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Wind effect on grooved and scallop domes

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ABSTRACT

This paper numerically studies the wind effect on grooved and scallop domes. The introduction of a groove on a spherical dome causes abrupt change on its wind pressure coefficient (Cp) in the vicinity of the groove. The sharpness of indentation varies with the position angle of the axis of the groove to wind direction and obtains its highest effect at 90°. This paper develops equations for the distribution of Cp on the surface of spherical, grooved and scallop domes with rise to span ratios [0, 0.7]. The results of the equations agree reasonably well with that of CFD.

1. Introduction

Scallop domes are a type of spherical domes that have alternate ridges and grooves that radiate from the centre of the dome (Fig. 1(a)). Due to its additional curvature, a scallop dome gains higher stiffness than the corresponding spherical dome. There are many ancient and modern examples of scallop domes constructed through the entire world (for example [1]). The term 'scallop' is coined to these domes due to their shape similarity to seashells and oysters [2,3]. Also, the term 'scalloping' refers to the process of transforming a spherical dome (or the base dome) to a scallop dome. A number of parameters define scallop and the other domes with similar geometries. Nooshin et al. [3–5] give the definitions, terminology, background and tools for shape generation of scallop and similar domes.

The scallop dome of Fig. 1(a) has two sets of meridional ribs (r_1) and (r_2), which divide the cap into five (equal) sectors. The arch r_1 defines the 'base dome' or the circumscribing spherical dome of Fig. 1(b), and the arch r_2 defines the grooved arch. Both domes Fig. 1(a) and (b), have identical rises. As the plan on the right-hand side of Fig. 1 shows, the base ring of the dome (b) circumscribes the base ring of the scallop dome of (a). Due to scalloping of the sectors, the seven (initially circular) circumferential rings are distorted. The distortion can occur vertically and/or horizontally. The vertical curving retains the circular plan of the dome. However, a type of horizontal curving will produce an outward 'bulging' of each segment (as that of Fig. 1(a)). The position of point c, the crown of the dome has not changed. The bulging has its maximum value at the base ring (which has the furthest distance from the crown), and gradually disappears as the rings get nearer to the crown. The arch distortion may follow various styles such as parabolic or sinusoidal law in a 'positive' or 'negative' sense. Additionally, the plan of scallop domes may have various shapes such as circular, elliptic, triangular, square … hexagon. The crown of the dome can be off-centre as well, and its segments can be uniform or non-uniform. Nonetheless, this paper considers the wind effect only on scallop domes with '(bulged) circular' plans, with their crown positioned at centre.

Various materials such as steel, concrete, aluminium, masonry and wood can be used for construction of load bearing structure of the domes. To cover and clad the domes, in addition to the above mentioned materials, membranes can also be used. The deformation of a membrane under the applied loads, varies according to its pre-tensioning stresses, however, in general, a membrane is classified as a large deflection element. This paper assumes that the structure and the surface of the domes have negligible deformations, consequently, the results of this paper may not be applicable to domes with membrane cladding.

Blocken [6], and Baker [7], outline the past, present and future of wind engineering and give a comprehensive account of the wind engineering. Among the enormous amount of work on CFD, this section mentions a limited number of research works on wind action on spherical domes and some types spatial structures. Uematsu et al. [8], studied the pressure fields on domes with

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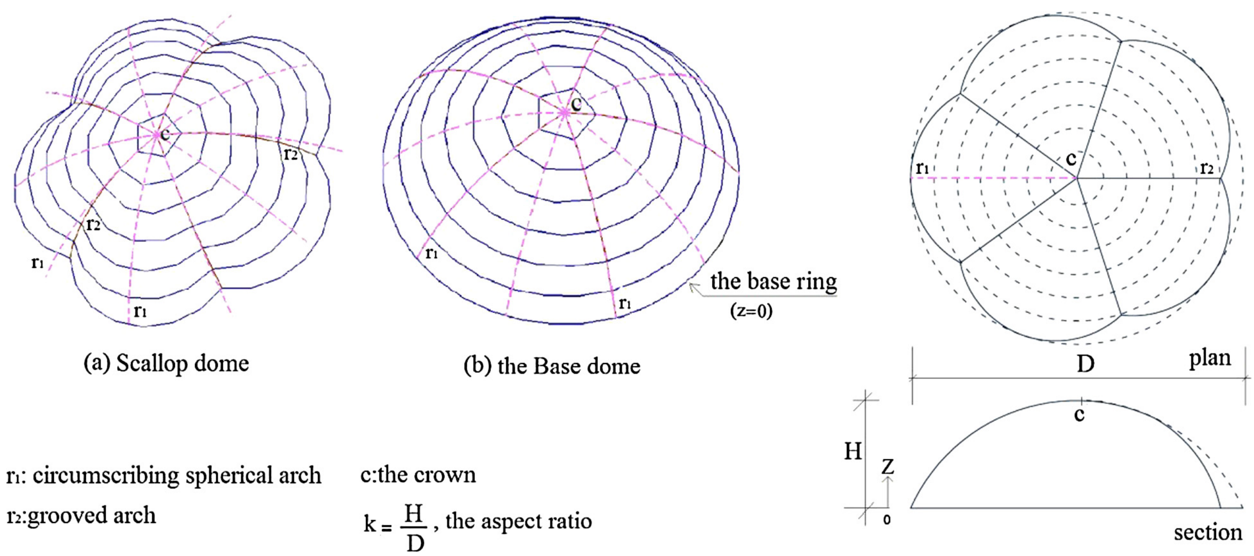

Fig. 1. A scallop dome (a), together with the circumscribing spherical dome (b).

