EXPERIMENTAL STUDY OF DYKE FORMATION USING SUBMERGED VANES

A DISSERTATION

Submitted in partial fulfillment of the
requirements for the award of the degree
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MASTER OF TECHNOLOGY
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WATER RESOURCES DEVELOPMENT

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled: **"Experimental Study of Dike Formation using Submerged Vanes"** in the partial fulfillment of the requirement for the award of the Degree of Master of Technology in Water Resources Development, submitted in Water Resources Development and Management Department, Indian Institute of Technology Roorkee, is an authentic record of my own work carried out during the period from July 2006 to June 2007, under the supervision and guidance of Dr. Nayan Sharma.

The matter embodied in this Dissertation has not been submitted by me for the award of any other degree.

Date : June , 2007.

Place : Roorkee

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Certified that the above declaration given by the candidate is correct to the best of my knowledge.

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ABSTRACT

Submerged vanes are thin rectangular-shaped low-profile foils, typically set at small angles to the main current and arranged in either single or multiple parallel arrays in the longitudinal direction. When installed in a channel bend they induce a helicoidal vortex that interacts with and weakens the centrifugally induced secondary current. The latter effect leads to reduced local erosion near the bend's outer bank. Physical model testing was performed to determine the effects of several parameters affecting submerged vane performance, including submerged vane height H, length L, angle to main flow direction α, vane streamwise spacing δs, vane transverse spacing from outer bank δ n.

Submerged vanes effectively stabilize channel bend erosion by reducing the scour depth at the outer bank, generating positive transverse bed slope at the outer bank, and by reducing the net sediment loss through the channel.

Increasing capital costs, emerging environmental concerns and rising maintenance expenses of the conventional river training works around the world have led to the development of submerged vanes in practice. In the last two decades, there has been an increase in the use of submerged vanes as sediment management devices as opposed to the traditional sediment control structures. Smaller vane dimension and the relatively better alignment with the flow field compared to conventional structures lead to the required modification of the flow field at less flow resistance and low structural as well as low maintenance cost and these are some of the reasons behind their increased popularity.

The formation of dike due to submerged vane in its downstream is the outcome of the application of submerged vane. The location of vane to safeguard the area will encourage the result oriented application of submerged vane. This area may be under the erosion or deposition due to natural behaviour of the alluvial stream. Safeguarding the area under

consideration can be achieved by enhancing the effect of the vane in that area. Erodible area can be protected by keeping the pressure side of the vane in the side of the area and area under deposition can be eroded by keeping the suction side in the side of the area. Thus, a heaps of sediment formed may be considered as dike formation. The dike formation in the downstream of submerged vanes is the real field application in the actual scenario at higher Froude number.

Experiments were performed in a 50 cm wide mobile bed flume using two types of plastic plates with varying angle of attack, aspect ratios. The vanes were made of plastic plates.The experiments were performed in non-uniform sediment and subject to clear water live bed conditions. Therefore, experiments were conducted to examine the effects of aspect ratios at different lower angles of attack on dike formations in flow depth, discharge intensity, vane, height and length, their shape and sediment size, in clear water conditions.Three sizes of rectangular submerged vanes were taken for the study. All the vanes were of equal heights and different lengths.

Keeping the submergence ratio (T/D = 0.75) and velocity of flow constant , the experiments were done at lower angles of attack 15°, 20° and 25°.

Angles used : 15°, 20°, 25°

Aspect ratios (H/L) used : 0.33, 0.25, 0.20

It was found that maximum height of dike was formed at aspect ratio 0.33 and angle of attack 25° (Exp A3). and minimum height of dike was formed at aspect ratio 0.33 and angle of attack 15° (Exp A1).

The contour plotting was done by surfer and shown here in this chapter. The 3D view of the dike is also shown here supporting with the photographs of the dike.

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NOTATIONS

A	cross-sectional area of grid;
B	channel width;
B/d	channel width-depth ratio;
d	pre-vane flow depth;
d_{50}	median diameter of sediment;
D	scour depth;
F_D	sediment Froude number;
F_r	flow Froude number;
g	acceleration due to gravity;
H	vane height;
H/L	aspect ratio of the vane;
$\vec{i}, \vec{j}, \vec{k}$	unit vectors along X,Y,Z axes;
L	vane length;
MOM	moment of momentum;
m	mass;
N	number of vanes in lateral arrays;
$\vec{R}$	location vector;
T	water depth above the top of vane;
T/d	degree of submergence;
t	thickness of vane;
U	mean flow velocity;

Vx, Vy, Vz time-average Velocity components in X,Y,Z directions, respectively;

X,Y,Z cartesian axes;

x,y,z streamwise, transverse and vertical coordinates, respectively;

Symbols

α vane angle of attack;

δ_b vane-to-bank distance;

δ_n vane spacing across the stream;

δ_s streamwise spacing of the vanes;

ρ_w density of water; and

η exponent of Froude number.

Chapter 1

INTRODUCTION

1.1 GENERAL

Sediment control in alluvial channels, the control of sediment movement, scour, and deposition, is one of the most difficult problems encountered by river engineers. Bed scour along the outer bank of river bends frequently causes undermining of the banks and loss of land. Deposition of sediment in the river bed often reduces flood-conveyance capacity of river and interferes with navigation. The thalweg in a braided stream often switches from one side to other. Conventional practices for river training are not only costly but also ineffective in many cases. Spurs constructed at one place may also induce changes in upstream or downstream of that reach making them river environmental unfriendly.

Submerged vanes stabilize a channel reach without inducing changes upstream or downstream of that reach. Smaller vane dimension and the relatively better alignment with the flow field compared to conventional structures lead to the required modification of the flow field at less flow resistance and low structural as well as low maintenance cost. They are constructed on a river or stream bed and set with an angle of attack to the direction of flow to create secondary current. The vanes can be laid out to make the water and sediment move through a curve as if it were straight. Vanes may not be visible in time as they become buried by depositing sediment, and aid the stream in doing the work by redistributing the flow energy to produce a more uniform cross-section without an appreciable increase in the energy loss through the reach and also are effective even after they are buried by depositing sediment.

Submerged vanes may be considered as alternative device to the traditional structures. Vane designed system changes in flow depth occurred by transporting sediment sideward/transverse direction without changing overall channel characteristics rather than downstream, while many traditional structures for sediment control produce a stream wise redistribution of sediment and a change in the flow.

1.2 EARLIER RESEARCH

The main difficulty in the treatment of these problems is the absence of cost-effective, low-maintenance and environmentally acceptable sediment control structures related to river training. Principal obstacles to amelioration of the conventional practices eg. spurs and groynes, revetments etc. for river training are not only costly but also ineffective in many cases.

Conventional structures have many limitations in respect of cost and suitability. In the case of deep and narrow rivers, where depths are considerable, solid spurs become expensive and may cause undesirable flow conditions.

The submerged vanes (Fig. 1) have been developed to meet the above problems and these have been successfully employed in other countries. The submerged vanes are small and submerged foils aligned at an angle to the flow to modify the near-bed flow pattern and redistribute flow and sediment transport within the channel cross section.

In the last two decades, there has been an increase in the use of submerged vanes as sediment management devices as opposed to the traditional sediment control structures. Smaller vane dimension and the relatively better alignment with the flow field compared to conventional structures lead to the required modification of the flow field at less flow resistance and low structural as well as low maintenance cost and these are some of the reasons behind their increased popularity.

The submerged vanes function by generating secondary circulation in the flow, which alters the magnitude, and direction of the bed shear stresses and causes a change in the distributions of velocity, depth and sediment transport area affected by vanes. They are constructed on a river or stream bed and set with an angle of attack to the direction of flow to create secondary current. The strongest circulation will give the maximum effects of submerged vanes at optimal angle of attack.

The vanes can be laid out to make the water and sediment move through a curve as if it were straight. As per Odgaard and Spoljaric (1986), significant changes in depth can be achieved without causing significant changes in cross-sectional area, energy slope, roughness and downstream sediment transport. As per literature, number, size and layout of the vanes depend on the channel morphology, velocity and depth at a meander bend. Vanes stabilize a channel reach without inducing changes upstream or downstream of that reach. Gupta et al. (2006) reported about the physical process of dike formation with submerged vanes which are quite useful as filed application.

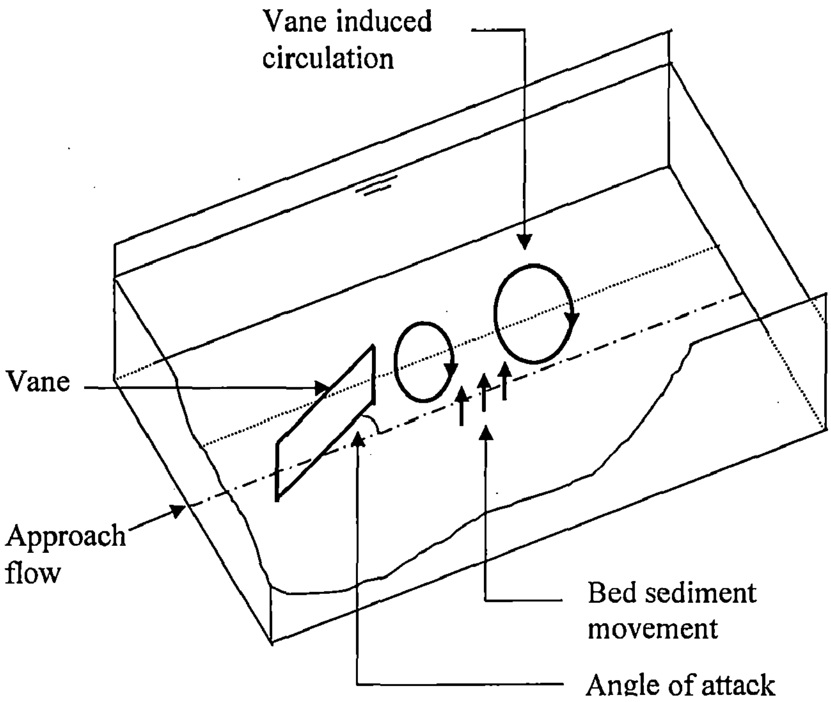

Fig. 1.1 Definition sketch of submerged vane

1.3 DIKE FORMATION

The formation of dike due to submerged vane in its downstream is the outcome of the application of submerged vane. The location of vane to safeguard the area will encourage the result oriented application of submerged vane. This area may be under the erosion or deposition due to natural behaviour of the alluvial stream. Safeguarding the area under consideration can be achieved by enhancing the effect of the vane in that area. Erodible area can be protected by keeping the pressure side of the vane in the side of the area and area under deposition can be eroded by keeping the suction side in the side of the area. Thus, a heaps of sediment formed may be considered as dike formation. The dike formation in the downstream of submerged vanes is the real field application in the actual scenario at higher Froude number.

The physical process of dike formation, which may give some indications for deciding upon the location of submerged vanes with respect to the river bank and the alignment of dike formation in the downstream of vane. Aspect ratio (H/L) is one of the most important parameters which influence the effect of submerged vanes in actual scenario.

1.4 OBJECTIVES

The aim of the study titled "Study of dike formation with submerged vanes" is focused to assess the applicability of vane for dike formation and the variation of dike with strength of vortex at lower angle of attacks with different aspect ratios.

1.5 ORGANISATION OF THESIS

The organisation of chapters:

Chapter 1: It introduces the topic of investigation, underlying objectives and the organization of thesis.

Chapter 2: Literature review related to submerged vanes is included here.

Chapter 3: It provides the detailed of experimental programme.

Chapter 4: This provides the dike formation of submerged vanes of different aspect ratios at lower angle of attacks. It also gives details of effects of vane-induced strength of vortex on dike formation.

Chapter 5: It provides the general remarks, result of present investigation and outlines the main findings and provide framework for future work.

Bibliography

Appendices

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

The use of submerged vanes found to be very effective in varieties of solutions, as described in Chapter 1.

Sediment control in alluvial channels, in particular the movement, scour, and deposition of sediments, is one of the most difficult problems encountered by river engineers. Bed scour along the outer bank of river bends frequently causes undermining of the banks and loss of land. Deposition of sediment in the river bed often reduces conveying capacity of river and interferes with navigation. The main difficulty in tackling these problems is the absence of cost-effective, low-maintenance and environmentally acceptable sediment control measures related to river training.

Principal obstacles to amelioration of the conventional practices eg. spurs and groynes, revetments etc. for river training are not as costly but are ineffective in many cases. Inadequacy of the currently available conventional sediment control structures and these costs need a critical review in some other alternatives. The submerged vanes have been developed to meet the above problems and these have been successfully employed in other countries.

The formation of dike due to submerged vane in its downstream is the outcome of the application of submerged vane. The location of vane to safeguard the area will encourage the result oriented application of submerged vane. This area may be under the erosion or deposition due to natural behaviour of the alluvial stream. Safeguarding the area under consideration can be achieved by enhancing the effect of the vane in that area. Thus, a heaps of sediment formed may be considered as dike formation.

Thus, it is important to investigate the formation of dike in the downstream of submerged vane.

The dike formation at lower angle of attack such as 15°, 20° and 25° at lower aspect ratios and influence of vane-induced strength of vortex on dike formation are required to be investigated.

2.2 CONVENTIONAL RIVER TRAINING MEASURES

Gupta et al. (2006), reported the brief comparative description of river training measures like bandalling, surface panels, bottom panels prior to introduction of vanes as secondary current generating devices, which are as follows:

2.2.1 Bandalling

Bandalling is quite an old technique, successfully used as a palliative measure in Assam (India), mainly to improve navigation conditions (Remillieux, 1970). The bandalling system comprises of a mat placed oblique to the flow and are extensively used in the Ganga-Brahmaputra rivers. Bandals are vertical mats or screens made of bamboo, fixed on bamboo poles driven into the bed which helps in the generation of secondary currents. They are erected at mid-water after the flood, with their upper edges rising clear of the water and their lower edges penetrating below the surface for about one third to one half the depth. They are set at an angle to the stream to divert the surface currents towards the navigation channel, encouraging deposition of the bed load, and deepening the navigation channel. A small opening is left between the mat and the bank so that the surface flow together with bed load passes under the mat. The resulting helical flow transports the sediment away from the navigation channel.

2.2.2 Surface Panels

According to Jansen et al. (1979), the system of surface panels was developed in the USSR by Potapov and his associates in 1936. As described in an unpublished report (1962), the surface panels is composed of an assembly of deflectors linked to four wings connected to a barge fitted with an anchor. The unit gives rise to a double helical circulation, which extends downstream along the channel to be deepened. This report also concludes that the size distribution of the deposits, which form the sills and the velocity of flow past the surface panels affect the movement of deposits. Surface panels, placed oblique to the current cause deviation of surface flow and accelerates the flow under the panel, deviating the bottom flow in the other direction resulting into a helical flow downstream of the panel. The increased sediment transport follows the bottom flow.

2.2.3 Bottom Panels

The bottom panels are placed at an angle of about 45^0 to the current at the edge of the channel to be eroded. According to Jansen et al. (1979), bottom panels have not only been applied for the deepening of navigation channels, but also found very effective for the closure of secondary river branches. The bottom panel is submerged excepting the first panel of the system which is placed in at a location where the channel does not need deepening. Bottom panels are temporary regulation structures only and their effect is local and dependent on the stability of river channel (Jansen et al., 1979). According to Remillieux (1970), unlike bandals which have to be renewed each year after the flood, bottom panels remain in place, and are found to be more effective. Although, the common objective of all the above secondary current generating devices is to accentuate the effect of secondary current, the strength of secondary current was not explicitly explored in quantitative terms and examined.

Vane designed system changes in flow depth occurred by transporting sediment sideward/transverse direction without changing overall channel characteristics rather than downstream, while many traditional structures for sediment control produce a streamwise redistribution of sediment and a change in the flow.

2.3 PRINCIPLE OF SUBMERGED VANES

The idea of submerged vanes was introduced for channel bends by Zimmermann and Kennedy (1978). They examined the torque (including the flux of moment of momentum) exerted on the flow about a streamwise axis at the channel bed or centroid. As a result of streamline curvature in a bend, the centrifugal force per unit mass exerted on the fluid increases upward from the bed (as the square of the tangential component of the local fluid velocity) and is greatest near the water surface. Consequently, the fluid in the upper portion of the channel bend is driven outward towards the concave bank. The fluid at the lower levels moves towards the inner bank to satisfy continuity relation. A spiral motion or secondary flow is generated in the cross-sectional plane transverse to the main flow. Near the bed of stream where the concentration of sediment is higher, the secondary current moves sediment inward across the channel and deposits some of it near the inner bank of the bend. The concave bank is subjected to the erosive attack of sediment deficient fluid moving from inner to outer bank in the upper layers of the stream causing scour of the outer bank.

The first known attempt to develop a theoretical design of submerged vanes was made by Odgaard and Kennedy (1983), and Odgaard and Spoljaric (1986). They introduced short vertical submerged vanes, inclined to the channel axis in the outer half of the river-bend to neutralise the secondary currents responsible for scouring of the outer bank.

Odgaard and Spoljaric (1986) concluded that the change in flow depth induced by vane is proportional to the vane-induced transverse velocity component near the bed, which is a function of the angle of attack. They found changes in flow depth due to transport of sediment sideward rather than downstream. Many traditional structures used for sediment control, on the other hand, produce a streamwise redistribution of sediment and a change in the flow depth. With the change in the energy conditions of the flow (slope, roughness etc.), the vane system redistributes the bed sediment in the transverse direction without changing overall channel characteristics. Also, the vanes do not change the cross-sectional area of the channel and the strength of vane-induced helical motion varied little, when H/d varied within the range $0.2 \leq H/d \leq 0.5$ (where, H = vane height, d = flow depth). Based on their laboratory study, they also suggested that the vane height, H, should be so chosen such that the ratio H/d remains within the range $0.2 < H/d < 0.5$ and the vane length, L, should be of the order of 3-4 times the vane height. Gupta (2003) concluded through experimental investigations that submergence ratio (T/d) of vane is not sensitive to the strength of vane induced strength of vortex in terms of moment of momentum. Submergence ratio of vane is the ratio of depth of flow (T) above top of vane and the depth of flow. Marelius and Sinha (1998) reported that vane functions optimally at optimal angle of attack, 40^0. Vanes should be placed at an angle α, between vane axis and the approach streamline, inclined towards outer bank. Recommended value of α varies from 10-15^0 for best result. The lateral spacing of the vanes and the distance from the outermost vane to the bank should be less than about twice the water depth at bankfull flow. Fig. 4 indicates the various notations.

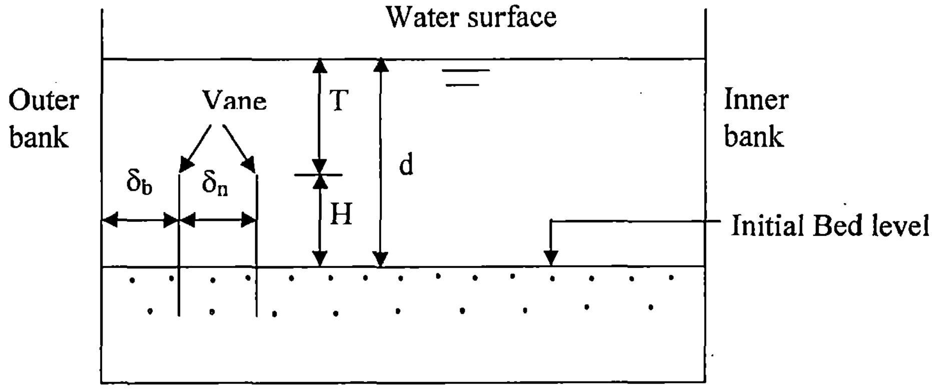

Fig. 2.1 Typical sketch showing different notations

Based on field data, Odgaard and Mosconi (1987) concluded that submerged vane technique is a feasible and realistic alternative to the traditional techniques, e.g., rock riprap and spur dikes.

Use of submerged vanes resulted in a reduction of transverse bed slope of at least 50% and a reduction of the near bank velocity of, generally 10-20%, moving maximum velocity toward the centre of channel.

They concluded that the technique is notable by its simplicity in both design and construction, and the vane system did not cause any measurable change in the longitudinal slope of the water surface nor in the average depth of flow. Thus, the vane system does not interfere with the overall sediment balance and stability of channel.

2.4 USE OF SUBMERGED VANES IN ACTUAL SCENARIO IN CONTEXT OF DIKE FORMATION

There are various applications of submerged vanes. However, its use in context of dike formation are mainly for protection of bank erosion (Jansen et al. 1979; Odgaard and Kennedy, 1983; Odgaard and Mosconi, 1987; Odgaard and Wang, 1991 a,b), and maintaining depth in navigation channel (Odgaard and Spoljaric, 1986).

2.4.1 Anti Bank Erosion Function

The vanes can be laid out to make the water and sediment move through a curve as if it were straight.

Based on theoretical and physical model, Odgaard and Kennedy (1983) concluded that submerged vanes installed at incidence to the channel axis in the outer half of a river-bend channel are significantly effective in nullifying the secondary currents produced in channel bends, which often lead to undermining and accelerated erosion of river banks. A typical layout of the two-row array of vanes is depicted in the Fig. 5, which was installed along the outer half of the bend. A typical section at A-A has been shown in Fig. 6.

