Effectiveness of a Dimpled Non-Even Surface For Oscillations Control For Flow Over Fissure: Numerical Analysis

Yogesh Madaria, Vijay Kanjarla

Abstract: To decay the pressure oscillation in the flow above an open crater, a passive control method, namely introduction of a dimpled non-even surface, is attempted. This paper presents the numerical analysis of the above system, which was undertaken to govern the effectuality of the said control modem. This work focuses on an open fissure with the length-to-depth ratio in proportions of 1: 2. To check the oscillation persuaded in the flow, a textured non-even surface is fitted at the upstream of the crater. The even and dimpled non even cases are compared for the flow instability and noise around fissure. Large eddy simulation coupled with acoustic model is utilized as a tool for this. The results obtained for even cases were compared with available experimental and computation data. On the basis of flow visualizations, it can be said that introduction of dimpled non-even surface upstream was significantly effective in suppressing the oscillations in fissure flow. Based on the comparison of flow filed structure in the even and dimpled non-even cases, the control mechanism of void oscillation technique is evaluated.

Keywords: fissure flow oscillation, passive control, numerical simulation, dimpled non-even surface.

I. INTRODUCTION

The current over an open fissure is subjected to pressure oscillations and this is an imperative bench mark problem for aero-acoustics and has been the focal node of substantial curiosity over the bygone decades. Owing to its extraordinary academic and practical connotation, quite a good number of investigations have been reported in this area. Still the adequate examination of the basic physical mechanism underlying oscillations govern over a wide assortment of flowing conditions, is lacking. The research scholars of fluid dynamics and aero-acoustics seems to be the determinate about the appropriate technique to accurately exempla rate the noise source and disturbances that cause oscillation. The most substantial challenge at this instance is to achieve suppression of various modes of oscillation. These concerns have made the flow induced fissure oscillation as a part of extensive research terminal.

II. LITERATURE REVIEW

The 3D incompressible flow pattern across a rectangular 2D open fissure was probed by Kyoungsik chang et al. [1]. This was the first computational work been successful in resolving all the three dimensional structures arising as a result of fissure oscillations in shear layer mode. Two kind of simulations at the same fissure Reynolds number (Re_D = 3360) were presented. In both cases, the resolved stress in downstream region governs those at the upstream region. The oscillation control methods for fissure flows can be broadly classified as active and passive controls. Active control is applied to suppress noise and this is adjustable as per various conditions [2,3]. Techniques like spoiler, mass injection and changes in the fissure are some of the passive control techniques which are quite easy to enhance and are extremely affordable. Alam et al. [4] modified the geometry of the fissure by fastening two separate flat surfaced plates to the wall right upfront of a squar eshaped fissure. The flat plates were attached in the horizontal plane and vertical positions. It was purported that the applied approach effectively reduced the fissure pressure oscillations. On the basis of their numerical and experimental exploration of the noise induced in a subsonic flow over the open fissure, Wang et al. [5] used a vented spoiler. They claimed that the technique was superior in noise reduction. To find the effectiveness of a passive control technique in suppression of oscillations for a supersonic open fissure flow, Chokani and Kim [6] performed a numerical simulation. Sarno and Franke [7] compared different techniques namely, static and oscillating fences with pulsating flow injections.. They found the application of static fences to be the most efficient approach. The results of experimental investigations on shallow and deep cavities flows at subsonic and transonic velocities show that out of the several passive venting techniques, the permeable floor and the permeable floor pooled with slot vents were found to have most significant effect on the distribution of the shallow fissure pressures [8]. Leading edge compression rams, expansion surfaces and mass injection techniques were analysed for their effects on suppression of oscillations in a supersonic fissure flow [9]. In another study, a cylindrical rod was suspended (along with a leading-edge fence) in the approaching boundary layer parallel to the leading edge. This technique was reported to play an important role in surface pressure clampdown features [10]. A numerical study was conducted

Revised Manuscript Received on February 22, 2019.