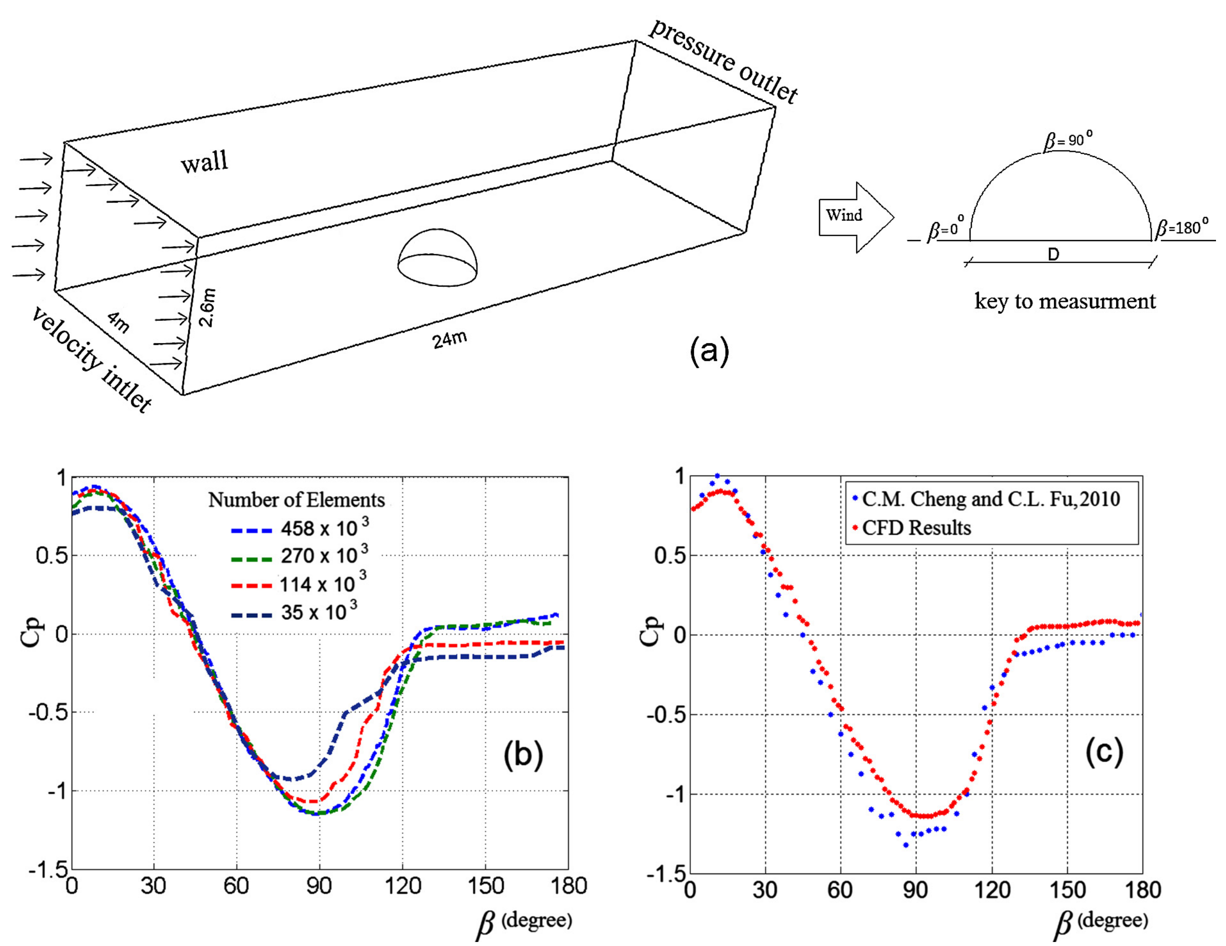

Fig. 2. A hemispherical dome within the wind domain.

rise/span ratios 1/20, 1/10 and 1/5. Cheng and Fu [9], investigated the effect of Reynolds number on the aerodynamic characteristics of hemispherical domes. Sun et al. [10,11], produced a model for the wind pressure spectra of domes, and reported the results of wind tunnel tests on various rise-to-span spherical domes. Vizotto and Ferreira [12], studied theoretically and experimentally the wind force on the hexagonal shells. Kateris et al. [13], calculated the wind pressure on 2-D cylindrical roofs and compared it with the provisions of Codes of Practice. Qui et al. [14], modelled the wind loads on cylindrical roofs and considered the effect of the