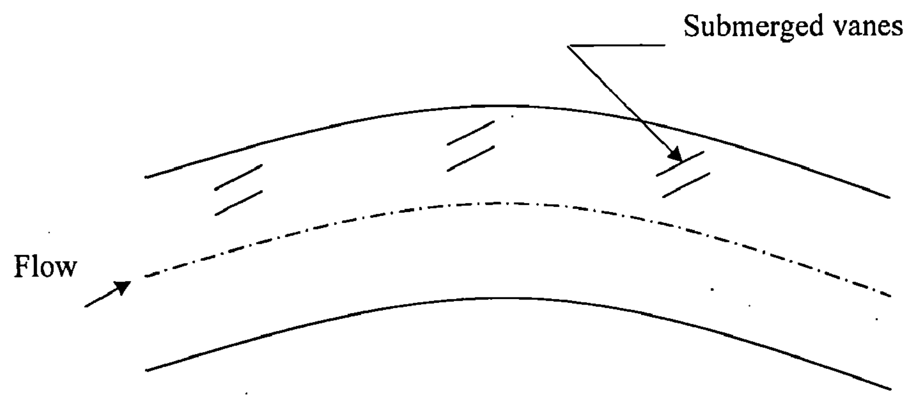

Fig. 2.2 Layout of submerged vane as Anti bank erosion structure

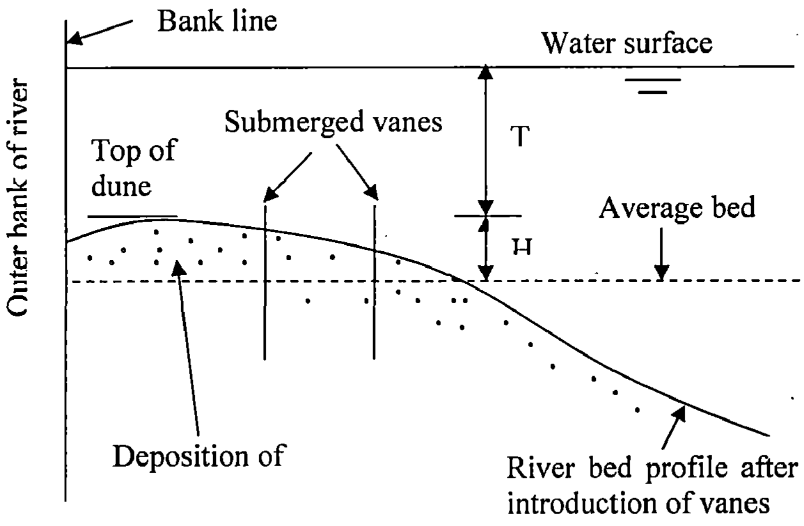

Fig.2.3 Typical Section at A – A

Based on field data, Odgaard and Mosconi (1987) reported that a system of submerged vanes was installed for erosion protection in a bend of East Nishnabotna River, Iowa (USA). Based on the field installation, they concluded that bank protection technique using submerged vanes is a feasible and realistic alternative to the traditional techniques, e.g. rock riprap and spur dikes. Odgaard and Mosconi (1987) also recommended that water and sediment move through a channel curve as if it were straight, thus reducing the bank erosion to the level of that of the equivalent straight channel.They also concluded that the technique is notable by its simplicity in both design and construction, and the system did not cause any measurable change in the longitudinal slope of the water surface nor in the average depth for a given discharge. In other words, as per them the vane system should not interfere with the overall sediment balance and stability of channel.

Odgaard and Wang (1991a) carried out theoretical studies of the vanes for non-separated flow and concluded that vanes are applicable to channels with any shape and planform.

Odgaard and Wang (1991b) conducted laboratory experiments in both curved and straight channels and found that submerged vane technique has merits as a general sediment control technique for rivers. They also concluded that the vanes alter the distribution of bed shear stresses across the river channel and cause a redistribution of flow velocity and depth by generating secondary circulation.

2.4.2 Maintaining Navigation Depth in Alluvial Channel

As per Odgaard and Spoljaric (1986), significant changes in depth can be achieved without causing significant changes in cross-sectional area, energy slope, roughness and downstream sediment transport. A typical layout of the two-row array of vanes is depicted in the Figs. 6 and 7.

They also found that changes in flow depth occurred by transporting sediment sideward rather than downstream, while many traditional structures for sediment control produce a streamwise redistribution of sediment and a change in the flow. With the change in the energy conditions of the flow (slope, roughness), the vane system designed redistributes the bed sediment in the transverse direction without changing overall channel characteristics.

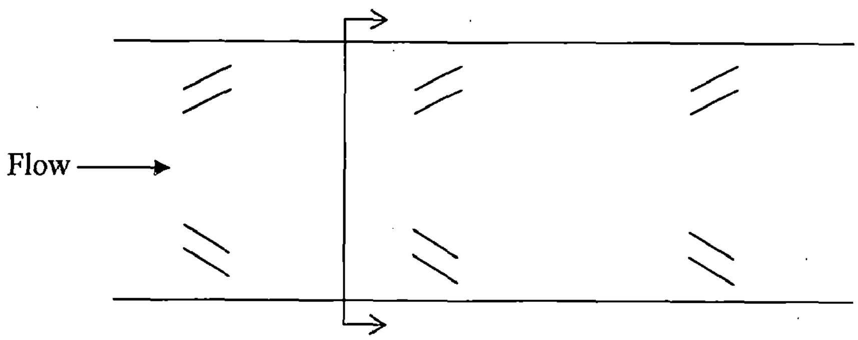

Fig. 2.4 Typical layout of Submerged vane for maintaining navigation depth

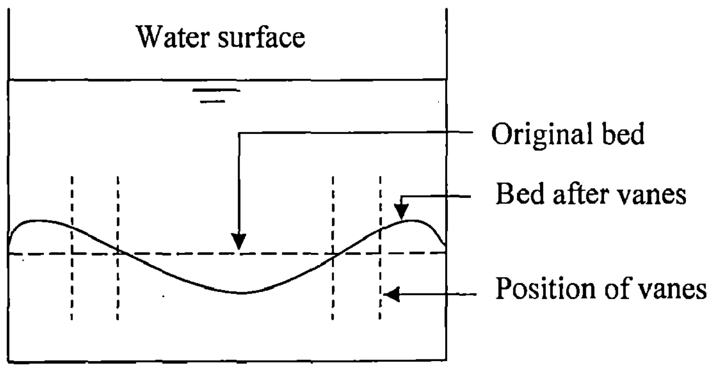

Fig. 2.5 Section A-A

2.5 DIKE FORMATION AND VANE INDUCED STRENGTH OF VORTEX

Odgaard and Kennedy (1983) suggested that for values of angle of attack, α greater than or equal to approximately 20^{o}, a persistent scour hole is produced near the upstream end of a vane. As α was reduced the number of vanes producing objectionable scouring also decreased. Marelius and Sinha (1998) concluded that the induced strength of the vortex resulting from a rectangular vane without a collar is maximum at an angle of attack very close to 40^{o}. At optimal angle of attack, vane induced strength of vortex is maximum. At the optimal angle of attack, considerable scour develops around the submerged vane, which may dislodge the vane. Gupta et al. (2006) reported that optimal angle of attack for a rectangular vane even with a collar is same i.e. 40^{0}.

Table 2.1 gives the summary of aspect ratio used by different investigators in model and prototype studies.

The strength of vane induced secondary flow is highly influenced by their aspect ratios. There is complete lack of literatures on effect of aspect ratio of submerged vanes on their performances in terms of numerical values. The aspect ratio of submerged vanes is one of the most important parameters, which is mainly responsible for generation of strength of vane-induced secondary circulation. The vane induced secondary circulation causes the formation of dike downstream of submerged vanes.

Thus, it is important to investigate the effect of aspect ratio of submerged vanes on dike formation. Gupta et al. (2006) presented the detailed procedure to calculate the vane-induced strength of vortex in terms of moment of momentum.

Table 2.1: Aspect Ratio used by different Investigators in their Model or Prototype Studies

Name of investigators	Aspect ratio
Odgaard and Spoljaric (1986)	0.4
Odgaard and Mosconi (1987)	0.25 to 0.33
Odgaard and Wang (1991a)	0.3
Odgaard and Wang (1991b)	0.5
Wang and Odgaard (1993)	0.5
Wang et al. (1996)	0.33
Marelius and Sinha (1998)	0.5
Barkdoll et al. (1999)	0.32

The formation of dike due to submerged vane in its downstream is the outcome of the application of submerged vane. The location of vane to safeguard the area will encourage the result oriented application of submerged vane. This area may be under the erosion or deposition due to natural behaviour of the alluvial stream. Safeguarding the area under consideration can be achieved by enhancing the effect of the vane in that area. Erodible area can be protected by keeping the pressure side of the vane in the side of the area and area under deposition can be eroded by keeping the suction side in the side of the area. Thus, a heaps of sediment formed may be considered as dike formation. The dike formation in the downstream of submerged vanes is the real field application in the actual scenario at higher Froude number.

Thus, it is important to investigate the formation of dike in the downstream of submerged vane.

There are few literatures available on the dike formation due to submerged vanes. First time, Gupta et al. (2006) studies the physical process of dike formation in the downstream of a submerged vane at optimal angle of attack 40°, which may give some indications for deciding upon the location of submerged vanes with respect to the river bank and the alignment of dike formation in the downstream of vane.

Odgaard and Kennedy (1983) performed laboratory experiments with submerged vanes with angle of attack of 15^0, sediment mean diameter of 0.30 mm and its geometric standard deviation of 1.45 and H/d ratio as 1/3 in a curved flume at the Iowa Institute of Hydraulic Research and reported for values of $\alpha > \cong 20^0$, flow separation occurred around a third or more vane length and produced a persistent scour hole near the upstream end of each vane. As α was reduced, the scouring also decreased.

All the investigators agree that local scour depth increases with the increase of angle of attack. Therefore, lower angle of attacks such as 15°, 20°, and 25° has been considered in present research.

Gupta et al. (2006) also reported that formation of dike is one of the outcomes of submerged vane-induced strength of vortex. The investigation on strength of vortex with the magnitude of dike formation is also very important.

In the light of above following studies have been considered:

(1) Dike formation with downstream of submerged vane at lower angle of attacks 15° , 20° and 25° with aspect ratios 0.2, 0.25, 0.33.

(2) Effect of submerged vane induced strength of vortex with in terms of moment of momentum on dike formation.

2.6 SUMMARY

Based on the literature review discussed in this chapter, detailed experimental programme to carry out the experiments on (i) Dike formation with downstream of submerged vane at lower angle of attacks 15°, 20° and 25° with aspect ratios 0.2, 0.25, 0.33, and (ii) Effect of submerged vane induced strength of vortex with in terms of moment of momentum on dike formation, has been presented in Chapter 3.

Chapter 3

EXPERIMENTAL PROGRAMME

3.1 GENERAL

From the preceding chapter, it is apparent that few studies are available on the effect of aspect ratio on dike formation. Strength of vane induced strength of vortex causes the formation of dike downstream of submerged vanes. Strength of vane induced strength of vortex increases with the increase of angles of attack. In actual scenario, vane has been used for lower angle of attack. It is obvious that certain studies on the effect of submerged vanes at lower angle of attack with different aspect ratios of vanes are necessary in order to investigate the dike formations downstream of submerged vanes. With this in view, the experimental programme was organized.

Experiments were performed in a 50 cm wide mobile bed flume using two types of plastic plates with varying angle of attack, aspect ratios. The vanes were made of plastic plates.

The experiments were performed in non-uniform sediment and subject to clear water live bed conditions. Therefore, experiments were conducted to examine the effects of aspect ratios at different lower angles of attack on dike formations in flow depth, discharge intensity, vane, height and length, their shape and sediment size, in clear water conditions. With this background, the details of the experimental programme are presented below.

3.2 LABORATORY FLUME

The flume used was eleven metre long tilting flume, made of mild steel with side walls made of transparent Perspex sheet. Flume has an in-built up stream tank of 40 cm x 90 cm x 115 cm dimensions. The depth of flume is 50 cm and the width is 50 cm. Diagrammatic scheme is given in Fig. 3.1. The bed of flume is supported on angle iron sections, the lower ends of which are connected to a shaft, placed length-wise parallel to the central portion of flume below it. Shaft is movable horizontally backwards and forwards with the help of a gearbox and electric motor such that if the shaft moves towards the direction of flow, the front portion of flume moves upwards and lower portion moves downward and vice-versa. This is the mechanism of changing the required slope.

The water flowing in the flume falls into a sump, which is connected to an underground tank of 1.5 m x 1.5 m x 3 m dimensions. From the underground, tank water is lifted with the help of a pump of 10HP capacity. 10 cm diameter pipes carry water from the underground tank to the upstream tank. The discharge is regulated with the help of a gate valve placed after the pump. A venturimeter is placed at a distance of 180 cm from the gate valve and 70 cm before the bend pipe leading to the top of upstream tank. The venturimeter is attached to the mercury manometer.

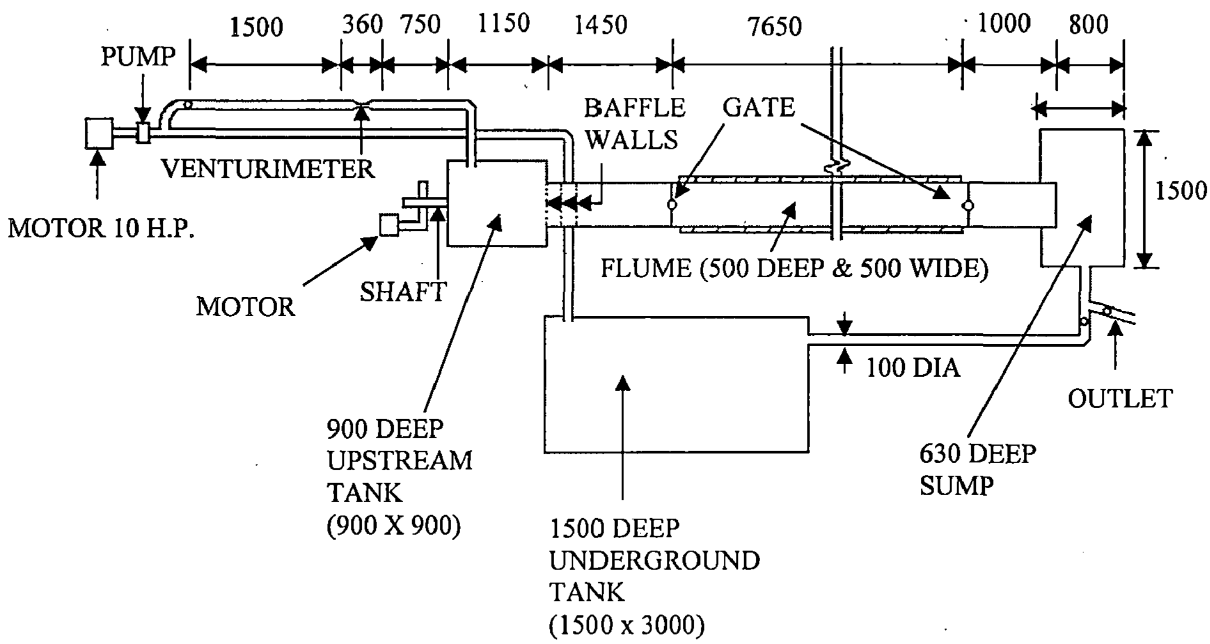

Fig. 3.1 PLAN OF TILTING FLUME AND ITS COMPONENTS USED IN EXPERIMENTS (ALL DIMENSIONS ARE IN MM)

3.2.1 Sediments Used

Experiments were performed with sediment having median diameter as 0.225 mm (geometric standard deviation 1.42) (as shown in the Table 3.1 and Fig. 3.2).

3.2.2 Other equipment

The depth of flow along the length of flume and the scour pattern around the submerged vanes were measured with the help of a pointer gauge, which could be moved along the hand rails fitted at the top of flume. The three-dimensional (3D) components of velocity were measured by means of an Acoustic Doppler Velocimeter (ADV). The velocimeter was capable of measuring all of the three components of the velocity with an accuracy of 0.25% of the velocity magnitude or 0.0025m/s (whichever was greater).

The sampling rate used in the experiment was 20Hz. A minimum of 800 values was taken at each measured point, and the mean value of these measurements was taken as representative velocities. The technique employed in ADV is superior to the other conventional methods, since the actual sampling volume is located at a lower depth (0.05m below the probe, in the present case) than the probe, and hence, is less disturbed.

Table 3.1: The sieve analysis of the sediment material of d_{50} = 0.225 mm

Sieve Size	Weight retained(gm)	Cum. weight retained (gm)	Cum. % retained	% Passing
0.6	0.345	0.345	0.069	99.931
0.425	9.568	9.913	1.983	98.017
0.3	37.546	47.459	9.492	90.508
0.225	226.858	274.317	54.863	45.137
0.15	160.959	435.276	87.055	12.945
0.075	53.716	488.992	97.798	2.202
0.063	2.565	491.557	98.311	1.689
0.05	8.269	499.826	99.965	0.035

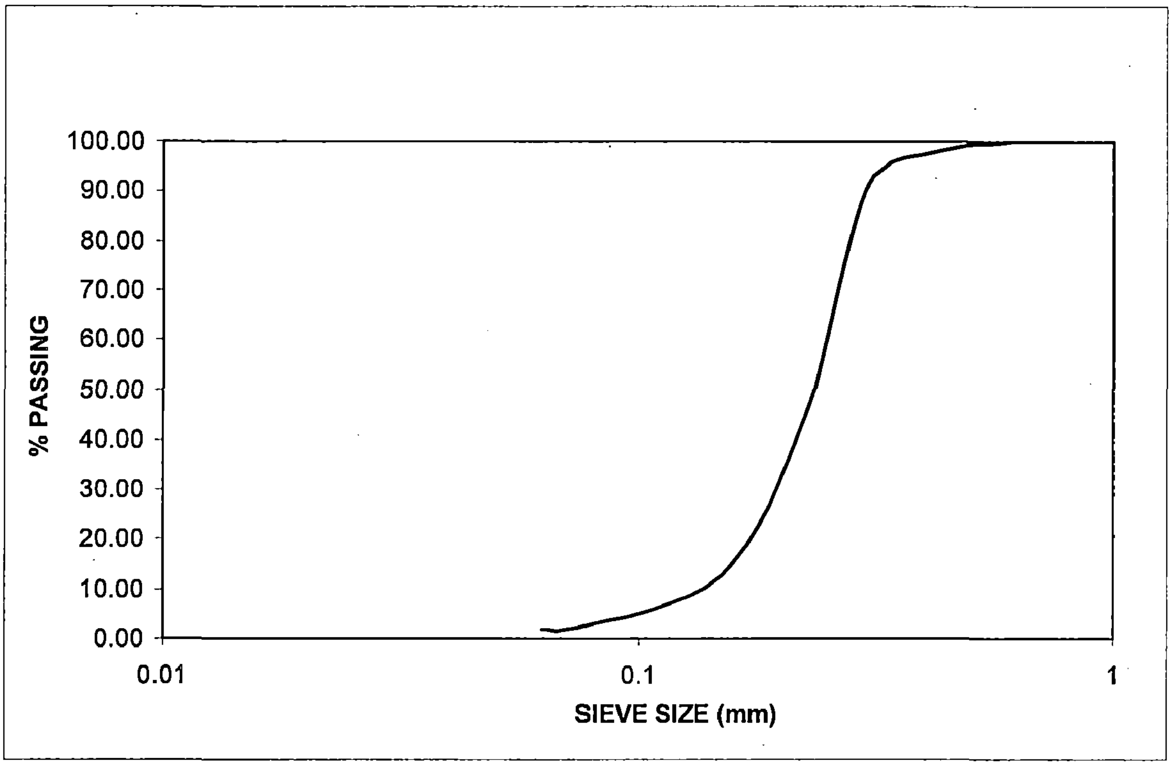

Fig. 3.2 Cummulative frequency curve for sand d_{50} = 0.225 mm

3.2.3 MODELS

Three sizes of rectangular submerged vanes were taken for the study. All the vanes were of equal heights and different lengths (Fig. 3.3 and Table 3.2).

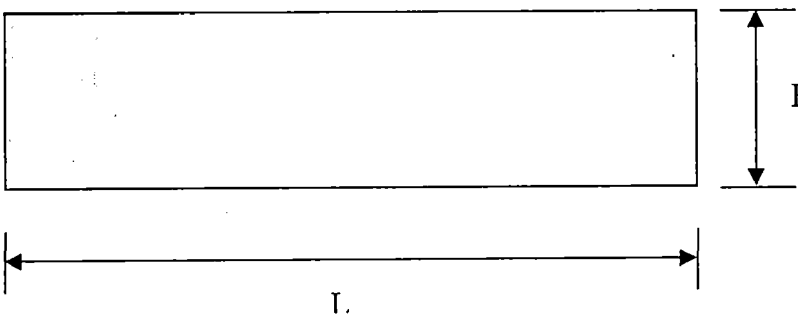

Fig. 3.3 Rectangular Vane

Table 3.2: Dimensions of Rectangular Vane

S. No.	Length of Vane (L) in cm	Height of Vane (H) in cm	Aspect Ratio of Vane (H/L) in cm
1	15	5	0.33
2	20	5	0.25
3	25	5	0.20

3.3 EXPERIMENTAL PROCEDURE

Experiments were conducted in the following steps:

(i) The experiments were carried out in the River Engineering Laboratory, WRD&M of Indian Institute of Technology, Roorkee, India.

(ii) First flume was adjusted to required slope.

(iii) The depth of sediment bed layer of the test section was fixed at 15 cm. Uniform flow without sediment motion corresponding to a selected discharge was established with the help of tailgate.

(iv) Before placement of submerged vanes, the sediment bed of flume was levelled.

(v) After placement of submerged vanes, the sediment bed of flume was again levelled around the submerged vanes.

(vi) Flow was introduced in the flume very slowly by closing the tail gate so that no scouring occurred around the submerged vanes due to operation.

(vii) After the experiment was over, dike formation was measured with the help of pointer gauge to see the magnitude of dike formation in the downstream of submerged vanes.

(viii) All three components of velocities were measured by ADV at a distance of 20 cm from the centre of the vane to calculate the downstream strength of vortex in terms of moment and momentum. Near both the vertical walls of the flume, velocity measurements were not taken to avoid the effects of walls on secondary flow.

(ix) Photographs were taken of the developed profile of dike formation, after the termination of the run.

3.4 MODEL EXPERIMENTS

In this phase of experiments, three sizes of rectangular submerged vanes were deployed to investigate the dike formation. Further, the strengths of vane induced vortex were also studied. The experiments were run for 8 hrs. All the experiments were conducted in clear water conditions. The flow was adjusted to less than critical conditions. All the three components of velocities were measured at a distance of 15 cm downstream from the centre of the vanes. The grid was taken 4 cm × 4 cm. Experiments were conducted at the angle of attack of 15^0, 20^0 and 25^0 for all aspect ratios of vanes. The detailed experimental programme has been presented in Table 3.3.

Table 3.3: Experimental Programme

Expt. No.	Rate of flow (m3/s)	d (cm)	T/d	H/L	α
A1	0.0239	20	0.75	0.33	15^0
A2	0.0239	20	0.75	0.33	20^0
A3	0.0239	20	0.75	0.33	25^0
A4	0.0239	20	0.75	0.25	15^0
A5	0.0239	20	0.75	0.25	20^0
A6	0.0239	20	0.75	0.25	25^0
A7	0.0239	20	0.75	0.20	15^0
A8	0.0239	20	0.75	0.20	20^0
A9	0.0239	20	0.75	0.20	25^0

3.5 SUMMARY

After performing the experiments, the detailed analysis of dike formation at aspect ratios 0.2, 0.25, 0.33 and degree of submergence (T/d) 0.75 and related strength of vortex has been presented in Chapter 4.

CHAPTER - 4

DIKE FORMATION AND STRENGTH OF VORTEX

4.1 DIKE FORMATION

Dike formation in the downstream of a submerged vane is one of the important outcomes of the application of submerged vanes. Due to submerged vanes, heaps of sediment is formed as the redistribution of sediments take place due to secondary currents generated by vanes. Knowing the layout of the dikes may be helpful in deciding the magnitude of the protected area.

The formation of the dike starts at some distance from the trailing edge of the submerged vanes. It is important to investigate the dike formation with different angles of attack and different aspect ratios.

Based on review of literature, it could be found that no research has been conducted for lower angles of attack. Keeping the submergence ratio (T/D = 0.75) and velocity of flow constant , the experiments were done at lower angles of attack 15°, 20° and 25°.

