th}(\Gamma L), \tag{1}$$

where Z_c and Γ are respectively the characteristic impedance and the wave constant of the tube (see (5) for numerical values). The equivalent length correction DL is defined with:

$$kDL = \mathrm{Im}\,[\mathrm{arctanh}(Z_r)] \text{ where k is the wave number.} \tag{2}$$

NUMERICAL SIMULATION

The numerical calculation using the Boundary Elements Method (BEM) has been done using the software RAYON (6). A tube of length $L = 100\text{mm}$ and radius $r = 10\text{mm}$ terminated by a circular flange of thickness 3mm has been modeled. A flat piston, moving with a given velocity and radiating on one side only, has been located at the beginning of the tube. The pressure on the piston is proportional to the input impedance Z_m of the tube and the radiation impedance Z_r is calculated using equation (1). We note that because the software does not take into account viscothermal losses the wave constant Γ is reduced to the wave number k ($\Gamma = jk$). We verified that the influence of the thickness of the flange on the radiation impedance is negligible.

RESULTS

Results are presented on figure 1 for 6 different flange radii: 11, 12, 15, 20, 30 and 50 mm. Measurements and BEM calculation are in a good agreement but both results do not tend to the low frequency limit of the radiation impedance because of electrical and numerical low frequency noise respectively. Oscillations in the measurements are due to remaining calibration errors. Results show that the radiation impedance is significantly different from the case of an unflanged pipe even for small flanges. It is noticeable that the curved obtained are not limited by the case of the infinite flange and the case of the unflanged pipe. Oscillations can be observed on the curves which seem to be related to the radius of the flange. This suggest that a theoretical model of the radiation impedance should take into account the diffraction by the edges of the flange and that the impedance of large circular flanges can not be approximated by the impedance of an infinite flange.

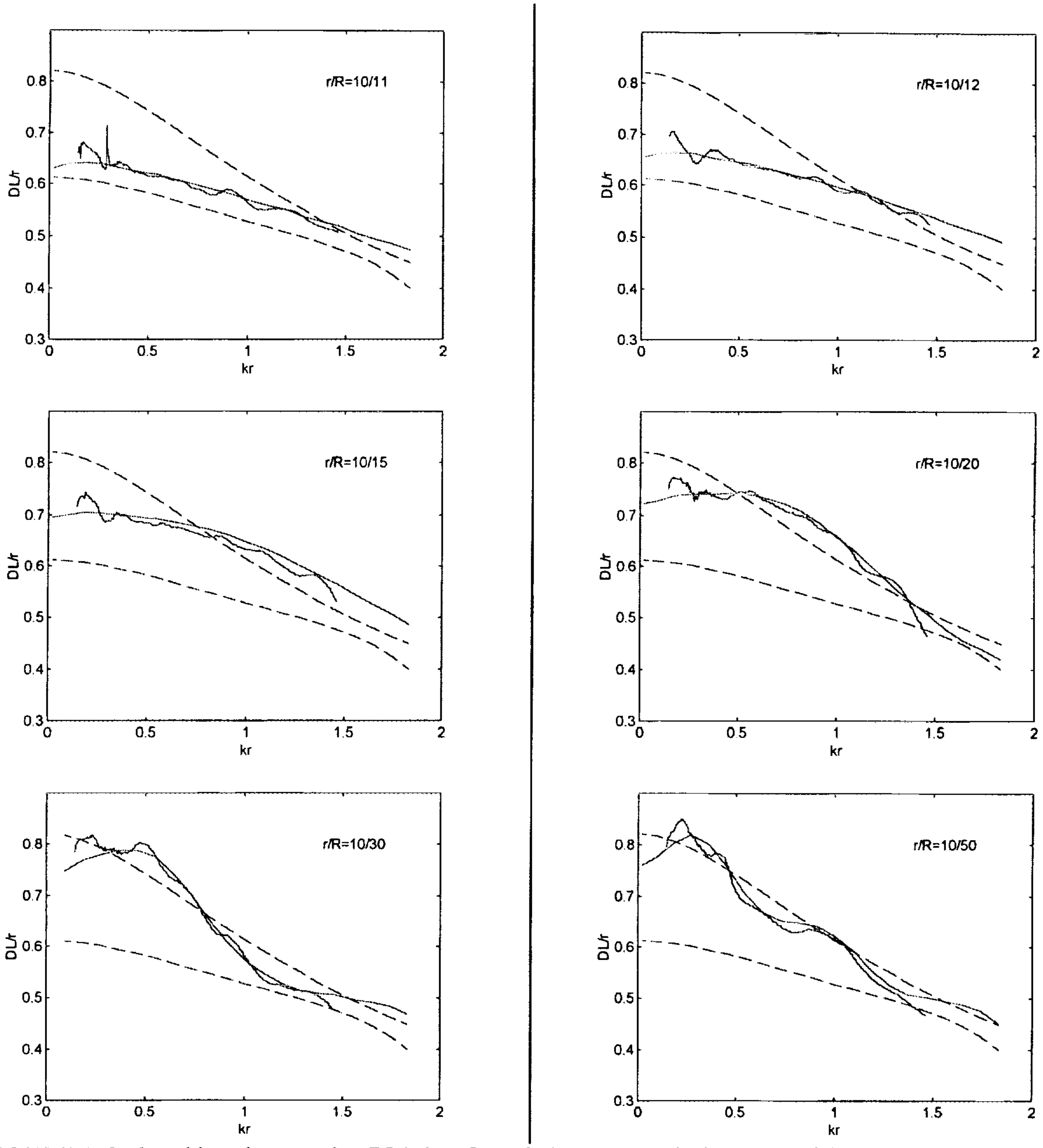

FIGURE 1. Reduced length correction DL/r (see formula 2, r = 10mm is the radius of the tube) versus reduced frequency, kr, for 6 different flange radii R

______ Experiment (noisy) and BEM calculation; ------ Infinite flange (upper) and unflanged (lower). Formulas for infinite flange and unflanged cases can be found respectively in (1) and (5).

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