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to explore the mechanism and efficiency of noise control. This could result in weakening of the large-scale vortices which are impinged together [11].

Despite the fact that the aforementioned passive control techniques can subdue pressure induced at cavities and their corresponding oscillations, most of these regulatory devices cannot be expected to perform aptly in the practical flow conditions and are not successful in simultaneously suppressing multiple acoustic models. To cater this condition, many passive approaches like, deflector [4] and sub-fissure [12], were devised to suppress the oscillations. However, in case of deflector, increase in drag, cost and structure reliability are the issues which need consideration. While in case of sub-fissure, its presence in the stream direction will lead to the accumulation of sedimentary particulates and dirt, and the need for frequent cleansing or maintenance servicing shall arise. Therefore, there is a need to have some techno economical optimum technique to obtain a turbulence boundary layer of appropriate thickness without causing the drag to increase. In the past decade, introduction of non-even surfaces for reducing the pressure drag and friction, has received good attention [13,14]. The benefits of non-even surface are that the boundary layer resists the adverse pressure [15]. Henceforth dimpled non-even surface is implemented to enhance the thickness of the upstream boundary layer.

III. BOUNDARY CONDITIONS FOR GOVERNING EQUATIONS

The 3D Navier stokes equations for unsteady state Newtonian liquids at incompressible flow in Cartesian co-ordinate system are

Continuity:

$$\frac{\partial \bar{u}_j}{\partial x_j} = 0. \tag{2.1}$$

Momentum:

$$\frac{\partial \bar{u}_i}{\partial t} + \frac{\partial}{\partial x_j}(\bar{u}_j \bar{u}_i) = -\frac{\partial \bar{P}}{\partial x_i} + \frac{1}{\mathrm{Re}}\nabla^2 \bar{u}_i - \frac{\partial \tau_{ij}}{\partial x_j} + \bar{F}_i. \tag{2.2}$$

Where ui -velocity field , Re - Reynolds number, Fi is the body force.

The boundary conditions may be as follows;

At Inlet the wall normal and the span wise velocity components have been set to zero. Mathematically, $u_{in}=U, v_{in}=0, w_{in}=0$ where the subscript "in" indicates the inlet plane.

At Outlet a non reflective boundary condition (convective) is imposed which can be written as

$$\frac{\partial u_i}{\partial t} + U_c \frac{\partial u_i}{\partial x_c} = 0 \tag{2.3}$$

Here subscript c designates the direction normal to the outflow boundary. the convicting U_c is considered as constant across the outflow boundary.

At Upper boundary free-slipping condition is applied so the boundary state at this surface is,

$$v = 0, \frac{\partial u}{\partial y} = 0, \frac{\partial w}{\partial y} = 0$$

At Lower boundary no slipping condition is applied hence boundary state at this surface is u=0,v=0,w=0.

Disturbance strip

The disturbance strip is applied on the flat shape plate region inlet of the domain passing through normal wall velocity that is sinusoidal in nature with respect to time and span wise direction to induce or trigger the transition process following Alam et al.[10]

$$v = a_f \exp[-b_f (x - c_f)^2] \sin(\omega t) \sin(\beta y)$$

Where a_f, b_f and c_f are constants controlling the stream wise variation of the forcing ω is the frequency and β is the span wise wave number.

IV. COMPUTATIONAL DOMAIN

4.1 Geometrical model of a Dimpled Non-even surface fissure:

The probing is performed on a rectangular designed box with a enormous volumetric space and minor top-opening. The depth and length(L) of the fissure is D (=50mm), 2D respectively. And overall box dimensions are: 1) span wise width 3D, 2) depth 3D 3) length 11D.