Angles used : 15°, 20°, 25°

Aspect ratios (H/L) used : 0.33, 0.25, 0.20

It was found that maximum height of dike was formed at aspect ratio 0.33 and angle of attack 25° (Exp A3). and minimum height of dike was formed at aspect ratio 0.33 and angle of attack 15° (Exp A1).

The contour plotting was done by surfer and shown here in this chapter. The 3D view of the dike is also shown here supporting with the photographs of the dike.

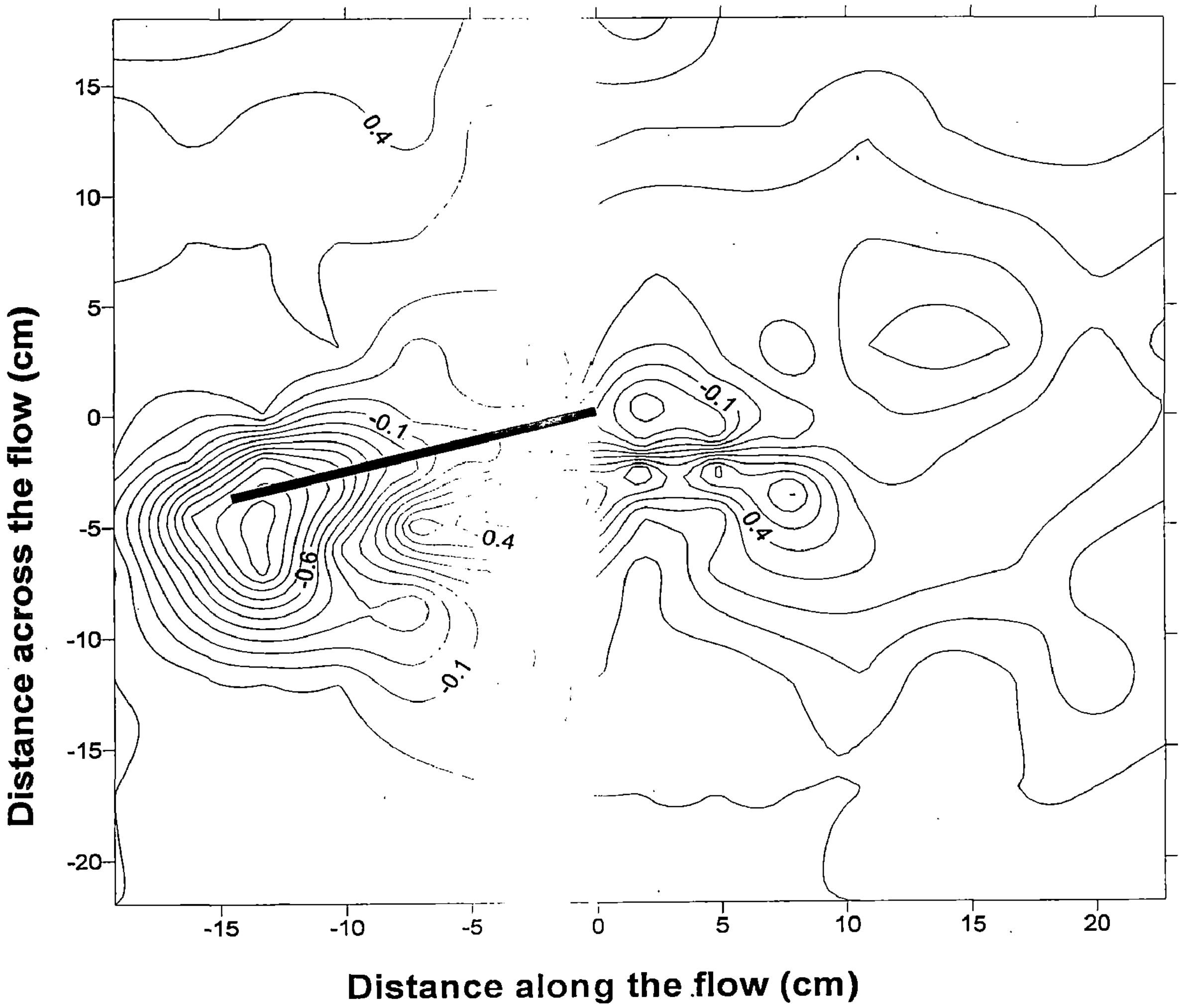

Figure - 4.1

Contours of dike formation for submerged vanes with aspect ratio 0.33 and α = 15°

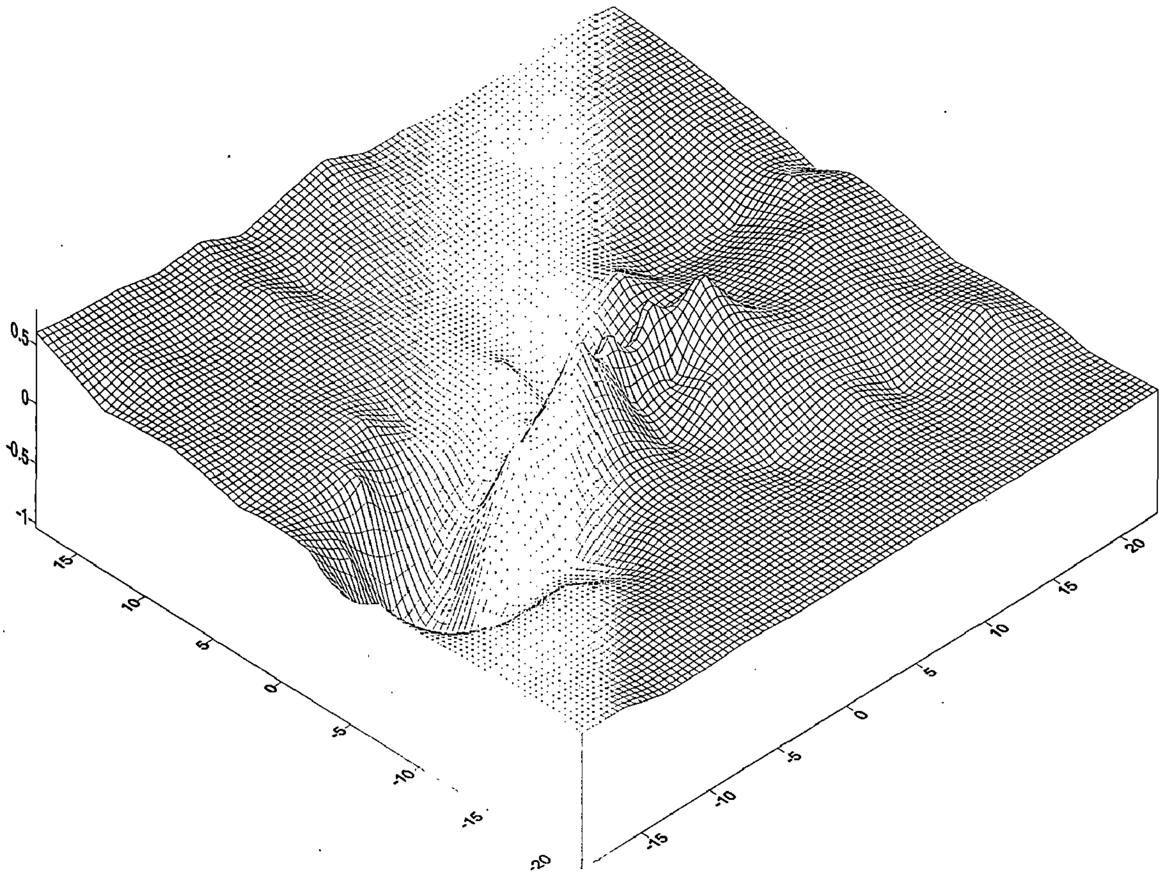

Figure - 4.2

3D view of dike formation for submerged vanes with aspect ratio 0.33 and α = 15°

Plate 4.1

Dike formation due to vane with aspect ratio 0.33 and α = 15°

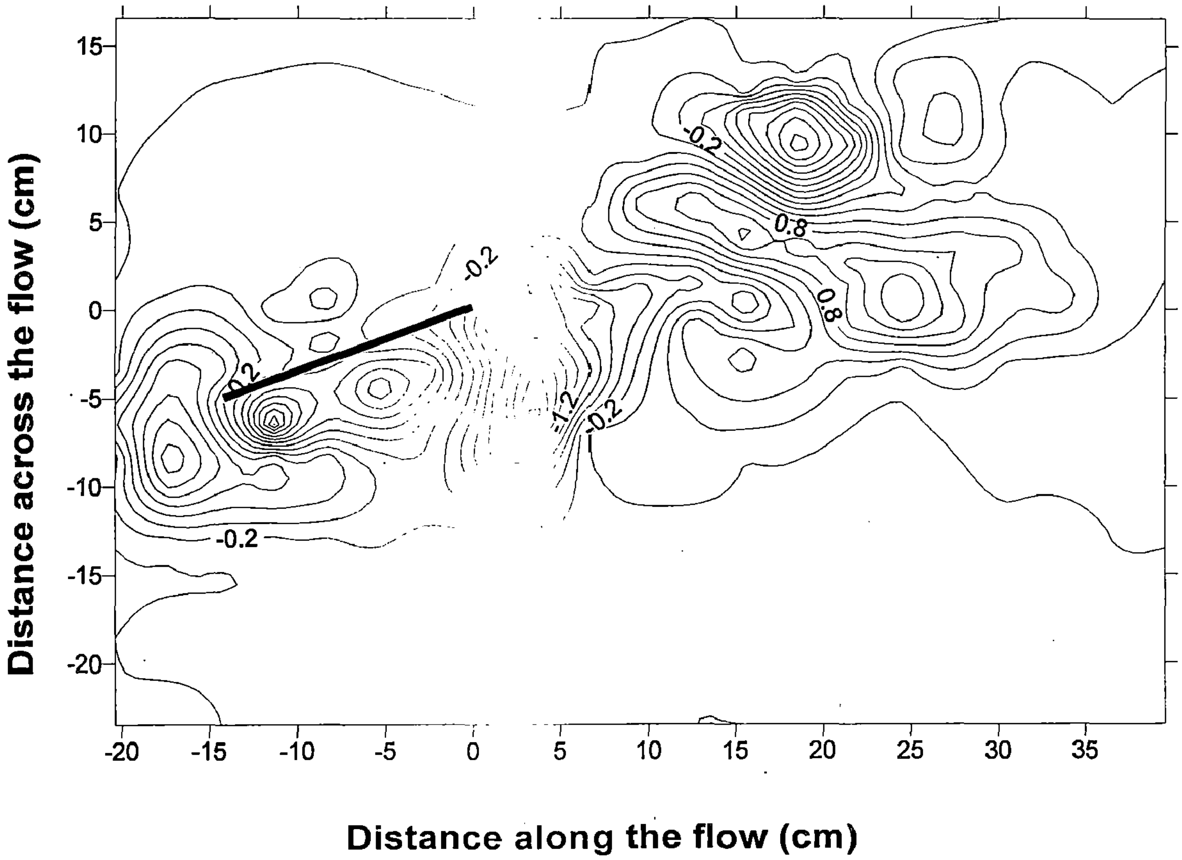

Figure - 4.3

Contours of dike formation for submerged vanes with aspect ratio 0.33 and $\alpha = 20^{\circ}$

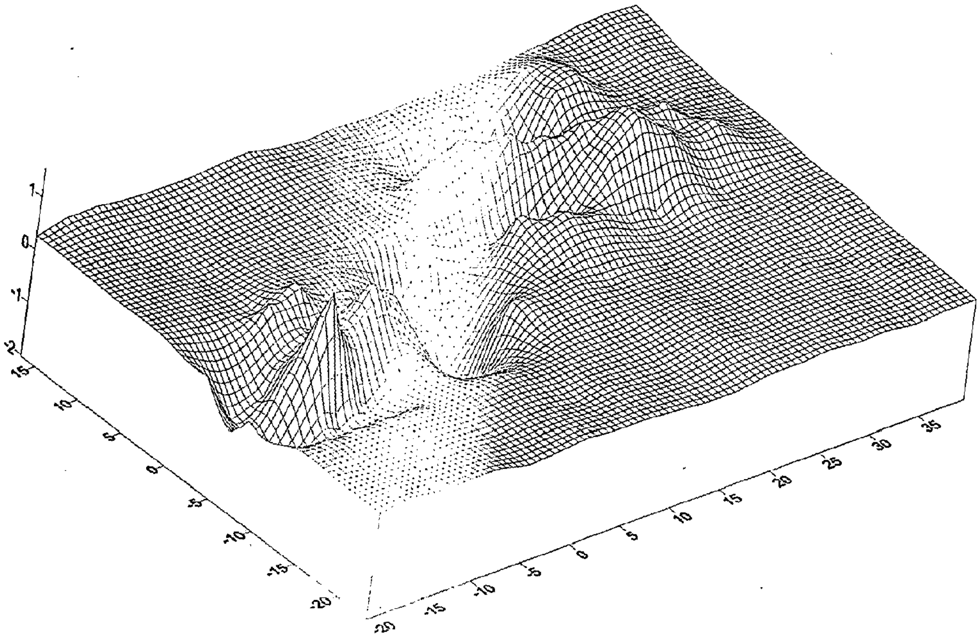

Figure - 4.4
3D view of dike formation for submerged vanes
with aspect ratio 0.33 and α = 20°

Plate 4.2

Dike formation due to vane with aspect ratio 0.33 and α = 20°

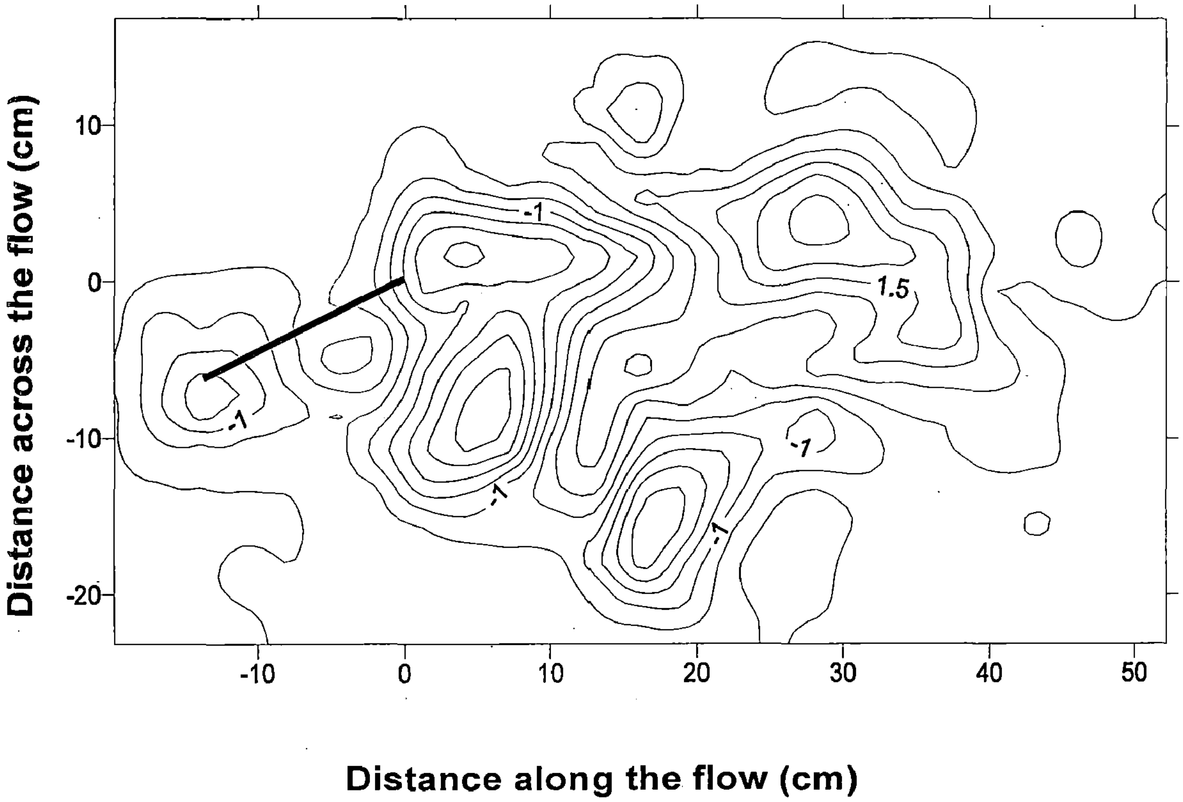

Figure - 4.5

Contours of dike formation for submerged vanes

with aspect ratio 0.33 and $\alpha = 25^{\circ}$

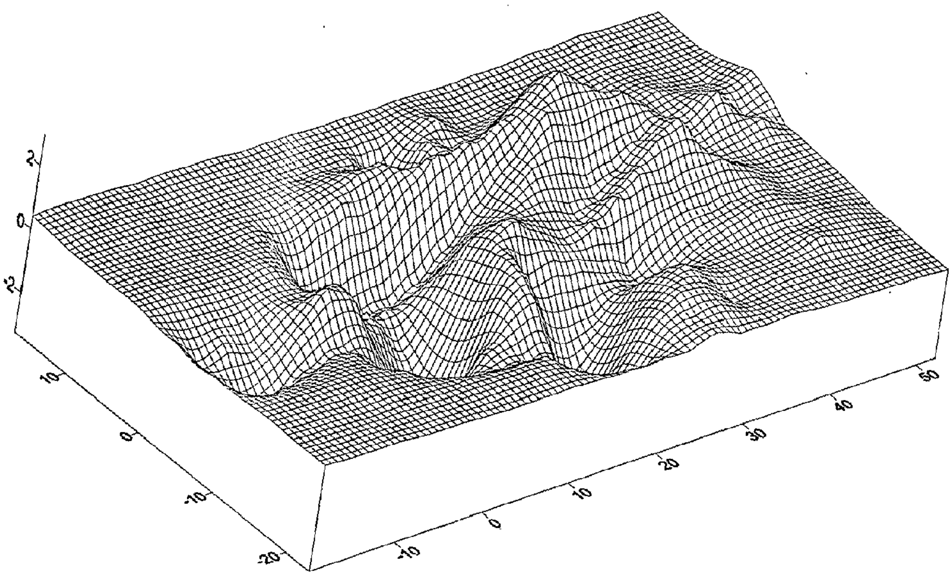

Figure - 4.6
3D view of dike formation for submerged vanes
with aspect ratio 0.33 and $\alpha = 25^{\circ}$

Plate 4.3

Dike formation due to vane with aspect ratio 0.33 and α = 25°

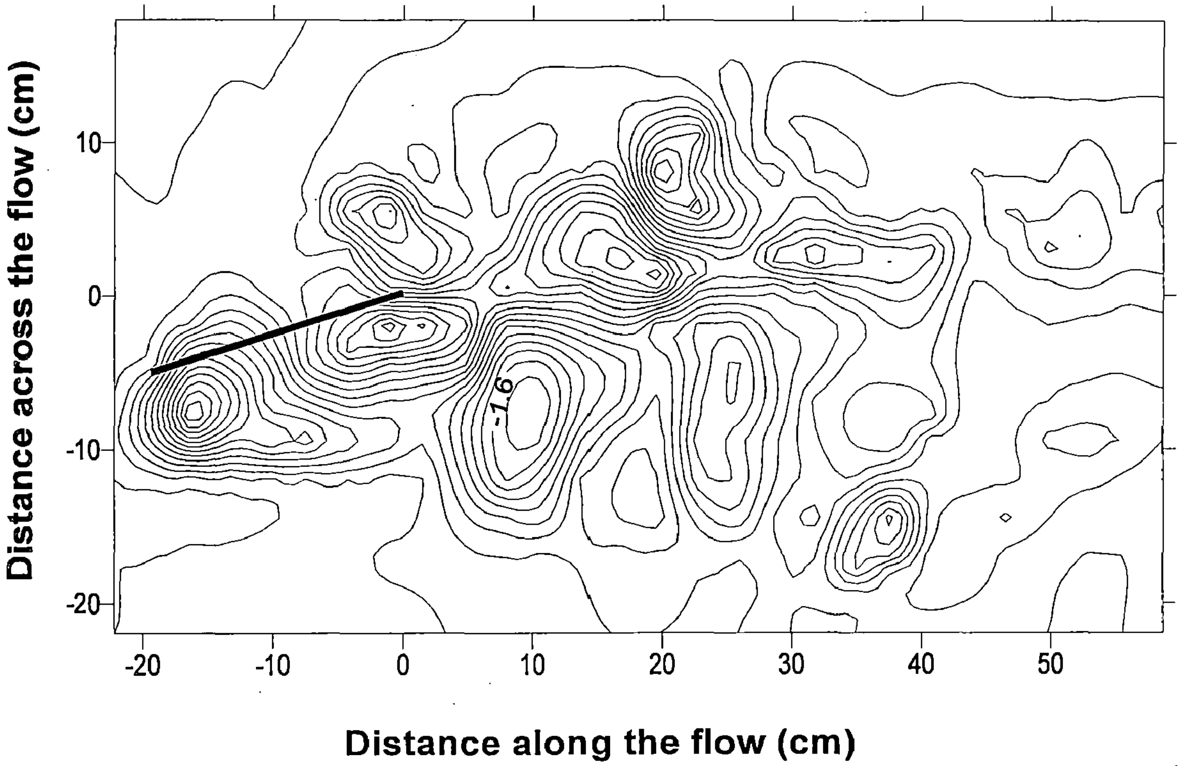

Figure - 4.7

Contours of dike formation for submerged vanes with aspect ratio 0.25 and $\alpha = 15^{\circ}$

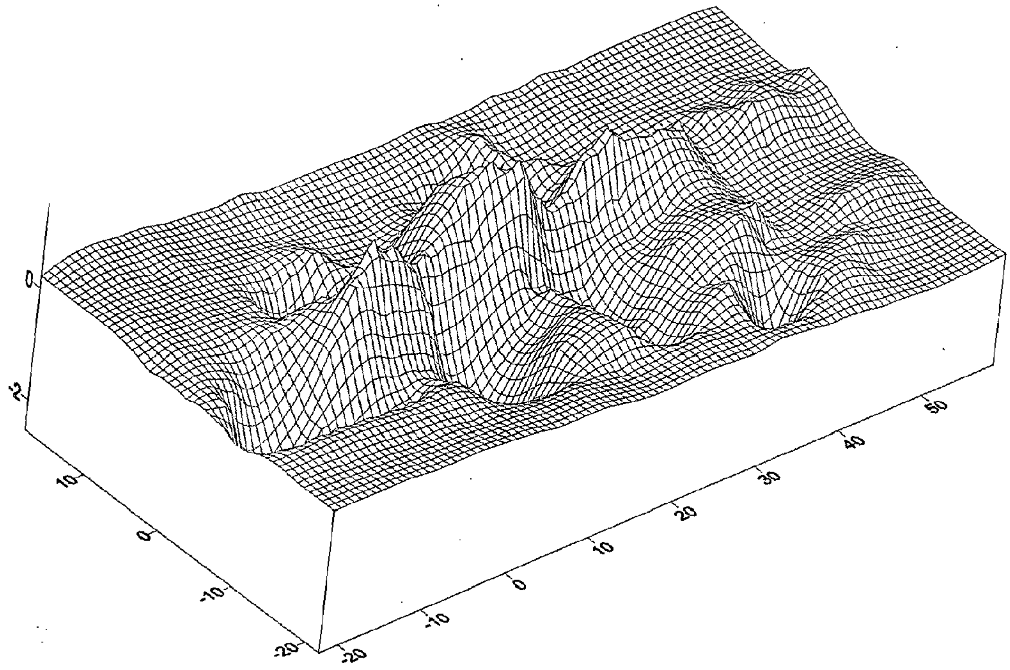

Figure - 4.8
3D view of dike formation for submerged vanes
with aspect ratio 0.25 and $\alpha = 15^{\circ}$

Plate 4.4

Dike formation due to vane with aspect ratio 0.25 and α = 15°

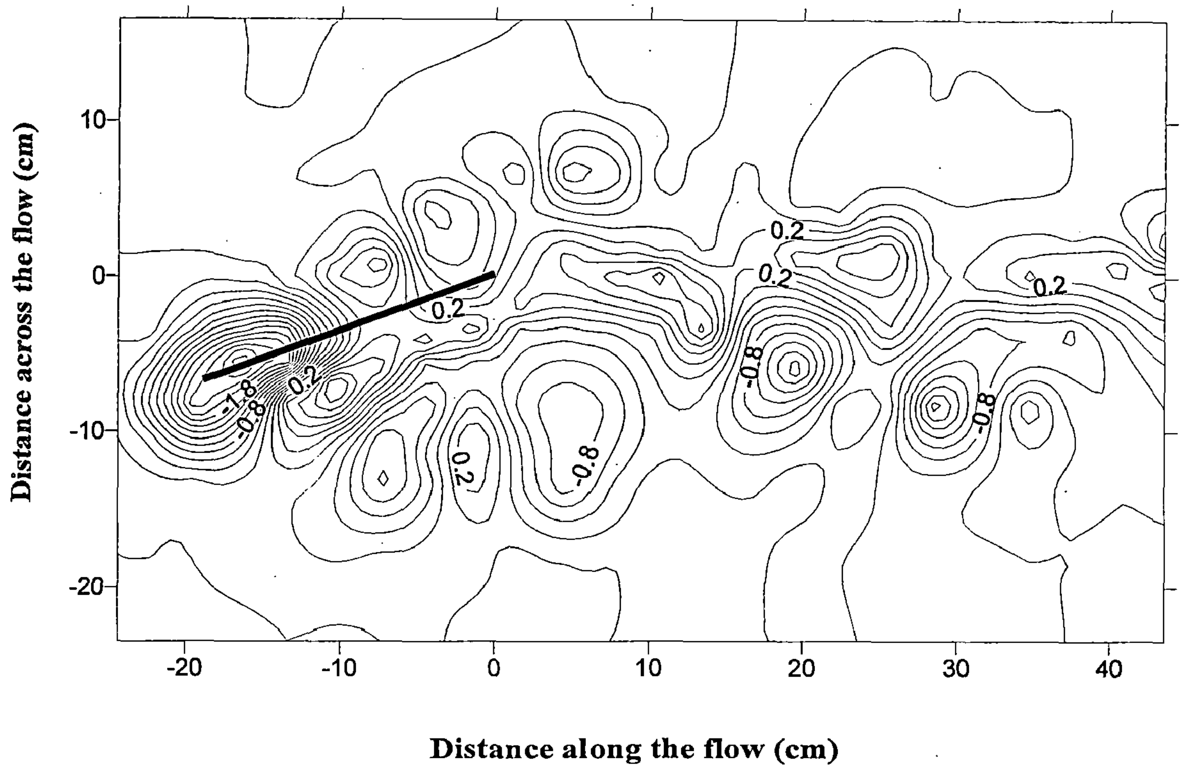

Figure - 4.9

Contours of dike formation for submerged vanes with aspect ratio 0.25 and α = 20°

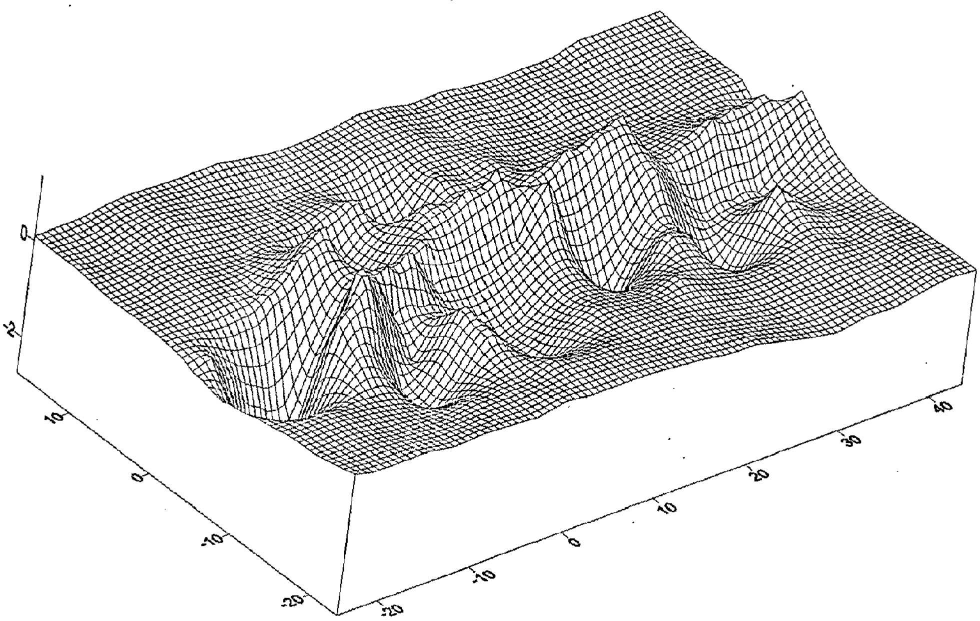

Figure - 4.10
3D view of dike formation for submerged vanes
with aspect ratio 0.25 and $\alpha = 20^{\circ}$

Plate 4.5

Dike formation due to vane with aspect ratio 0.25 and $\alpha = 20^\circ$

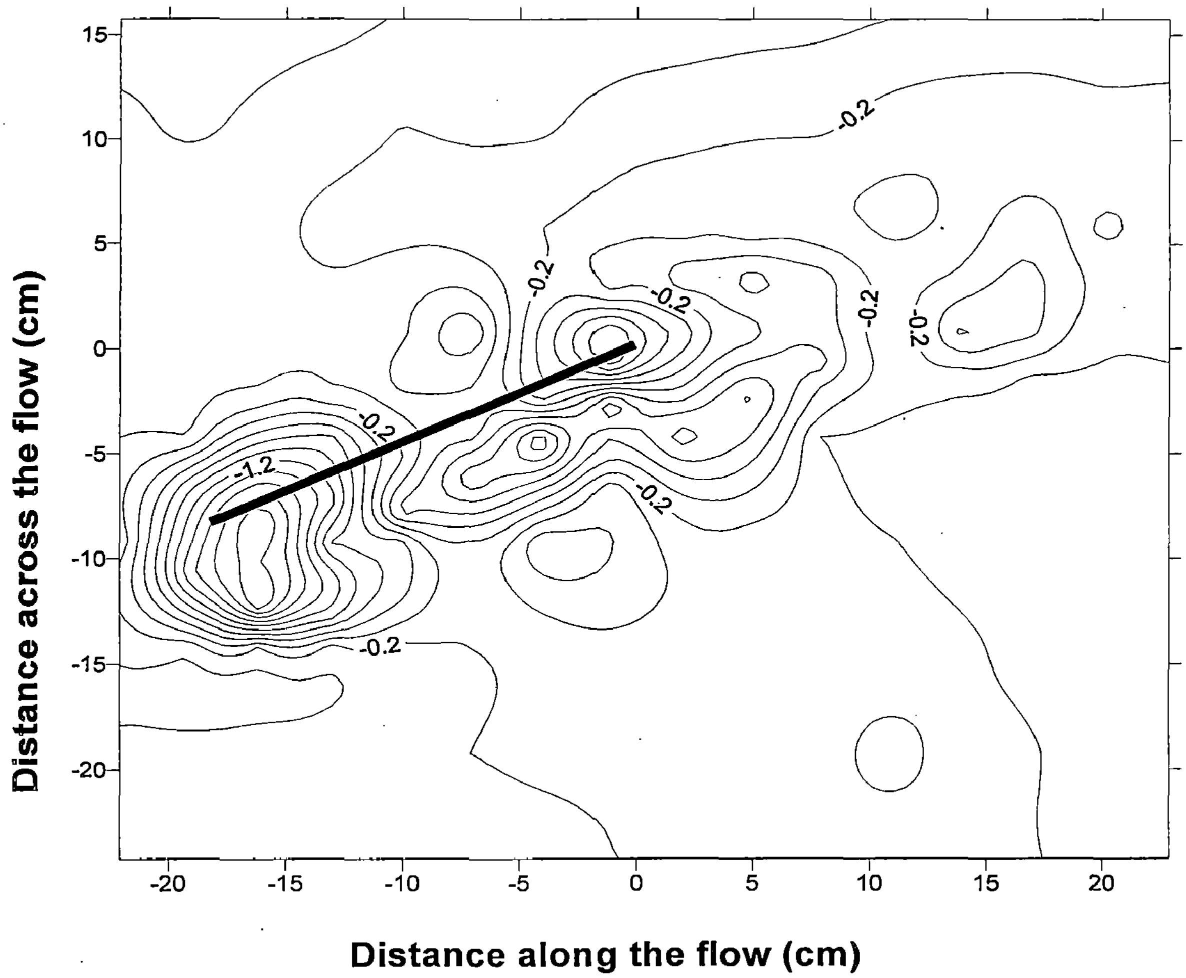

Figure - 4.11

Contours of dike formation for submerged vanes with aspect ratio 0.25 and α = 25°

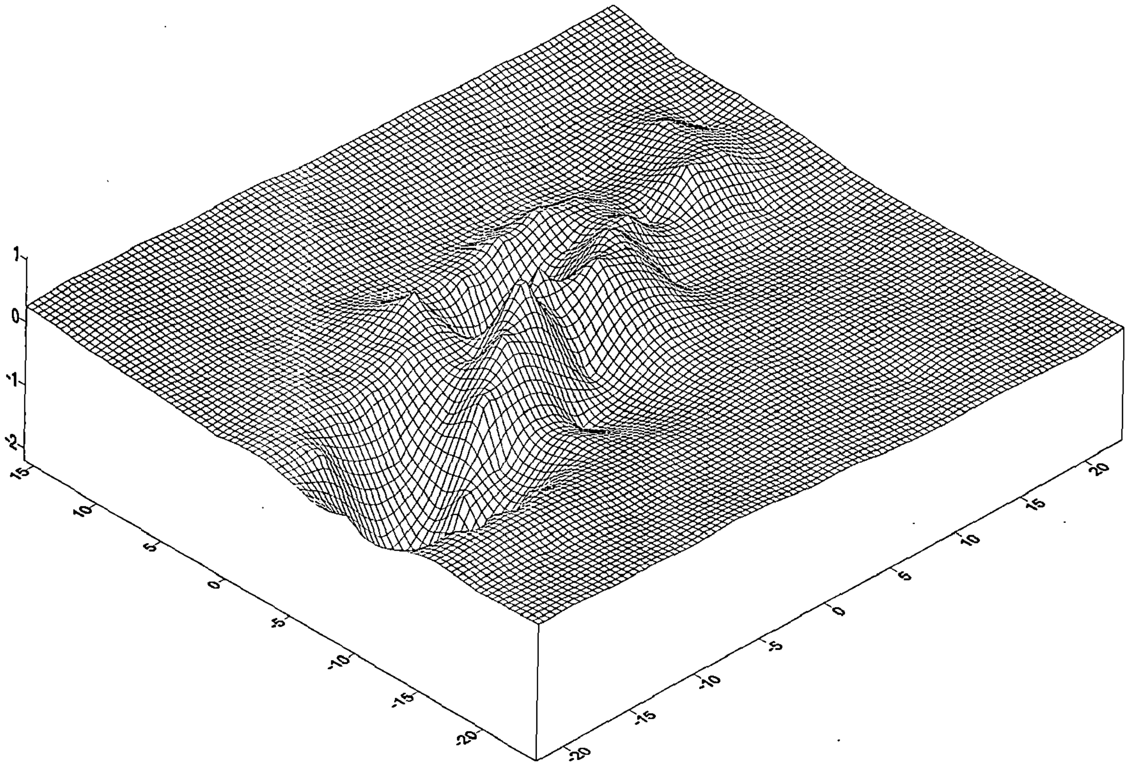

Figure - 4.12
3D view of dike formation for submerged vanes
with aspect ratio 0.25 and $\alpha = 25^{\circ}$

Plate 4.6

Dike formation due to vane with aspect ratio 0.25 and $\alpha = 25^{\circ}$

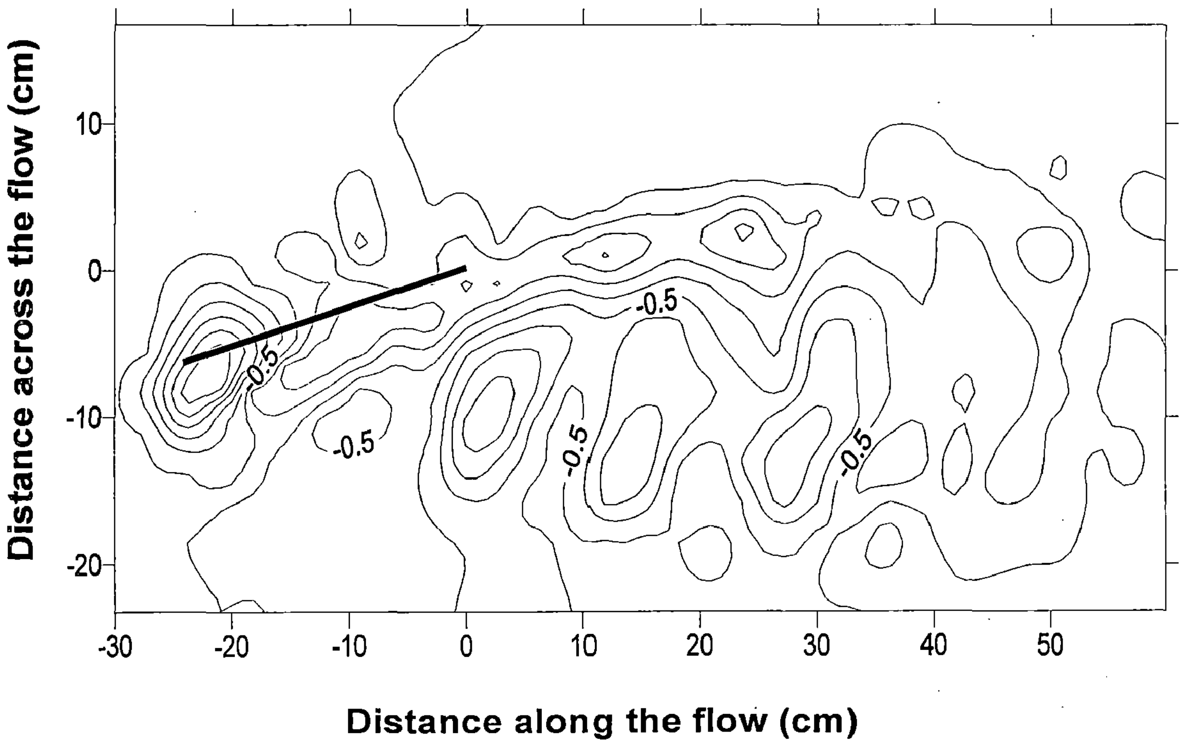

Figure - 4.13

Contours of dike formation for submerged vanes with aspect ratio 0.20 and $\alpha = 15^{\circ}$

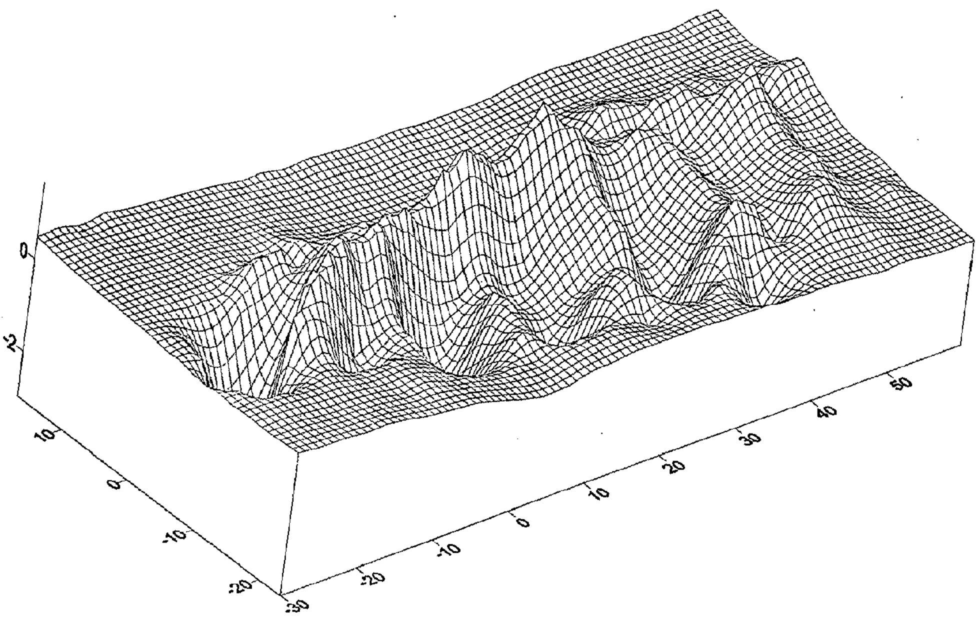

Figure - 4.14
3D view of dike formation for submerged vanes
with aspect ratio 0.20 and α = 15°

Plate 4.7

Dike formation due to vane with aspect ratio 0.20 and $\alpha = 15^{\circ}$

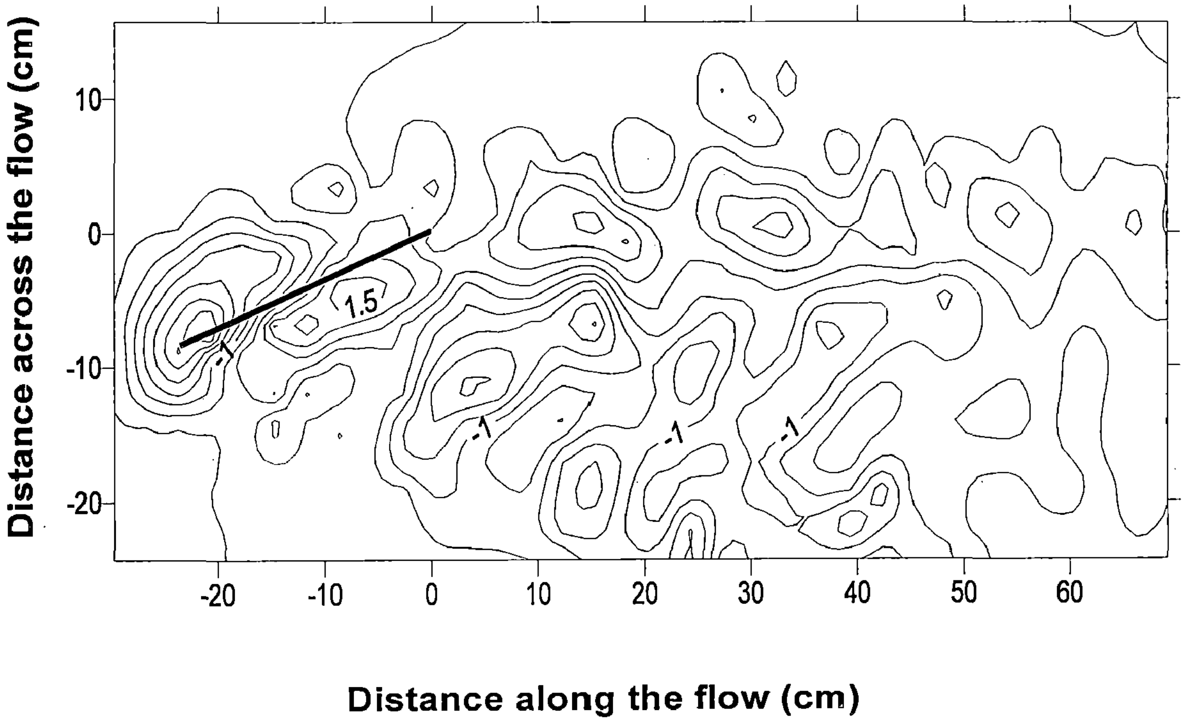

Figure - 4.15

Contours of dike formation for submerged vanes with aspect ratio 0.20 and α = 20°

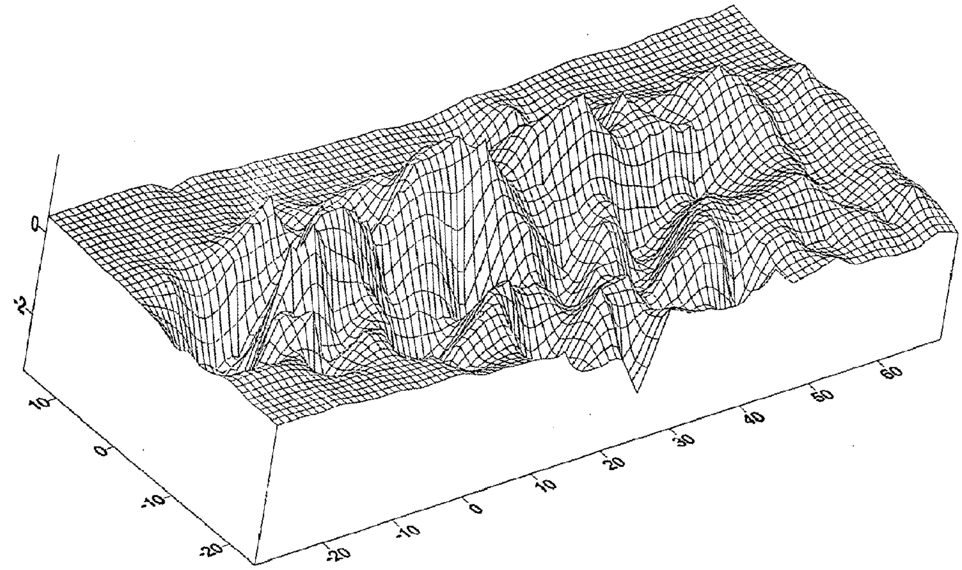

Figure - 4.16
3D view of dike formation for submerged vanes
with aspect ratio 0.20 and $\alpha = 20^{\circ}$