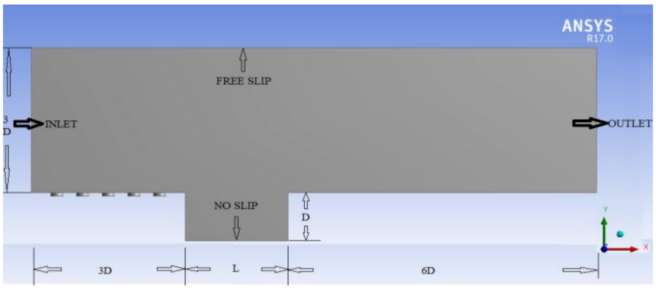

Fig: 1. Computational domain with applied boundary conditions

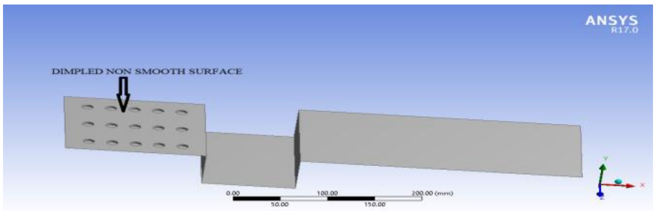

Fig: 2. Detailed view of the upstream porous non-even surface

As shown in fig the upstream leading surface modified by the creating of dimpled non-even surface, this dimples may inhibit a turbulent flow type boundary state condition and increases the thickness of the upper stream peripheral [15].

Meshing: in the meshing the grid is very fine near the surface of the fissure and is slowly stretched out away from it.

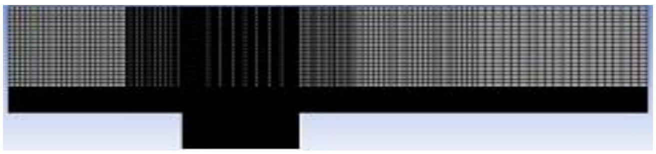

Fig: 3 Grid distribution

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3.2 Validations of computational domain

3.2.1 Mean flow characteristics

Fig 4 shows mean velocity profile along the longitudinal axis with the computational data of Chang et al.(2006) at five stages from x/D=0.02 to x/D=1.7.It is perceived that at all stages between the computational data content and the laminar forecasts by the present LES was feasible.

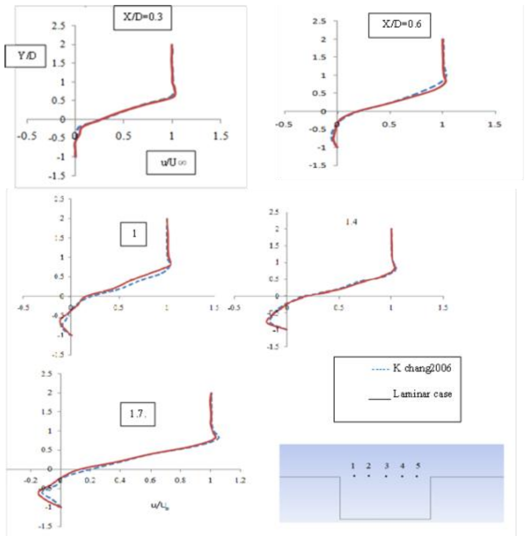

Fig: 4 Comparision of mean stream velocity profiles at different stations

And figure 5 shows about the normal stress $\overline{u'u'}$, $\overline{v'v'}$ at different the stream wise locations. A very good agreement is absorved at all the stations