Plate 4.8

Dike formation due to vane with aspect ratio 0.20 and $\alpha = 20^\circ$

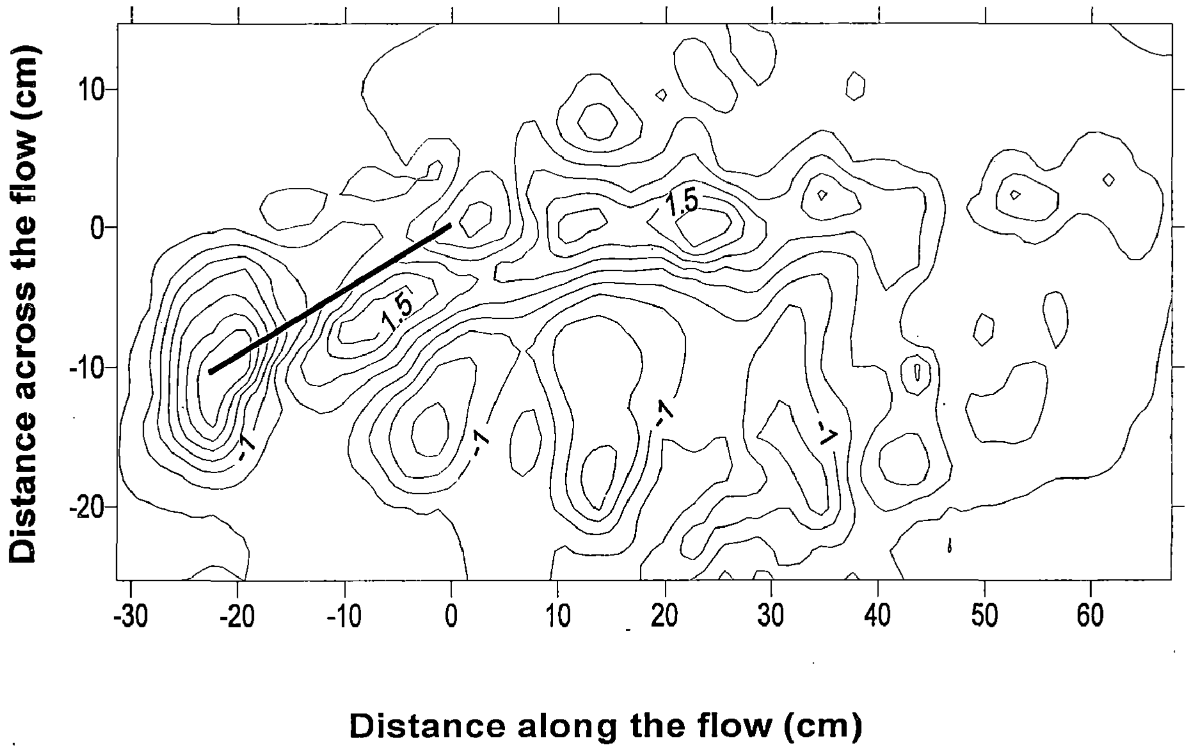

Figure - 4.17
Contours of dike formation for submerged vanes
with aspect ratio 0.20 and α = 25°

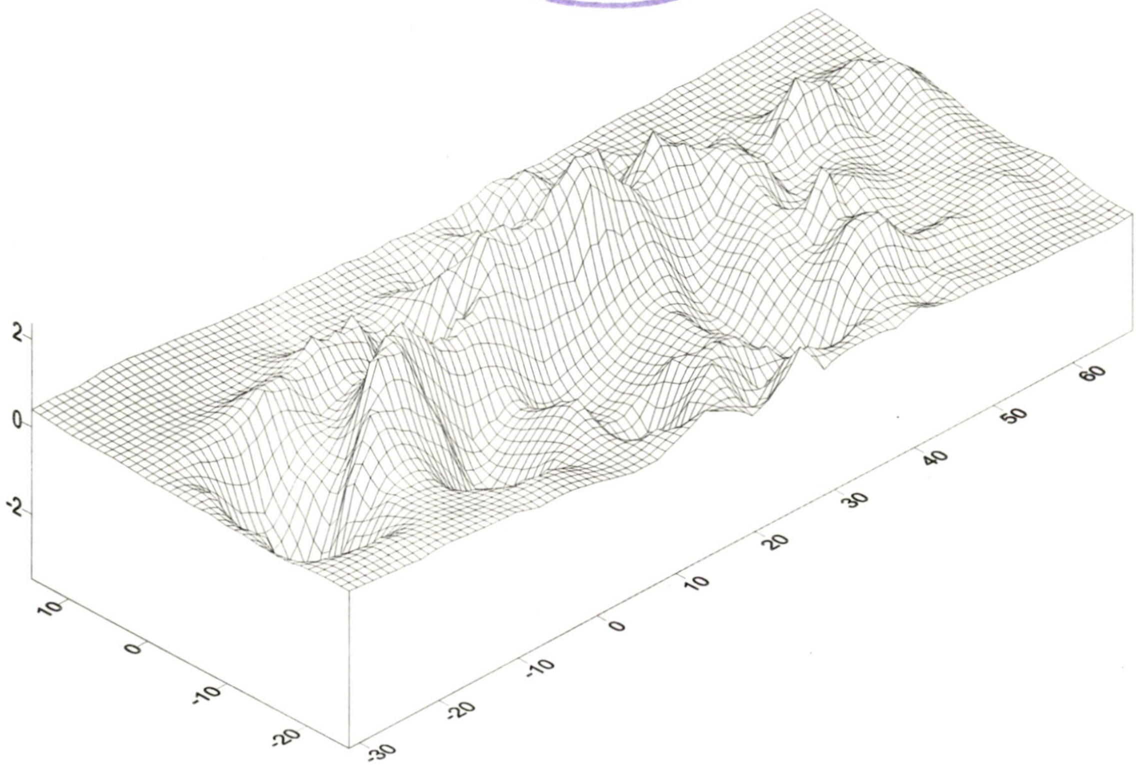

Figure - 4.18

3D view of dike formation for submerged vanes with aspect ratio 0.20 and $\alpha = 25^{\circ}$

Plate 4.9

Dike formation due to vane with aspect ratio 0.20 and $\alpha = 25^{\circ}$

4.2 STRENGTH OF VORTEX

For this purpose, 4cm x 4cm grids across the flume have been taken at the distance of 20 cm downstream from the centre of vanes. At each grid points all the components of velocity were measured using ADV (Acoustic Doppler Velocimeter).

The velocity at each grid points is the representative velocity of the grid area 4cm x 4 cm.

Fig shows the layout of grids in flow area cross-section. Velocity near the wall of the flume was not considered for the calculation of strength of vortex in order to neglect the wall effect on the generation of secondary flow due to submerged vanes.
Centre of vortex was observed at z = 0.9H. The origin was taken at the mid of average vane length at initial bed level in this chapter. For a mass 'm' concentrated at point A (fig 4.), one can write the following expression for moment of momentum, MOM_A.

$$MOM_A = (mass)(\vec{R} \times \vec{V}) \quad \text{.......(4.1)}$$

In equation (4.1), R represents the location vector of point A with respect to centre of vortex C and is given as $\overrightarrow{CA}$.

The location vector of point A with respect to origin O is given as $\overrightarrow{OA}$,
Where,

$$\overrightarrow{OA} = y\vec{j} + z\vec{k} \quad \text{.......(4.2)}$$

In equation 4.2, y and z are coordinates of grid points and $\vec{j}$ and $\vec{k}$ are unit vectors along Y and Z directions, respectively. With the centre of vortex at C, one can write

$$\overrightarrow{OC} = 0.9H\,\vec{k} \quad \text{.......(4.3)}$$

Where, H = Height of vane and C = Centre of vortex

From eqs. (4.2) and (4.3), location vector of point A with respect to point C can be written as

$$\begin{aligned}\vec{R} &= \overrightarrow{OA} - \overrightarrow{OC} \\ &= y\vec{j} + z\vec{k} - 0.9H\vec{k} \\ &= y\vec{j} + (z-0.9H)\vec{k} \quad \text{.......(4.4)}\end{aligned}$$

thus, MOM of mass 'm' at point A with respect to centre of vortex C can be expressed as

$$MOM_A = m[\{y\vec{j} + (z - 0.9H)\vec{k}\} \times (V_y\vec{j} + V_z\vec{k})]$$

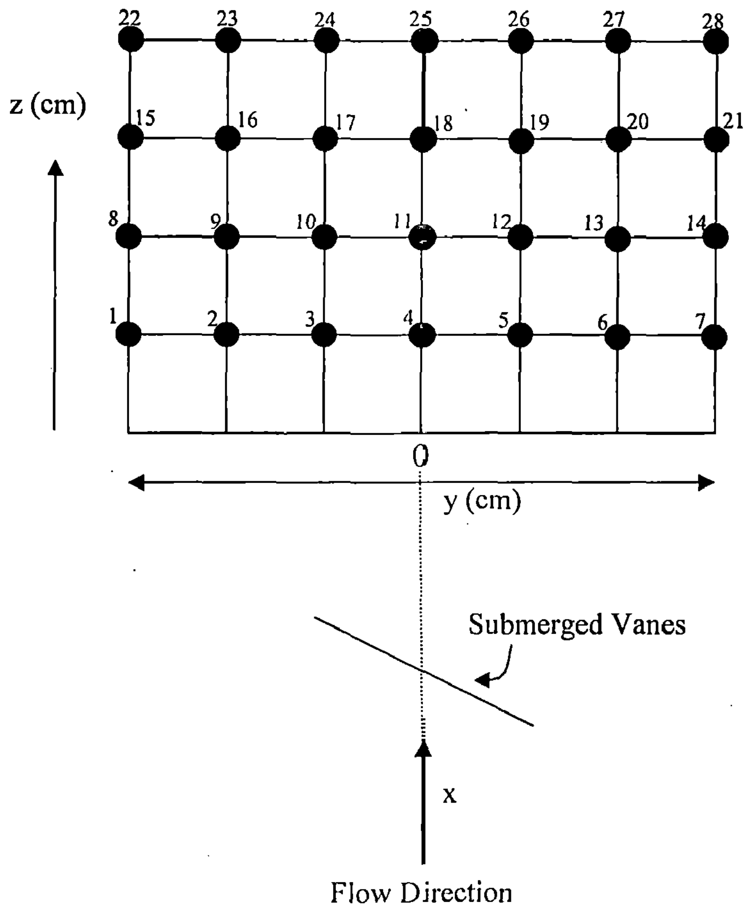

Fig. 4.19 Grid points for the collection of data

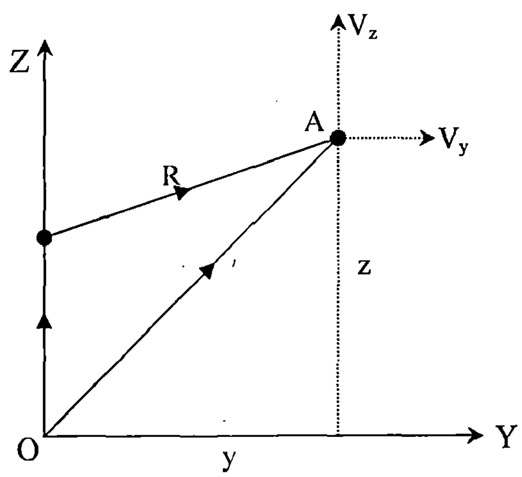

Fig. 4.20 Definition sketch for velocity vectors

$= m\vec{i}\,[y\,V_z - (z - 0.9H)\,V_y]$

$= m\vec{i}\,[y\,V_z + \{-(z - 0.9H)\,V_y\}]$ ....(4.5)

In eqn (4.5), $\vec{i}$ indicates the direction of MOM along the direction of flow of fluid (here water). In eqn (4.5), ($m\,y\,V_z$) is MOM due to vertical velocity and $\{-m(z - 0.9H)\,V_y\}$ is MOM due to transverse velocity.

For grid area of 4cm x 4cm and 1 cm length of flume with ρ as 1 gm/cm^3, mass m can be computed as,

$$M = 1 \times 4 \times 4 \times 1 = 16 \text{ gm} \qquad \text{.................................(4.6)}$$

Using eqn (4.5) and (4.6), one can write

$$MOM_A = 16\vec{i}\,[y\,V_z + \{-(z - 0.9H)\,V_y\}] \qquad \text{............................(4.7)}$$

Thus, total MOM can be expressed as

$$\text{Total MOM} = \Sigma\, MOM_i \qquad \text{.............................(4.8)}$$

In table (4.1), MOM at different grid points is presented.

Table 4.1 Moment of momentum at different nodes

Grid Points	Co-ordinates		Velocity		Moment of Momentum
	Symbols	Values	Vy	Vz	
1	y_1, z_1	2.4H, 0.8H	Vy_1	Vz_1	$16H\ [2.4Vz_1 + 0.1Vy_1]$
2	y_2, z_2	1.6H, 0.8H	Vy_2	Vz_2	$16H\ [1.6Vz_2 + 0.1Vy_2]$
3	y_3, z_3	0.8H, 0.8H	Vy_3	Vz_3	$16H\ [0.8Vz_3 + 0.1Vy_3]$
4	y_4, z_4	0H, 0.8H	Vy_4	Vz_4	$16H\ [0Vz_4 + 0.1Vy_4]$
5	y_5, z_5	-0.8H, 0.8H	Vy_5	Vz_5	$16H\ [-0.8Vz_5 + 0.1Vy_5]$
6	y_6, z_6	-1.6H, 0.8H	Vy_6	Vz_6	$16H\ [-1.6Vz_6 + 0.1Vy_6]$
7	y_7, z_7	-2.4H, 0.8H	Vy_7	Vz_7	$16H\ [-2.4Vz_7 + 0.1Vy_7]$
8	y_8, z_8	2.4H, 1.6H	Vy_8	Vz_8	$16H\ [2.4Vz_1 - 0.7Vy_1]$
9	y_9, z_9	1.6H, 1.6H	Vy_9	Vz_9	$16H\ [1.6Vz_2 - 0.7Vy_2]$
10	Y_{10}, z_{10}	0.8H, 1.6H	Vy_{10}	Vz_{10}	$16H\ [0.8Vz_3 - 0.7Vy_3]$
11	Y_{11}, z_{11}	0H, 1.6H	Vy_{11}	Vz_{11}	$16H\ [0Vz_4 - 0.7Vy_4]$
12	Y_{12}, z_{12}	-0.8H, 1.6H	Vy_{12}	Vz_{12}	$16H\ [-0.8Vz_5 - 0.7Vy_5]$
13	Y_{13}, z_{13}	-1.6H, 1.6H	Vy_{13}	Vz_{13}	$16H\ [-1.6Vz_6 - 0.7Vy_6]$
14	Y_{14}, z_{14}	-2.4H, 1.6H	Vy_{14}	Vz_{14}	$16H\ [-2.4Vz_7 - 0.7Vy_7]$
15	Y_{15}, z_{15}	2.4H, 2.4H	Vy_{15}	Vz_{15}	$16H\ [2.4Vz_1 - 1.5Vy_1]$
16	Y_{16}, z_{16}	1.6H, 2.4H	Vy_{16}	Vz_{16}	$16H\ [1.6Vz_2 - 1.5Vy_2]$
17	Y_{17}, z_{17}	0.8H, 2.4H	Vy_{17}	Vz_{17}	$16H\ [0.8Vz_3 - 1.5Vy_3]$
18	Y_{18}, z_{18}	0H, 2.4H	Vy_{18}	Vz_{18}	$16H\ [0Vz_4 - 1.5Vy_4]$
19	Y_{19}, z_{19}	-0.8H, 2.4H	Vy_{19}	Vz_{19}	$16H\ [-0.8Vz_5 - 1.5Vy_5]$
20	Y_{20}, z_{20}	-1.6H, 2.4H	Vy_{20}	Vz_{20}	$16H\ [-1.6Vz_6 - 1.5Vy_6]$
21	Y_{21}, z_{21}	-2.4H, 2.4H	Vy_{21}	Vz_{21}	$16H\ [-2.4Vz_7 - 1.5Vy_7]$
22	Y_{22}, z_{22}	2.4H, 3.2H	Vy_{22}	Vz_{22}	$16H\ [2.4Vz_1 - 2.3Vy_1]$
23	Y_{23}, z_{23}	1.6H, 3.2H	Vy_{23}	Vz_{23}	$16H\ [1.6Vz_2 - 2.3Vy_2]$
24	Y_{24}, z_{24}	0.8H, 3.2H	Vy_{24}	Vz_{24}	$16H\ [0.8Vz_3 - 2.3Vy_3]$
25	Y_{25}, z_{25}	0H, 3.2H	Vy_{25}	Vz_{25}	$16H\ [0Vz_4 - 2.3Vy_4]$
26	Y_{26}, z_{26}	-0.8H, 3.2H	Vy_{26}	Vz_{26}	$16H\ [-0.8Vz_5 - 2.3Vy_5]$
27	Y_{27}, z_{27}	-1.6H, 3.2H	Vy_{27}	Vz_{27}	$16H\ [-1.6Vz_6 - 2.3Vy_6]$
28	Y_{28}, z_{28}	-2.4H, 3.2H	Vy_{28}	Vz_{28}	$16H\ [-2.4Vz_7 - 2.3Vy_7]$

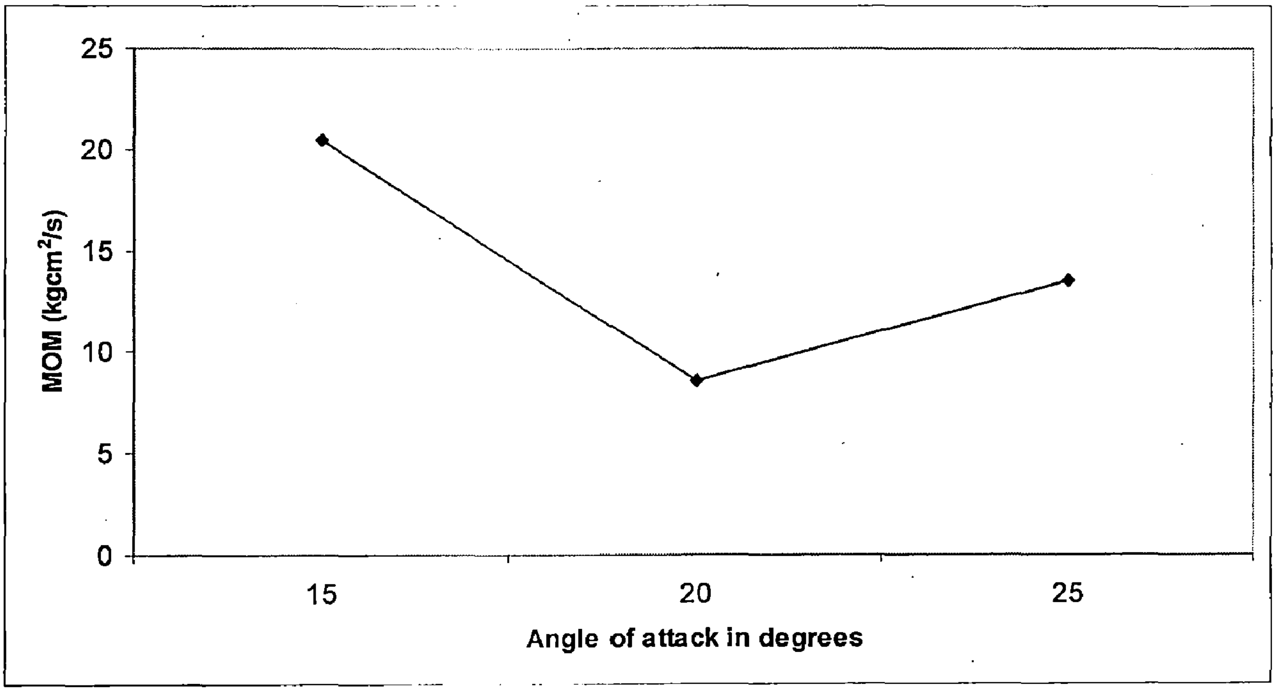

Fig. 4.21 Variation of MOM with angles of attack for aspect ratio 0.33

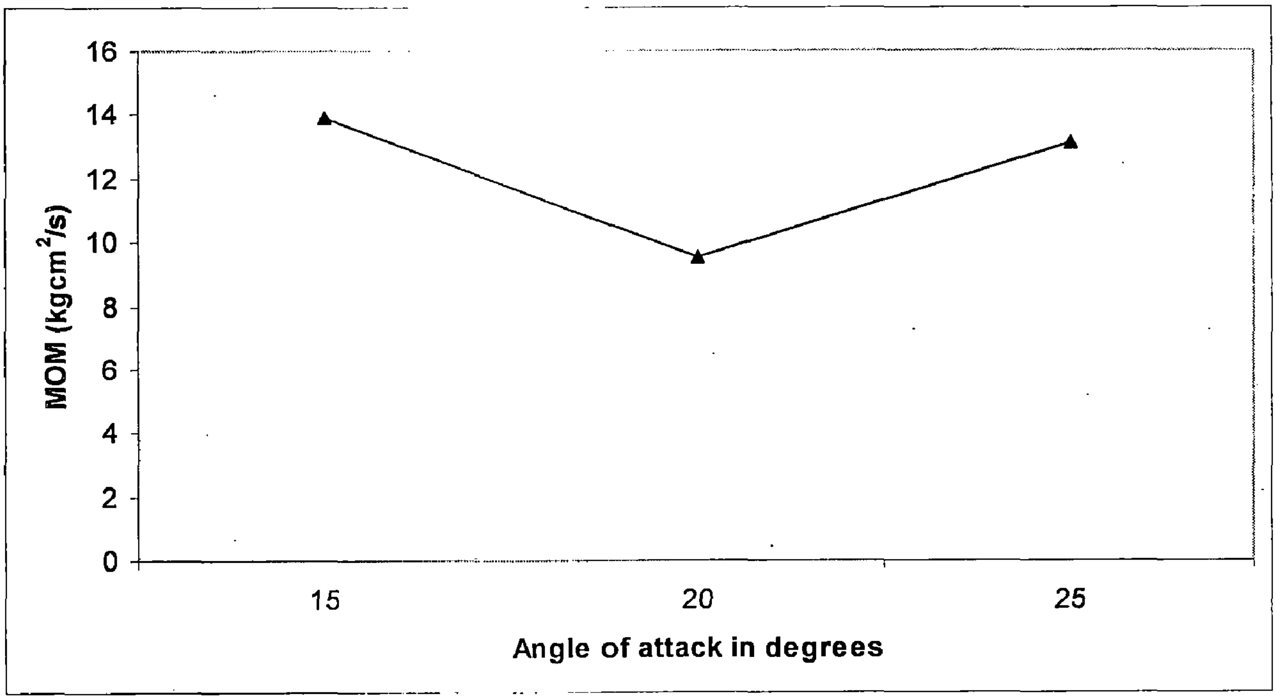

Fig. 4.22 Variation of MOM with angles of attack for aspect ratio 0.25

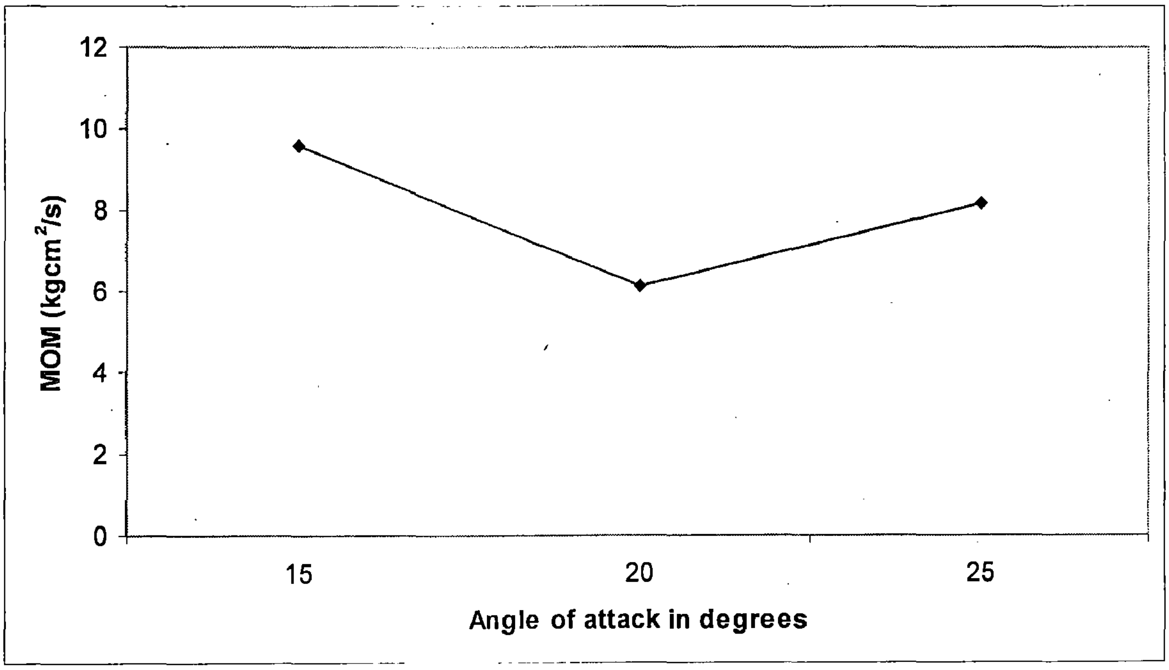

Fig. 4.23 Variation of MOM with angles of attack for aspect ratio 0.20

It is apparent from graph that the angle of attack 20^{O} is having minimum MOM.

Table 4.2 Details of Experiments and maximum height of dike

EXP No.	Water depth	Discharge	Aspect Ratio	T/d	α	MOM	Maximum height of dike
A1	20 cm	23900 cm3/s	0.33	0.75	15	20.5	0.85
A2	20 cm	23900 cm3/s	0.33	0.75	20	8.6	1.56
A3	20 cm	23900 cm3/s	0.33	0.75	25	13.6	3.02
A4	20 cm	23900 cm3/s	0.25	0.75	15	13.9	1.65
A5	20 cm	23900 cm3/s	0.25	0.75	20	9.5	1.544
A6	20 cm	23900 cm3/s	0.25	0.75	25	13.1	1.2
A7	20 cm	23900 cm3/s	0.2	0.75	15	9.57	1.8
A8	20 cm	23900 cm3/s	0.2	0.75	20	6.16	1.95
A9	20 cm	23900 cm3/s	0.2	0.75	25	8.2	2.39

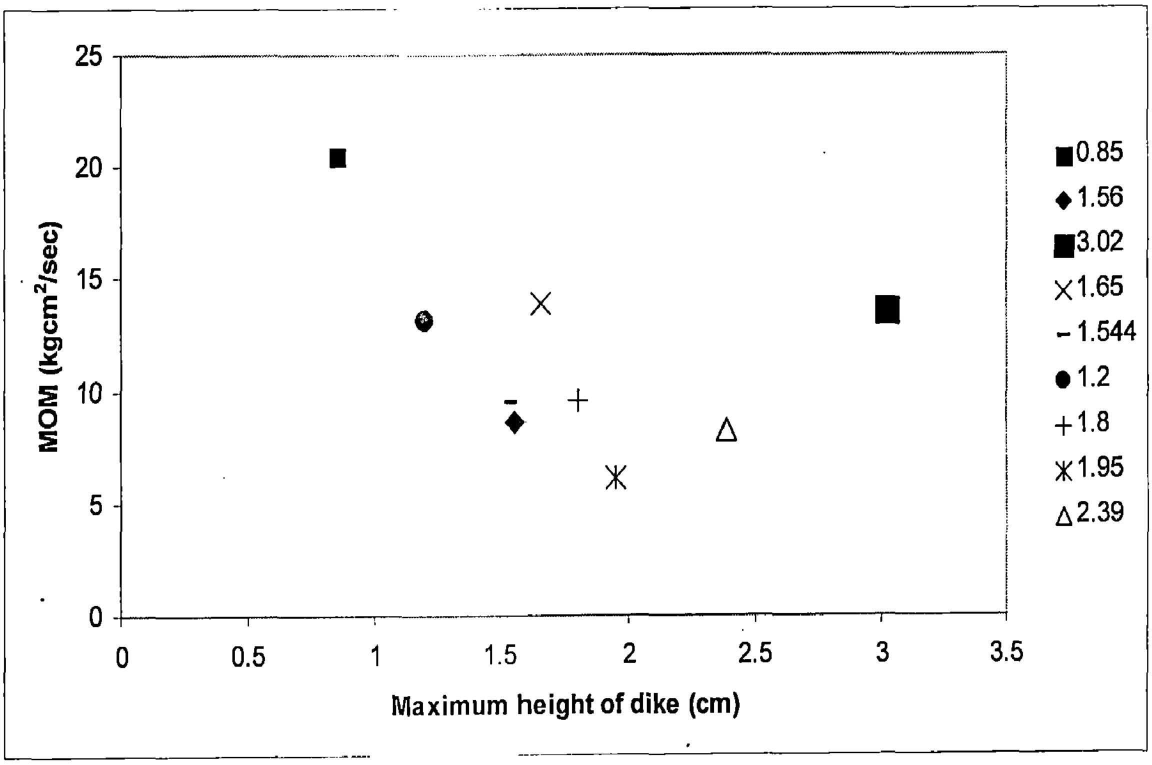

Fig. 4.24 Strength of vortex and maximum height of dike

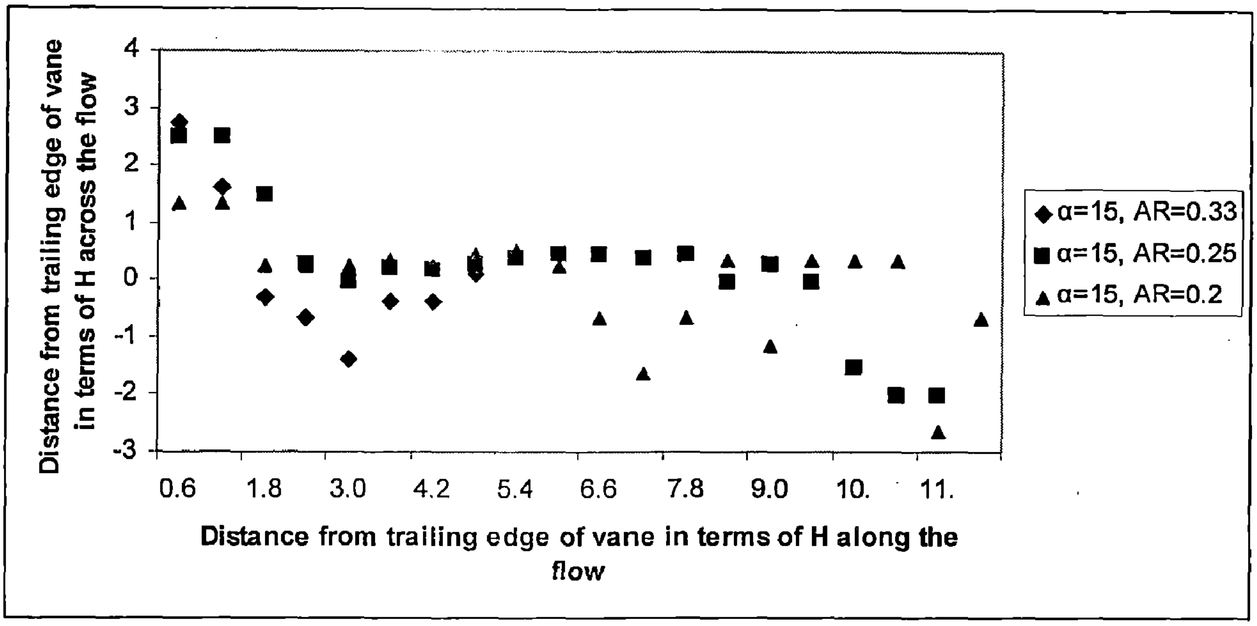

Fig 4.25 Scattering of dike alignment across the flow with different aspect ratios at $\alpha = 15^{O}$

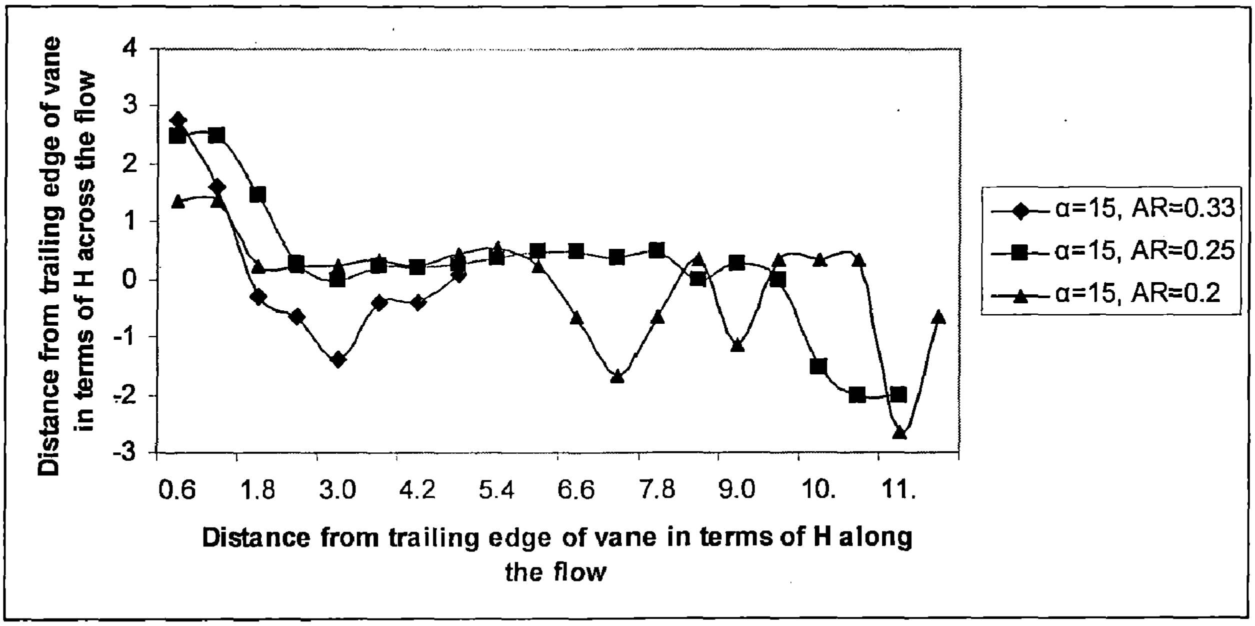

Fig 4.26 Dike alignment across the flow with different aspect ratios at $\alpha = 15^{O}$

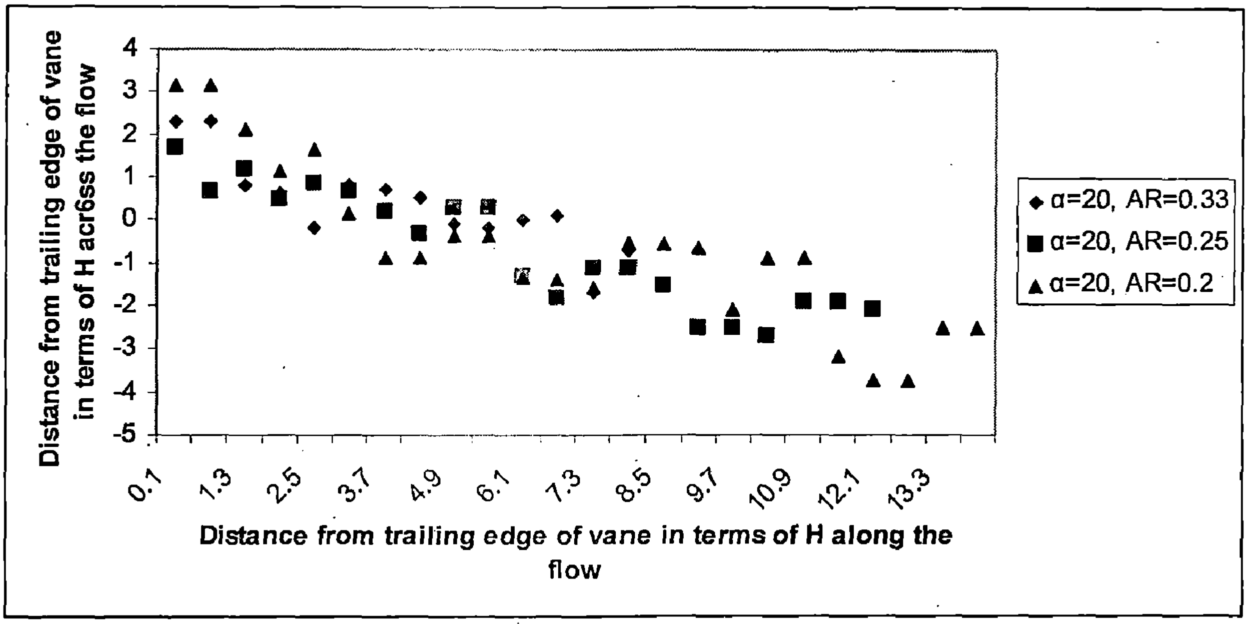

Fig 4.27 Scattering of dike alignment across the flow with different aspect ratios at $\alpha = 20^{O}$

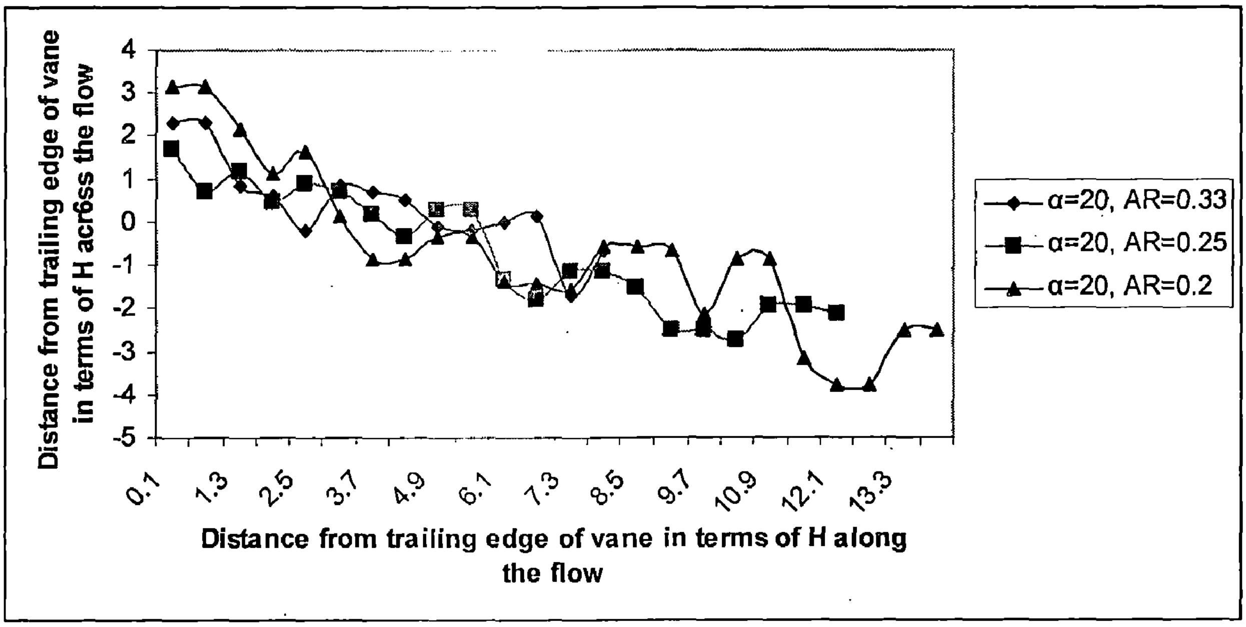

Fig 4.28 Dike alignment across the flow with different aspect ratios at $\alpha = 20^{O}$

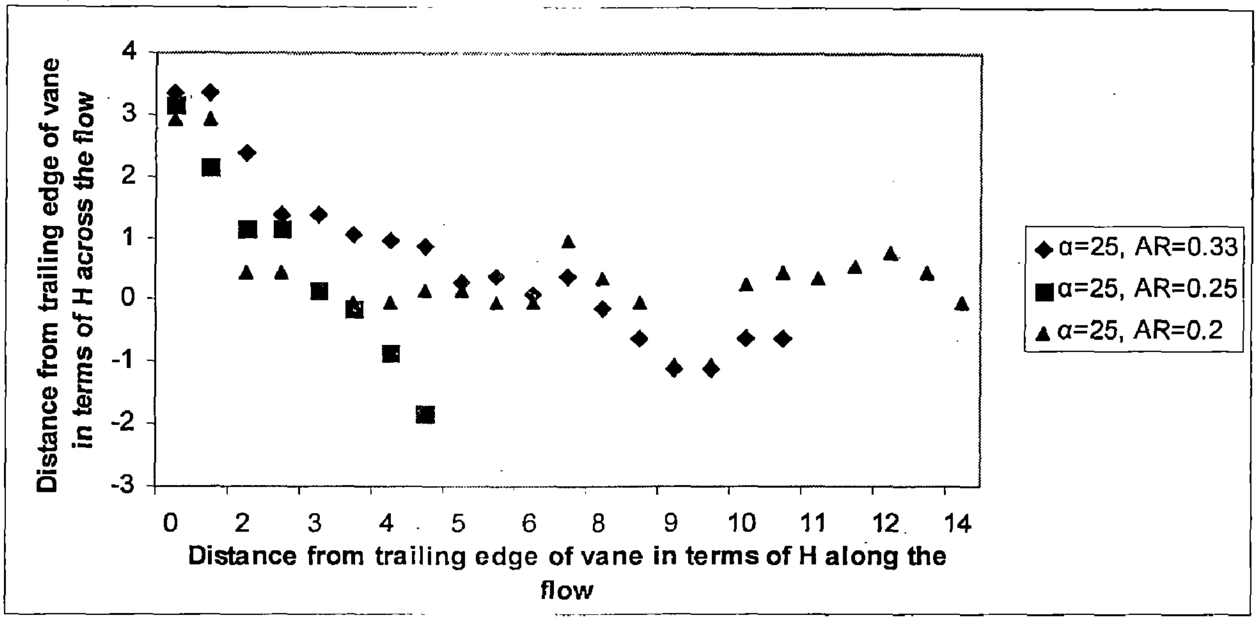

Fig 4.29 Scattering of dike alignment across the flow with different aspect ratios at $\alpha = 25^{O}$

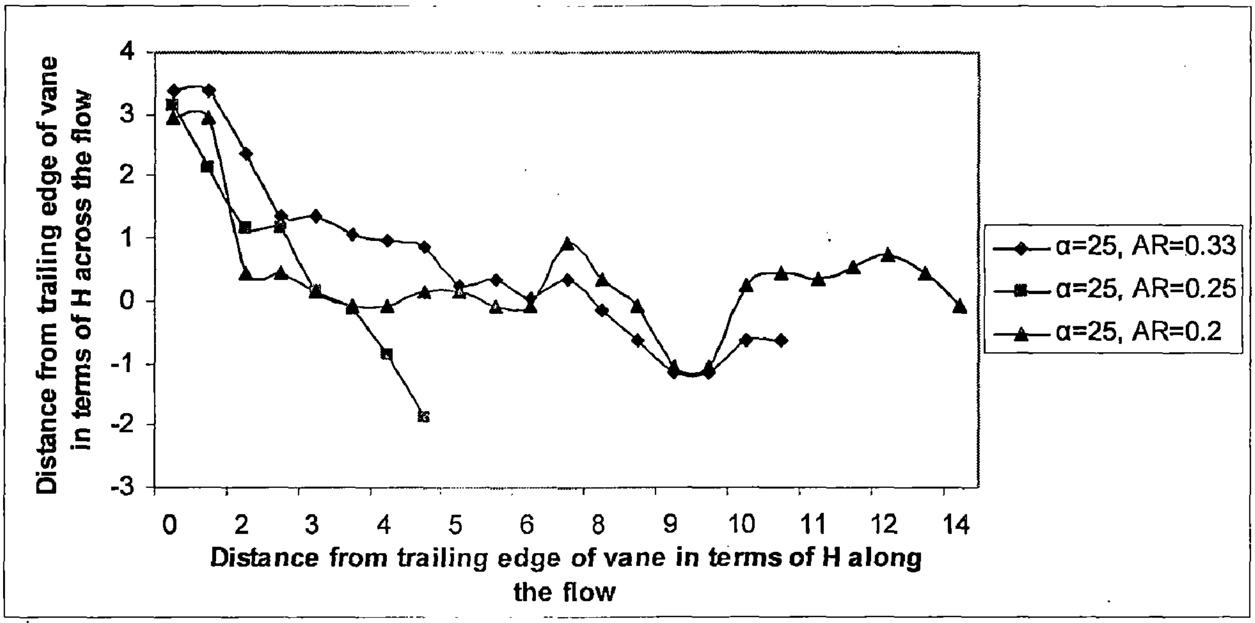

Fig 4.30 Dike alignment across the flow with different aspect ratios at $\alpha = 25^{O}$

Chapter - 5

GENERAL REMARKS, CONCLUSIONS AND FUTURE WORK

5.1 GENERAL REMARKS

The present work is primarily concerned with the formation of dike as an outcome of submerged vanes with lower angles of attack. The strength of vortex as moment of momentum is also calculated at 20 cm downstream of the trailing edge of the vane.