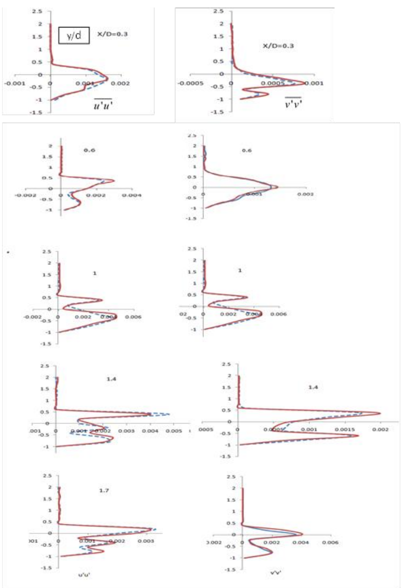

Fig 5 comparision of Reynolds stress at different stations

3.2.2. Velocity spectra

Fig 6 shows the time fluctuation status of the vertical velocity at five stations. From the we figure observe that the up to station 2 there is no substantial peak in velocity spectra. Downstream of the separation (starts from the station 3), peaks are observed indicating shear stress oscillating at the base frequency stage and its respective strouhal number St_D=fD/U=0.49 The amplitude of the above mentioned oscillations is investigated to be highly emergent in the stream wise course and furthermore, very small but still energetic frequency modulations were clearly observed. These mild energetic frequency oscillations and the main oscillatory frequency observed is due to shear layer interactions with the whirlpool like swirl motions inside the fissure (Chang et al. 2006).Fig 6 shows pressure spectra at stations 5 the strouhal number St_D=(0.36,0.70).

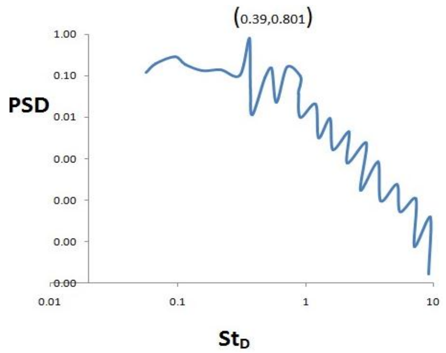

Fig 6 shows pressure spectra at station 5

V. RESULTS AND DISCUSSION

4.1 Meanflow characteristics

Figure 7 shows the comaprision of longitudinal velocity profiles between rough and even(regular) surface cavities. From the statistics were taken 4,5 stations as shown after flow had achived the state of dynamic stability. we don't observer much differences the remaining velocity profiles

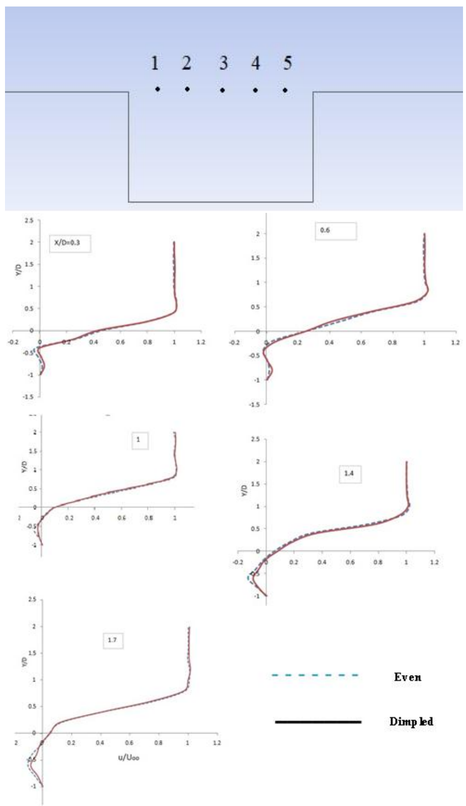

Fig 7 Comparison of mean scream velocity profiles at different stations

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4.2 Velocity spectra:

Figs 8 and 9 show Reynolds normal stress of u'u', v'v' respectevely at 5 stations. And we observed thatthe shear layer energy reductions starts from the station 3, so that we achive good fissure stabilty.