At such lower angles, vanes are very stable and the effect of scouring is not a threat to its stability. For these reasons, there were three aspects for planning of the present work is envisaged, viz. (i) observations of dike formation after the vane, identification of maximum dike height (ii) identification of angle of attack for maximum dike formation; and (iii) variation of strength of vortex in terms of moment of momentum.

To achieve these objectives of the study, vanes of different aspect ratios are used at different angles of attack. Experiments have been conducted at constant velocity of 23.90 cm/sec. In reality, the flow conditions may not correspond to a fixed velocity of flow. Thus, the velocity changes can be an important aspect for planning of future experiments to achieve the better understanding of performance of vanes at lower angles of attack.

The sediment size may play an important role in identification of dike formation. In present work, only sediment size 0.225 is considered due to limited scope of study. Thus, as a part of future investigations, the influence of sediment size on lower angles of attack needs to be explored.

Strength of vane induced vortices has been studied in terms of moment of momentum. The effect of angle of attack is in line with the findings of earlier investigators.

Based on present work, the following observations can be put forth in the form of conclusion.

5.2 CONCLUSIONS

1. Based on different aspect ratio and different angles of attack, it has been found that at lower angles of attack also we can get sizable dike formation to protect the area.

2. The dike formation was found to be longest in case of aspect ratio = 0.20 and angle of attack = 25^{O}. and it is shortest for aspect ratio = 0.25 and angle of attack = 25^{O}.

3. The moment of momentum is found to be minimum for angle of attack of 20^{O}.

4. It was found that maximum height of dike was formed at aspect ratio 0.33 and angle of attack 25^{o} (Exp A3). and minimum height of dike was formed at aspect ratio 0.33 and angle of attack 15^{o} (Exp A1).

5.3 FUTURE SCOPE FOR WORK

1. The dike formation at lower angles has to be tested in field.

2. The dike formations due to arrays of submerged vanes should be investigated to get important design parameters.

3. Sediment concentration may influence the density of fluid to be used in MOM computations. This aspect needs further considerations.

4. Use of collars with submerged vanes at lower angles of attack may give significant results which are still to be explored.

5. The effect of change of velocity at lower angles of attack still needs to be investigated.

6. Further investigation is required for the streamwise decay of vane induced vortex at these angles of attack.

7. In-depth experimental studies on the dike formation process with different size of sediments are suggested.

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EXPERIMENTAL DATA RELATED TO DIKE FORMATION

This appendix contains the experimental data collected in River engineering laboratory, Water Resources Development & Management Department, Indian Institute of Technology, Roorkee, India. The data presented here have been used in chapter 4 of this thesis. The fig. A.1 indicates the sign convention and axes used.

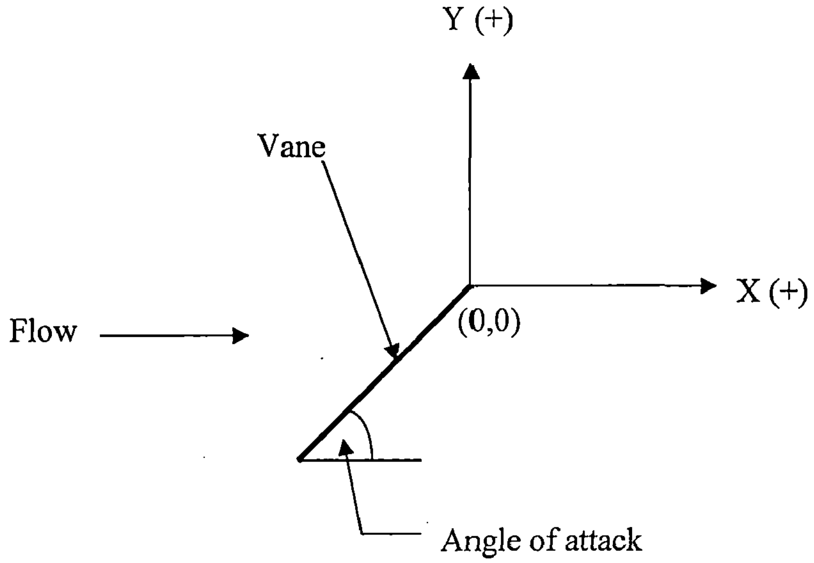

Fig. A.1 Definition sketch of origin for measurement of dike formation downstream of vane

Origin = Trailing edge of the vane at initial bed level

Table A.1 Experimental data for aspect ratio 0.33 & angle of attack 15^0

I			II			III		
x	y	z	x	y	z	x	y	z
-19.24	-21.94	0.1	-13.24	-1.94	-0.76	-7.24	0.06	0.05
-19.24	-16.94	0.1	-13.24	0.06	0.2	-7.24	3.06	0.06
-19.24	-11.94	0.1	-13.24	3.06	0.26	-7.24	8.06	0.3
-19.24	-6.94	0.12	-13.24	8.06	0.3	-7.24	13.06	0.45
-19.24	-1.94	0.2	-13.24	13.06	0.35	-7.24	18.06	0.5
-19.24	3.06	0.2	-13.24	18.06	0.53	-4.24	-21.94	0
-19.24	8.06	0.35	-10.24	-21.94	0	-4.24	-16.94	0
-19.24	13.06	0.3	-10.24	-16.94	0.06	-4.24	-11.94	0
-19.24	18.06	0.6	-10.24	-11.94	0	-4.24	-6.94	0.1
-16.24	-21.94	0.1	-10.24	-7.44	-0.34	-4.24	-4.44	0.55
-16.24	-16.94	0.05	-10.24	-5.94	-0.17	-4.24	-1.94	-0.05
-16.24	-11.94	0.05	-10.24	-3.44	-0.65	-4.24	1.06	0.16
-16.24	-6.94	-0.45	-10.24	-1.94	-0.57	-4.24	3.06	0.15
-16.24	-4.44	-0.8	-10.24	3.06	0.3	-4.24	8.06	0.24
-16.24	-1.94	-0.08	-10.24	8.06	0.3	-4.24	13.06	0.24
-16.24	3.06	0.25	-10.24	13.06	0.35	-4.24	18.06	0.35
-16.24	8.06	0.3	-10.24	18.06	0.46	-1.24	-21.94	0
-16.24	13.06	0.44	-7.24	-21.94	0.02	-1.24	-16.94	0
-16.24	18.06	0.55	-7.24	-16.94	0.02	-1.24	-11.94	0
-13.24	-21.94	0	-7.24	-11.94	-0.17	-1.24	-6.94	0.2
-13.24	-16.94	0	-7.24	-8.44	-0.38	-1.24	-3.44	0.85
-13.24	-11.94	0	-7.24	-6.94	-0.05	-1.24	-1.34	-0.1
-13.24	-6.94	-1.05	-7.24	-4.94	0.5	-1.24	1.56	0.24
-13.24	-4.14	-1.05	-7.24	-2.44	-0.24	-1.24	3.06	0.2

Table A.1 continued……

IV			V			VI		
x	y	z	x	y	z	x	y	z
-1.24	8.06	0.2	7.76	-6.94	0.33	16.76	-11.94	0
-1.24	13.06	0.35	7.76	-3.44	0.75	16.76	-6.94	0.2
-1.24	18.06	0.46	7.76	-0.94	0.05	16.76	-1.94	0.3
1.76	-21.94	0	7.76	2.56	0.3	16.76	3.06	0
1.76	-16.94	0	7.76	8.06	0.15	16.76	8.06	0.15
1.76	-11.94	0	7.76	13.06	0.3	16.76	13.06	0.35
1.76	-6.94	-0.05	7.76	18.06	0.4	16.76	18.06	0.35
1.76	-4.44	0.1	10.76	-21.94	0	19.76	-21.94	0
1.76	-2.44	0.65	10.76	-16.94	0	19.76	-16.94	0
1.76	-1.44	-0.16	10.76	-11.94	0.1	19.76	-11.94	0.2
1.76	0.56	-0.37	10.76	-6.94	0.3	19.76	-6.94	0.06
1.76	3.06	0	10.76	-3.94	0.25	19.76	-1.94	0.24
1.76	8.06	0.1	10.76	-1.94	0.13	19.76	2.06	0.3
1.76	13.06	0.3	10.76	0.56	0.12	19.76	5.06	0.2
1.76	18.06	0.56	10.76	3.06	0	19.76	8.06	0.24
4.76	-21.94	0	10.76	8.06	0.1	19.76	13.06	0.34
4.76	-16.94	0	10.76	13.06	0.2	19.76	18.06	0.4
4.76	-11.94	-0.1	10.76	18.06	0.35	22.76	-21.94	0
4.76	-6.94	0.24	13.76	-21.94	0	22.76	-16.94	-0.05
4.76	-4.44	0.1	13.76	-16.94	-0.05	22.76	-11.94	0.04
4.76	-2.44	0.7	13.76	-11.94	-0.1	22.76	-6.94	0
4.76	-0.94	-0.3	13.76	-6.94	0.24	22.76	-1.94	0.16
4.76	2.06	0.06	13.76	-1.94	0.2	22.76	0.56	0.2
4.76	8.06	0.14	13.76	3.06	-0.05	22.76	3.06	0.05
4.76	13.06	0.3	13.76	8.06	0.13	22.76	8.06	0.2
4.76	18.06	0.4	13.76	13.06	0.3	22.76	13.06	0.3
7.76	-21.94	0	13.76	18.06	0.35	22.76	18.06	0.35
7.76	-16.94	0	16.76	-21.94	0			
7.76	-11.94	0	16.76	-16.94	0			

Table A.2 Experimental data for aspect ratio 0.33 & angle of attack 20^0

I			II			III		
x	y	z	x	y	z	x	y	z
-20.4	-23.4	0	-14.4	16.6	0.4	-5.4	-1.4	-0.15
-20.4	-18.4	0	-11.4	-23.4	0	-5.4	1.6	0.1
-20.4	-13.4	0	-11.4	-18.4	-0.1	-5.4	6.6	0.1
-20.4	-8.4	-0.1	-11.4	-13.4	-0.06	-5.4	11.6	0.15
-20.4	-6.4	-0.58	-11.4	-10.4	-0.78	-5.4	16.6	0.3
-20.4	-3.4	0.1	-11.4	-8.4	-0.84	-2.4	-23.4	-0.1
-20.4	1.6	0.2	-11.4	-6.4	1.5	-2.4	-18.4	-0.1
-20.4	6.6	0.2	-11.4	-3.4	-0.15	-2.4	-13.4	-0.1
-20.4	11.6	0.25	-11.4	-0.9	0.1	-2.4	-8.4	-0.25
-20.4	16.6	0.25	-11.4	0.1	0.4	-2.4	-6.4	-0.16
-17.4	-23.4	0.1	-11.4	1.6	0	-2.4	-3.4	0.53
-17.4	-18.4	-0.07	-11.4	6.6	0	-2.4	-1.2	-0.24
-17.4	-13.4	-0.05	-11.4	11.6	0.12	-2.4	1.6	0.06
-17.4	-9.9	-1.26	-11.4	16.6	0.32	-2.4	6.6	0.1
-17.4	-8.4	-1.57	-8.4	-23.4	0	-2.4	11.6	0.17
-17.4	-6.4	-1.25	-8.4	-18.4	-0.07	-2.4	16.6	0.35
-17.4	-3.4	-0.95	-8.4	-13.4	-0.1	0.6	-23.4	-0.04
-17.4	1.6	0.1	-8.4	-11.1	-0.56	0.6	-18.4	-0.1
-17.4	6.6	0.15	-8.4	-8.4	-0.75	0.6	-13.4	-0.07
-17.4	11.6	0.22	-8.4	-5.4	0.35	0.6	-8.4	-0.95
-17.4	16.6	0.4	-8.4	-1.7	-0.14	0.6	-5.9	-0.77
-14.4	-23.4	0	-8.4	0.6	0.6	0.6	-3.4	-0.54
-14.4	-18.4	-0.05	-8.4	1.6	0.3	0.6	-0.9	-1.04
-14.4	-13.4	-0.06	-8.4	6.6	0.1	0.6	1.6	-0.36
-14.4	-10.4	-0.77	-8.4	11.6	0.1	0.6	6.6	0.1
-14.4	-8.4	-1	-8.4	16.6	0.3	0.6	11.6	0.2
-14.4	-5.2	-0.26	-5.4	-23.4	-0.15	0.6	16.6	0.4
-14.4	-3.4	-0.74	-5.4	-18.4	-0.15	3.6	-23.4	-0.1
-14.4	1.6	0.04	-5.4	-13.4	-0.2	3.6	-18.4	-0.2
-14.4	6.6	0.1	-5.4	-8.4	-0.3	3.6	-13.4	-0.15
-14.4	11.6	0.12	-5.4	-4.4	1.03	3.6	-8.4	-0.97

Table A.2 continued……

IV			V			VI		
x	y	z	x	y	z	x	y	z
3.6	-5.9	-2.16	9.6	8.6	0.1	18.6	-13.4	0
3.6	-3.4	-1.84	9.6	9.6	0.03	18.6	-8.4	0
3.6	-0.9	-1	9.6	11.6	0.1	18.6	-3.4	0.5
3.6	1.6	-1.34	9.6	16.6	0.25	18.6	-0.9	0.2
3.6	4.1	0.04	12.6	-23.4	-0.2	18.6	1.6	0.55
3.6	6.6	0.1	12.6	-18.4	-0.2	18.6	3.6	1.15
3.6	11.6	0.22	12.6	-13.4	-0.1	18.6	6.6	-0.4
3.6	16.6	0.26	12.6	-8.4	0.14	18.6	9.1	-1.76
6.6	-23.4	-0.1	12.6	-5.9	0.2	18.6	11.6	-1.25
6.6	-18.4	-0.1	12.6	-3.4	0.4	18.6	13.1	0.2
6.6	-13.4	-0.1	12.6	-0.9	0.63	18.6	16.6	0.2
6.6	-8.4	0	12.6	1.6	-0.35	21.6	-23.4	-0.1
6.6	-6.9	0.05	12.6	4.1	0.7	21.6	-18.4	-0.08
6.6	-3.4	-1.07	12.6	6.1	1.2	21.6	-13.4	-0.08
6.6	-0.9	-0.65	12.6	9.1	0.1	21.6	-8.4	-0.08
6.6	0.3	-1.04	12.6	10.6	-0.4	21.6	-3.4	0.23
6.6	1.6	0	12.6	16.6	0.2	21.6	-0.9	1.05
6.6	4.1	0.23	15.6	-23.4	-0.2	21.6	1.6	1
6.6	6.6	0.1	15.6	-18.4	-0.1	21.6	2.6	1.3
6.6	11.6	0.2	15.6	-13.4	-0.04	21.6	6.6	0.1
6.6	16.6	0.2	15.6	-8.4	0	21.6	9.6	-1
9.6	-23.4	-0.15	15.6	-2.4	0.7	21.6	11.6	0.05
9.6	-18.4	-0.16	15.6	0.4	-0.5	21.6	14.1	0.2
9.6	-13.4	-0.1	15.6	4.1	1.35	21.6	16.6	0.2
9.6	-8.4	0.07	15.6	6.6	0.52	24.6	-23.4	-0.04
9.6	-5.9	0.05	15.6	9.6	-0.8	24.6	-18.4	-0.04
9.6	-3.4	-0.1	15.6	11.6	-1	24.6	-13.4	-0.04
9.6	1.1	-0.55	15.6	12.1	0.1	24.6	-8.4	-0.04
9.6	3.1	0.2	15.6	16.6	0.2	24.6	-3.4	0.1
9.6	5.6	0.85	18.6	-23.4	-0.1	24.6	-0.4	1.56
9.6	6.1	0.95	18.6	-18.4	0	24.6	1.6	1.53

Table A.2 continued……

VII			VIII		
x	y	z	x	Y	z
24.6	3.6	0.9	30.6	16.6	0.4
24.6	6.6	0.14	33.6	-23.4	-0.15
24.6	9.1	0.76	33.6	-18.4	-0.1
24.6	11.6	0.6	33.6	-13.4	-0.1
24.6	13.1	0.74	33.6	-8.4	0.04
24.6	16.6	0.2	33.6	-3.4	0.1
27.6	-23.4	-0.1	33.6	0.6	0.74
27.6	-18.4	-0.04	33.6	3.1	0.44
27.6	-13.4	-0.04	33.6	6.6	0.3
27.6	-8.4	0	33.6	11.6	0.32
27.6	-3.4	0.4	33.6	16.6	0.5
27.6	-0.9	1.1	36.6	-23.4	-0.1
27.6	1.6	0.9	36.6	-18.4	0
27.6	3.6	1	36.6	-13.4	0
27.6	6.6	0.3	36.6	-8.4	0.1
27.6	9.6	0.85	36.6	-3.4	0.1
27.6	11.6	0.84	36.6	1.6	0.3
27.6	14.1	0.63	36.6	6.6	0.3
27.6	16.6	0.35	36.6	11.6	0.4
30.6	-23.4	-0.07	36.6	16.6	0.55
30.6	-18.4	-0.04	39.6	-23.4	-0.1
30.6	-13.4	0	39.6	-18.4	-0.04
30.6	-8.4	0.04	39.6	-13.4	0
30.6	-3.4	0.1	39.6	-8.4	0.1
30.6	0	0.64	39.6	-3.4	0.1
30.6	1.6	0.6	39.6	1.6	0.2
30.6	3.1	1	39.6	6.6	0.2
30.6	6.6	0.3	39.6	11.6	0.3
30.6	11.6	0.3	39.6	16.6	0.5

Table A.3 Experimental data for aspect ratio 0.33 & angle of attack 25^0

I			II			III		
x	y	z	x	y	z	x	y	z
-19.8	-23.17	0.1	-10.8	1.83	0.1	-1.8	6.83	0.05
-19.8	-18.17	0.1	-10.8	6.83	0.15	-1.8	11.83	0.1
-19.8	-13.17	0.1	-10.8	11.83	0.29	-1.8	16.83	0.29
-19.8	-8.17	0.1	-10.8	16.83	0.39	1.2	-23.17	-0.15
-19.8	-3.17	0.17	-7.8	-23.17	-0.05	1.2	-18.17	-0.1
-19.8	1.83	0.29	-7.8	-18.17	0	1.2	-15.17	-0.6
-19.8	6.83	0.29	-7.8	-13.17	-0.01	1.2	-13.17	-1.81
-19.8	11.83	0.29	-7.8	-9.67	-0.32	1.2	-10.67	-2.45
-19.8	16.83	0.4	-7.8	-8.17	-0.83	1.2	-8.17	-1.79
-16.8	-23.17	0.05	-7.8	-6.17	-0.25	1.2	-5.67	-1.42
-16.8	-18.17	0.05	-7.8	-4.17	-0.19	1.2	-3.17	-0.83
-16.8	-13.17	0.05	-7.8	-3.17	0	1.2	-0.67	-2.05
-16.8	-8.17	-0.92	-7.8	1.83	0.05	1.2	1.83	-2.3
-16.8	-5.67	-0.75	-7.8	6.83	0.05	1.2	4.33	-1.51
-16.8	-3.17	-0.89	-7.8	11.83	0.15	1.2	6.33	-0.6
-16.8	1.83	0.25	-7.8	16.83	0.29	1.2	11.83	0.05
-16.8	6.83	0.29	-4.8	-23.17	-0.05	1.2	16.83	0.29
-16.8	11.83	0.35	-4.8	-18.17	-0.05	4.2	-23.17	-0.15
-16.8	16.83	0.45	-4.8	-12.17	-0.25	4.2	-18.17	-0.15
-13.8	-23.17	0.05	-4.8	-9.67	-0.3	4.2	-15.17	-0.95
-13.8	-18.17	0.02	-4.8	-8.17	-0.6	4.2	-13.17	-1.63
-13.8	-13.17	0.01	-4.8	-4.97	0.89	4.2	-10.67	-3.1
-13.8	-10.17	-0.5	-4.8	-2.67	0.01	4.2	-8.17	-3.1
-13.8	-8.67	-1.7	-4.8	-0.17	-0.01	4.2	-5.67	-2.6
-13.8	-6.67	-1.8	-4.8	1.83	0.18	4.2	-3.17	-1.61
-13.8	-3.17	-0.45	-4.8	6.83	0	4.2	-1.17	-1.42
-13.8	1.83	0.18	-4.8	11.83	0.1	4.2	1.83	-2.83
-13.8	6.83	0.18	-4.8	16.83	0.35	4.2	4.33	-1.49
-13.8	11.83	0.29	-1.8	-23.17	-0.1	4.2	6.33	-0.15
-13.8	16.83	0.4	-1.8	-18.17	-0.1	4.2	11.83	0.05
-10.8	-23.17	0.05	-1.8	-13.17	-0.45	4.2	16.83	0.17
-10.8	-18.17	-0.05	-1.8	-10.67	-1.35	7.2	-23.17	-0.15
-10.8	-13.17	0	-1.8	-8.17	-0.51	7.2	-18.17	-0.15
-10.8	-9.67	-0.55	-1.8	-5.67	0.35	7.2	-16.17	-0.75
-10.8	-8.17	-1.15	-1.8	-3.17	0.45	7.2	-13.17	-0.69
-10.8	-7.67	-1.52	-1.8	-1.17	-0.45	7.2	-10.67	-2.67
-10.8	-5.37	-1	-1.8	1.83	-0.45	7.2	-8.17	-3.1
-10.8	-3.17	-0.85	-1.8	4.33	-0.1	7.2	-5.67	-3.05

Table A.3 continued……

IV			V			VI		
x	y	z	x	y	z	x	y	z
7.2	-3.17	-2.52	13.2	10.83	-0.55	22.2	-20.67	-0.15
7.2	-0.67	-1.75	13.2	11.83	0	22.2	-18.17	-0.15
7.2	1.83	-2.49	13.2	16.83	0.13	22.2	-15.67	-0.65
7.2	4.33	-1.15	16.2	-23.17	-0.2	22.2	-13.17	-1.45
7.2	6.33	0.2	16.2	-21.17	-0.75	22.2	-10.67	-1.47
7.2	7.83	0.25	16.2	-18.17	-2.75	22.2	-8.17	-0.25
7.2	11.83	0	16.2	-15.67	-2.85	22.2	-5.67	-0.01
7.2	16.83	0.2	16.2	-13.17	-2.25	22.2	-3.17	0.55
10.2	-23.17	-0.15	16.2	-10.67	-0.9	22.2	-0.67	1.25
10.2	-18.17	-0.19	16.2	-8.17	-0.42	22.2	1.83	1.15
10.2	-15.67	-0.9	16.2	-5.67	1.25	22.2	4.33	1.8
10.2	-13.17	-0.1	16.2	-3.17	0.55	22.2	6.83	0.5
10.2	-10.67	-0.05	16.2	-0.67	-0.17	22.2	9.33	-0.05
10.2	-8.17	-0.85	16.2	1.83	-1	22.2	11.83	0.55
10.2	-5.67	-1.09	16.2	4.33	0.65	22.2	16.83	0.15
10.2	-3.17	-1.15	16.2	5.33	1.3	25.2	-23.17	0.08
10.2	-0.67	-1.55	16.2	6.83	0.45	25.2	-20.17	0.05
10.2	1.83	-2.45	16.2	9.33	-0.83	25.2	-18.17	0.41
10.2	4.33	-1.05	16.2	11.83	-1.1	25.2	-13.17	-0.23
10.2	6.83	0.2	16.2	13.33	-0.1	25.2	-10.67	-0.97
10.2	7.83	0.65	16.2	16.83	0.15	25.2	-8.17	-0.71
10.2	11.83	0	19.2	-23.17	-0.17	25.2	-6.17	0.39
10.2	16.83	0.2	19.2	-20.67	-1.05	25.2	-4.67	-0.03
13.2	-23.17	-0.2	19.2	-18.17	-1.4	25.2	-3.17	0.16
13.2	-19.17	-0.82	19.2	-15.67	-2.42	25.2	-0.67	1.33
13.2	-18.17	-1.45	19.2	-13.17	-2.52	25.2	1.33	2.35
13.2	-15.67	-0.81	19.2	-10.67	-1.49	25.2	3.33	2.17
13.2	-13.17	0.18	19.2	-8.17	-0.05	25.2	5.03	2.15
13.2	-11.17	0.65	19.2	-5.67	0.55	25.2	6.83	1.29
13.2	-9.17	0.83	19.2	-3.17	0.55	25.2	9.33	0.15
13.2	-8.17	0.85	19.2	-0.67	0.4	25.2	11.83	-0.1
13.2	-6.17	0.74	19.2	1.83	0.25	25.2	16.83	0.12
13.2	-3.17	0.3	19.2	4.83	1.45	28.2	-23.17	-0.22
13.2	-0.67	-1	19.2	6.83	0.4	28.2	-20.67	0.12
13.2	1.83	-1.89	19.2	9.33	0.55	28.2	-18.17	0.27
13.2	4.33	0.05	19.2	11.83	0.05	28.2	-15.17	0.47
13.2	6.83	0.7	19.2	16.83	0.1	28.2	-13.17	0
13.2	8.83	0.59	22.2	-23.17	-0.25	28.2	-10.67	-1.1

Table A.3 continued......