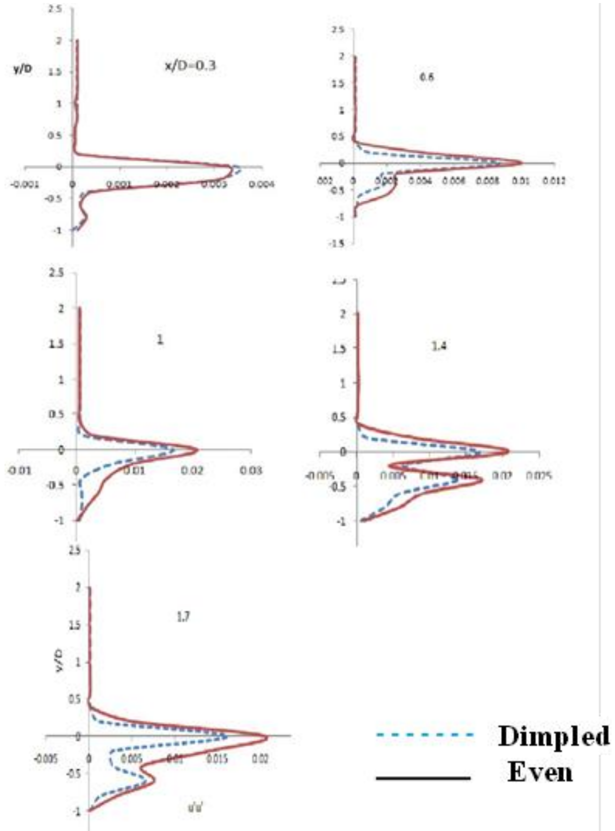

Fig 8 Profiles of u'u' at different stations

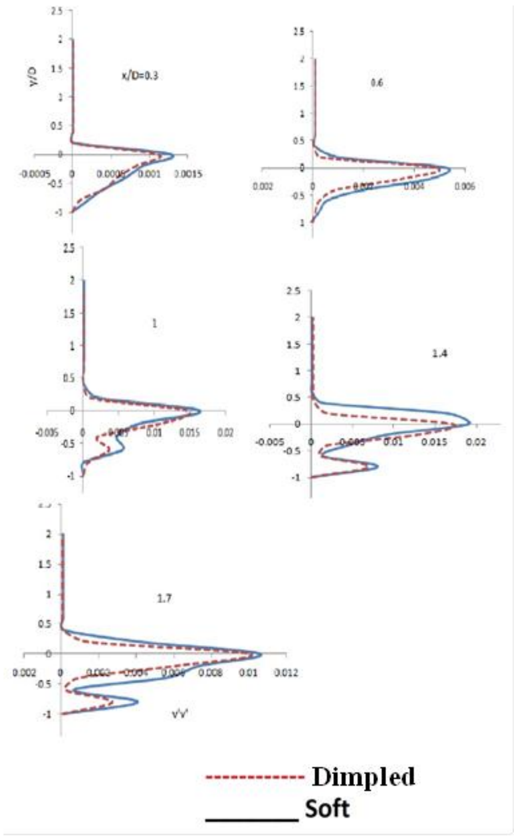

Fig 9 Delineations of v'v' at different stations

From the velocity history we observed at station 5th the strouhal number reduced from 0.39 to .30 so that the fissure oscillations are reduced effectively by the modifications. Fig 10 shows pressure spectra at station 5th.

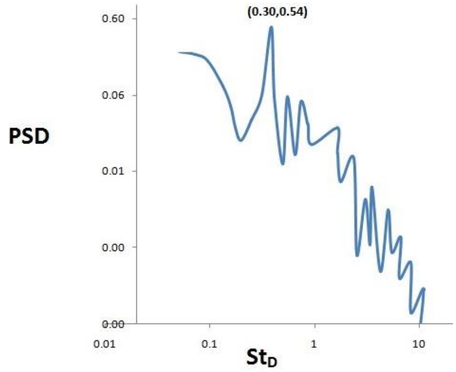

Fig 10 Pressure spectra at station 5th

VI. CONCLUSIONS

The publication demonstrates the porous non-even surface layer was very effectual in guiding and regulating the flow oscillation across the open fissure. For better clarity and substantiation of the above mechanism of the fissure flow oscillation, CFD was employed which in turn had analyzed the flow fields and flow fluxes induced by molting of irregular periodic vortices at the prominent peak edge of the fissure. The simulation during this control and regulatory mechanism projects that the porous non-even surface could make the upstream peripheral boundary layer change from the laminar peripheral boundary layer into turbulence peripheral boundary stratum. The oscillation course was effectively intimidated because of the characteristics of the porous non-even surface.

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