VII			VIII			IX		
x	y	z	x	y	z	x	y	z
28.2	-8.17	-1.15	34.2	16.83	0.1	43.2	4.33	0.25
28.2	-5.67	0.81	37.2	-23.17	-0.26	43.2	6.83	0.4
28.2	-3.17	0.12	37.2	-18.17	-0.19	43.2	11.83	0.1
28.2	-1.17	0.7	37.2	-13.17	-0.25	43.2	16.83	0.25
28.2	1.83	2.28	37.2	-10.67	0	46.2	-23.17	-0.35
28.2	3.83	3.02	37.2	-8.17	0.05	46.2	-18.17	-0.35
28.2	6.83	2.08	37.2	-5.67	0.9	46.2	-13.17	0
28.2	8.83	0.7	37.2	-3.17	2	46.2	-8.17	-0.25
28.2	11.83	-0.1	37.2	-0.67	1.55	46.2	-3.17	-0.15
28.2	16.83	0.08	37.2	1.83	1.5	46.2	-0.67	0.1
31.2	-23.17	-0.2	37.2	4.33	1.1	46.2	2.33	1
31.2	-18.17	-0.42	37.2	6.83	0	46.2	6.83	0.15
31.2	-14.67	-0.07	37.2	11.83	-0.05	46.2	11.83	0.05
31.2	-13.17	-0.31	37.2	16.83	0.2	46.2	16.83	0.15
31.2	-10.67	-0.85	40.2	-23.17	-0.3	49.2	-23.17	-0.37
31.2	-8.17	-0.31	40.2	-18.17	-0.2	49.2	-18.17	-0.3
31.2	-4.67	1.23	40.2	-13.17	-0.15	49.2	-13.17	-0.15
31.2	-3.17	0.78	40.2	-10.67	0.25	49.2	-8.17	-0.25
31.2	-1.67	0.67	40.2	-8.17	0.15	49.2	-3.17	-0.1
31.2	0.33	1.73	40.2	-5.67	0.9	49.2	-0.67	0.35
31.2	1.83	2.35	40.2	-3.17	0.5	49.2	1.83	-0.05
31.2	2.83	2.39	40.2	-0.67	0	49.2	4.33	0.35
31.2	5.83	1.85	40.2	1.83	0.57	49.2	6.83	0
31.2	9.33	0.57	40.2	4.33	0.15	49.2	11.83	0.05
31.2	11.83	0.04	40.2	6.83	0.2	49.2	16.83	0.15
31.2	16.83	0.12	40.2	11.83	0.05	52.2	-23.17	-0.45
34.2	-23.17	-0.15	40.2	16.83	0.15	52.2	-18.17	-0.45
34.2	-18.17	-0.26	43.2	-23.17	-0.3	52.2	-13.17	-0.45
34.2	-13.17	-0.29	43.2	-18.17	-0.25	52.2	-8.17	-0.25
34.2	-8.17	0.08	43.2	-15.67	0.1	52.2	-3.17	-0.15
34.2	-5.67	0.7	43.2	-13.17	-0.15	52.2	-0.67	-0.15
34.2	-3.67	1.68	43.2	-10.67	0.15	52.2	1.83	0.35
34.2	-1.17	1.18	43.2	-8.17	0.2	52.2	4.33	0.65
34.2	1.83	2.25	43.2	-5.67	0.4	52.2	6.83	0.4
34.2	4.33	1.08	43.2	-3.17	0	52.2	11.83	0.05
34.2	6.83	0.48	43.2	-0.67	-0.05	52.2	16.83	0.15
34.2	11.83	-0.08	43.2	1.83	0.15			

Table A.4 Experimental data for aspect ratio 0.25 & angle of attack 15^0

I			II			III		
x	y	z	x	y	z	x	Y	z
-22.24	-21.94	0	-10.24	-16.94	-0.1	-1.24	-6.94	-0.45
-22.24	-16.94	0	-10.24	-11.94	-0.11	-1.24	-4.44	0.35
-22.24	-11.94	0	-10.24	-9.44	-1.45	-1.24	-1.94	1.65
-22.24	-6.94	0	-10.24	-6.94	-0.81	-1.24	0.06	-0.05
-22.24	-1.94	0	-10.24	-4.94	-0.89	-1.24	3.06	-0.85
-22.24	3.06	0	-10.24	-3.44	-0.55	-1.24	5.56	-1.55
-22.24	8.06	0.2	-10.24	-1.94	-0.35	-1.24	8.06	-0.15
-22.24	13.06	0.2	-10.24	0.56	0.15	-1.24	13.06	-0.1
-22.24	18.06	0.2	-10.24	3.06	0.1	-1.24	18.06	0.1
-19.24	-21.94	0	-10.24	5.56	0.05	1.76	-21.94	-0.15
-19.24	-16.94	0	-10.24	8.06	0.05	1.76	-16.94	-0.25
-19.24	-11.94	-0.05	-10.24	13.06	0.2	1.76	-11.94	-0.2
-19.24	-9.44	-0.85	-10.24	18.06	0.3	1.76	-9.44	-0.4
-19.24	-6.94	-1	-7.24	-21.94	-0.05	1.76	-6.94	-0.55
-19.24	-4.44	-0.05	-7.24	-16.94	-0.15	1.76	-4.44	0.25
-19.24	-1.94	0.05	-7.24	-11.94	-0.15	1.76	-1.94	1.3
-19.24	3.06	0.2	-7.24	-9.44	-1.35	1.76	-0.94	0.75
-19.24	8.06	0.25	-7.24	-6.94	-0.6	1.76	1.26	-0.81
-19.24	13.06	0.25	-7.24	-4.44	0.25	1.76	3.06	-1
-19.24	18.06	0.35	-7.24	-1.94	0.19	1.76	5.56	-0.25
-16.24	-21.94	0	-7.24	0.56	0.25	1.76	8.06	0.15
-16.24	-16.94	-0.05	-7.24	3.06	-0.1	1.76	13.06	-0.2
-16.24	-11.94	-0.05	-7.24	5.56	0	1.76	18.06	0.15
-16.24	-8.94	-2.05	-7.24	8.06	0	4.76	-21.94	-0.25
-16.24	-7.74	-2.7	-7.24	13.06	0.05	4.76	-16.94	-0.35
-16.24	-5.44	-1.95	-7.24	18.06	0.19	4.76	-11.94	-0.85
-16.24	-2.94	-0.85	-4.24	-21.94	-0.05	4.76	-9.44	-1.05
-16.24	-1.94	-0.2	-4.24	-16.94	-0.15	4.76	-6.94	-0.95
-16.24	3.06	0.1	-4.24	-11.94	-0.2	4.76	-4.44	0.05
-16.24	8.06	0.15	-4.24	-9.44	-0.95	4.76	-1.94	0.7
-16.24	13.06	0.25	-4.24	-6.94	-0.3	4.76	0.56	-0.05
-16.24	18.06	0.4	-4.24	-4.44	0.65	4.76	3.06	-0.5
-13.24	-21.94	0	-4.24	-3.44	1.1	4.76	5.56	-0.1
-13.24	-16.94	-0.05	-4.24	-0.94	0.52	4.76	8.06	-0.35
-13.24	-11.94	-0.1	-4.24	0.56	0.45	4.76	10.56	-0.27
-13.24	-9.44	-1.2	-4.24	3.06	0.01	4.76	13.06	-0.2
-13.24	-6.44	-1.81	-4.24	5.56	-0.99	4.76	18.06	0
-13.24	-4.44	-1.3	-4.24	8.06	-0.2	7.76	-21.94	-0.25
-13.24	-1.94	-0.7	-4.24	13.06	0	7.76	-16.94	-0.4
-13.24	3.06	0.1	-4.24	18.06	0.15	7.76	-14.44	-0.75
-13.24	8.06	0.15	-1.24	-21.94	-0.1	7.76	-11.94	-1.65
-13.24	13.06	0.15	-1.24	-16.94	-0.25	7.76	-9.44	-1.75
-13.24	18.06	0.32	-1.24	-11.94	-0.1	7.76	-6.94	-1.75
-10.24	-21.94	-0.05	-1.24	-9.44	-0.75	7.76	-4.44	-1.51

Table A.4 continued……

IV			V			VI		
x	y	Z	x	y	z	x	Y	z
7.76	-1.94	-0.8	16.76	-1.94	-0.19	25.76	-14.44	-0.97
7.76	0.56	0.48	16.76	0.56	0.78	25.76	-11.94	-1.2
7.76	3.06	-0.2	16.76	2.56	1.45	25.76	-9.44	-1.05
7.76	5.56	-0.47	16.76	3.56	0.95	25.76	-6.94	-1.43
7.76	8.06	-0.45	16.76	5.56	0.65	25.76	-4.44	-1.45
7.76	13.06	-0.2	16.76	7.06	-0.05	25.76	-1.94	-1.1
7.76	18.06	0	16.76	8.06	-0.2	25.76	0.56	-0.19
10.76	-21.94	-0.26	16.76	10.56	-0.4	25.76	2.06	0.25
10.76	-16.94	-0.35	16.76	13.06	-0.35	25.76	3.06	-0.25
10.76	-14.44	-0.9	16.76	18.06	-0.05	25.76	5.56	-0.6
10.76	-11.94	-1.26	19.76	-21.94	-0.4	25.76	8.06	-0.07
10.76	-9.44	-1.81	19.76	-16.94	-0.45	25.76	10.56	0.11
10.76	-6.94	-1.93	19.76	-14.44	-0.1	25.76	13.06	0.18
10.76	-4.44	-1.65	19.76	-11.94	-0.2	25.76	18.06	-0.1
10.76	-1.94	-0.75	19.76	-9.44	-0.25	28.76	-21.94	-0.44
10.76	0.56	0.45	19.76	-6.94	-0.35	28.76	-16.94	-0.45
10.76	3.06	0.6	19.76	-4.44	-0.4	28.76	-14.44	-0.35
10.76	5.56	0.25	19.76	-1.94	-0.8	28.76	-11.94	-0.6
10.76	8.06	-0.4	19.76	0.56	1.1	28.76	-9.44	-0.62
10.76	13.06	-0.35	19.76	1.76	1.35	28.76	-6.94	-0.83
10.76	18.06	0	19.76	3.06	0.25	28.76	-4.44	-0.75
13.76	-21.94	-0.36	19.76	5.56	-0.9	28.76	-1.94	-0.6
13.76	-16.94	-0.42	19.76	8.06	-1.9	28.76	0.56	-0.37
13.76	-14.44	-0.41	19.76	10.56	-1.05	28.76	2.56	0.85
13.76	-11.94	-0.39	19.76	13.06	-0.3	28.76	4.06	0.09
13.76	-9.44	-0.81	19.76	18.06	-0.05	28.76	5.56	-0.12
13.76	-6.94	-1.18	22.76	-21.94	-0.38	28.76	8.06	0.11
13.76	-4.44	-1.17	22.76	-16.94	-0.43	28.76	10.56	-0.4
13.76	-1.94	-0.47	22.76	-14.44	-0.69	28.76	13.06	-0.33
13.76	0.56	0.29	22.76	-11.94	-1.15	28.76	18.06	-0.1
13.76	2.06	1.12	22.76	-9.44	-1.31	31.76	-21.94	-0.34
13.76	3.06	1.01	22.76	-6.94	-1.16	31.76	-16.94	-0.38
13.76	5.56	0.79	22.76	-4.44	-0.97	31.76	-14.44	-0.1
13.76	7.06	0.3	22.76	-1.94	-1.04	31.76	-11.94	-0.38
13.76	8.06	-0.21	22.76	0.56	-0.09	31.76	-9.44	-0.24
13.76	13.06	-0.29	22.76	1.66	0.5	31.76	-6.94	-0.15
13.76	18.06	-0.02	22.76	3.06	-0.04	31.76	-4.44	-0.52
16.76	-21.94	-0.41	22.76	5.56	-1.3	31.76	-1.94	-0.55
16.76	-16.94	-0.5	22.76	8.06	-0.82	31.76	0.56	-0.15
16.76	-14.74	-0.2	22.76	10.56	-1.25	31.76	2.56	1.1
16.76	-11.94	-0.19	22.76	13.06	-0.27	31.76	4.56	0.26
16.76	-9.44	-0.3	22.76	18.06	0	31.76	6.56	0
16.76	-6.94	-0.83	25.76	-21.94	-0.4	31.76	8.06	-0.41
16.76	-4.44	-0.87	25.76	-16.94	-0.39	31.76	13.06	-0.34

Table A.4 continued……

VII			VIII			IX		
x	y	Z	x	y	z	x	Y	z
31.76	18.06	-0.01	40.76	-1.94	-0.08	49.76	0.56	-0.3
34.76	-21.94	-0.4	40.76	3.06	0.48	49.76	3.06	0.25
34.76	-19.44	-0.44	40.76	5.56	-0.21	49.76	5.56	-0.1
34.76	-17.94	-1.24	40.76	8.06	-0.25	49.76	8.06	-0.25
34.76	-16.94	-1.2	40.76	13.06	-0.22	49.76	13.06	-0.2
34.76	-14.44	-0.87	40.76	18.06	-0.1	49.76	18.06	-0.05
34.76	-11.94	-0.18	43.76	-21.94	-0.55	52.76	-21.94	-0.6
34.76	-6.94	0.03	43.76	-16.94	-0.2	52.76	-16.94	-0.61
34.76	-4.44	-0.11	43.76	-14.44	-0.25	52.76	-12.44	-0.39
34.76	-1.94	-0.37	43.76	-11.94	-0.5	52.76	-9.44	-0.1
34.76	0.56	0.18	43.76	-9.44	-0.55	52.76	-6.94	-0.35
34.76	3.06	0.76	43.76	-6.94	-0.55	52.76	-1.94	-0.45
34.76	5.06	-0.23	43.76	-4.44	-0.53	52.76	3.06	0.19
34.76	8.06	-0.45	43.76	-1.94	-0.51	52.76	5.56	0.19
34.76	13.06	-0.25	43.76	0.56	-0.45	52.76	8.06	-0.1
34.76	18.06	-0.1	43.76	3.06	-0.23	52.76	13.06	-0.2
37.76	-21.94	-0.47	43.76	5.56	-0.3	52.76	18.06	-0.05
37.76	-17.94	-0.49	43.76	8.06	-0.19	55.76	-21.94	-0.6
37.76	-16.94	-1.26	43.76	13.06	-0.23	55.76	-16.94	-0.6
37.76	-14.44	-1.75	43.76	18.06	-0.05	55.76	-11.94	-0.45
37.76	-11.94	-0.53	46.76	-21.94	-0.55	55.76	-9.44	-0.2
37.76	-9.44	0.2	46.76	-16.94	-0.5	55.76	-6.94	-0.3
37.76	-6.94	0.05	46.76	-14.44	-0.15	55.76	-1.94	-0.45
37.76	-4.44	-0.07	46.76	-11.94	-0.45	55.76	0.56	-0.35
37.76	-1.94	0	46.76	-9.44	-0.43	55.76	3.06	-0.05
37.76	0.56	0.35	46.76	-6.94	-0.5	55.76	5.56	-0.25
37.76	2.56	0.65	46.76	-1.94	-0.45	55.76	8.06	-0.25
37.76	4.06	0	46.76	2.06	-0.2	55.76	13.06	-0.2
37.76	5.56	-0.4	46.76	3.06	-0.2	55.76	18.06	-0.05
37.76	8.06	-0.25	46.76	5.56	0.05	58.76	-21.94	-0.55
37.76	13.06	-0.2	46.76	8.06	-0.23	58.76	-16.94	-0.55
37.76	18.06	0	46.76	13.06	-0.2	58.76	-11.94	-0.55
40.76	-21.94	-0.47	46.76	18.06	-0.05	58.76	-6.94	-0.35
40.76	-16.94	-0.27	49.76	-21.94	-0.6	58.76	-4.44	-0.5
40.76	-14.44	-0.47	49.76	-16.94	-0.55	58.76	-1.94	-0.45
40.76	-11.94	-0.52	49.76	-13.44	-0.35	58.76	3.06	-0.05
40.76	-9.44	-0.5	49.76	-11.94	-0.4	58.76	5.56	0.05
40.76	-7.94	0.11	49.76	-9.44	-0.15	58.76	8.06	-0.25
40.76	-6.94	0	49.76	-6.94	-0.4	58.76	13.06	-0.2
40.76	-4.44	-0.2	49.76	-1.94	-0.4	58.76	18.06	-0.1

Table A.5 Experimental data for aspect ratio 0.25 & angle of attack 20^0

I			II			III		
x	Y	z	x	y	z	x	Y	z
-24.4	-23.4	0.2	-19.4	1.6	0	-13.4	16.6	0.24
-24.4	-18.4	0	-19.4	6.6	0.1	-10.4	-23.4	0.04
-24.4	-13.4	-0.1	-19.4	11.6	0.04	-10.4	-18.4	-0.2
-24.4	-8.4	-0.25	-19.4	16.6	0.1	-10.4	-13.4	-0.35
-24.4	-3.4	-0.2	-16.4	-23.4	0.1	-10.4	-10.4	0
-24.4	1.6	0	-16.4	-18.4	-0.1	-10.4	-8.4	1.14
-24.4	6.6	0	-16.4	-13.4	-0.15	-10.4	-6.9	1.55
-24.4	11.6	0.1	-16.4	-9.4	-1.05	-10.4	-4.4	-0.3
-24.4	16.6	0.1	-16.4	-5.4	-2.86	-10.4	0.2	0.83
-22.4	-23.4	0.1	-16.4	-3.4	-1.45	-10.4	1.6	0.35
-22.4	-18.4	0	-16.4	-0.4	-0.18	-10.4	6.6	-0.06
-22.4	-13.4	-0.1	-16.4	1.6	0.05	-10.4	11.6	0.1
-22.4	-10.4	-0.45	-16.4	6.6	0.1	-10.4	16.6	0.2
-22.4	-8.4	-0.98	-16.4	11.6	0.2	-7.4	-23.4	0
-22.4	-5.4	-0.5	-16.4	16.6	0.2	-7.4	-18.4	-0.1
-22.4	-3.4	-0.05	-13.4	-23.4	0	-7.4	-13.4	-1.07
-22.4	1.6	0	-13.4	-18.4	-0.15	-7.4	-10.4	-0.96
-22.4	6.6	0	-13.4	-13.4	-0.16	-7.4	-8.4	-0.24
-22.4	11.6	0	-13.4	-11.4	0.2	-7.4	-5.9	0.92
-22.4	16.6	0.1	-13.4	-7.9	0.7	-7.4	-3.3	0.55
-19.4	-23.4	0.1	-13.4	-5.4	-2.2	-7.4	-0.4	0.8
-19.4	-18.4	0	-13.4	-3.4	-1.64	-7.4	0.9	1.2
-19.4	-13.4	-0.1	-13.4	-0.4	0.17	-7.4	4.1	0.14
-19.4	-8.4	-2.35	-13.4	1.6	0	-7.4	6.6	0
-19.4	-5.4	-1.8	-13.4	6.6	0	-7.4	11.6	0
-19.4	-3.4	-0.8	-13.4	11.6	0.24	-7.4	16.6	0.2

Table A.5 continued......

IV			V			VI		
x	y	Z	x	y	z	x	y	z
-4.4	-23.4	-0.05	1.6	-23.4	0	7.6	6.6	-0.75
-4.4	-18.4	-0.1	1.6	-18.4	0.1	7.6	11.6	0.05
-4.4	-15.9	-0.26	1.6	-13.4	-0.35	7.6	16.6	0.05
-4.4	-13.4	-0.55	1.6	-8.4	-0.66	10.6	-23.4	-0.05
-4.4	-11.4	-0.36	1.6	-3.4	-0.25	10.6	-18.4	-0.1
-4.4	-8.4	-0.8	1.6	-1.9	0.5	10.6	-13.4	-0.08
-4.4	-5.4	-0.2	1.6	1.6	0.16	10.6	-8.4	-0.25
-4.4	-4.4	0.73	1.6	6.6	0.35	10.6	-3.4	0.05
-4.4	-2	0.1	1.6	11.6	-0.15	10.6	0.1	1.13
-4.4	1.6	-0.46	1.6	16.6	0	10.6	1.6	0.16
-4.4	4.6	-0.7	4.6	-23.4	0	10.6	6.6	0.12
-4.4	6.6	-0.1	4.6	-18.4	0	10.6	11.6	0.05
-4.4	11.6	-0.1	4.6	-13.4	-0.96	10.6	16.6	0.16
-4.4	16.6	0.2	4.6	-8.4	-0.98	13.6	-23.4	-0.1
-1.4	-23.4	0.08	4.6	-3.4	-0.27	13.6	-18.4	-0.1
-1.4	-18.4	-0.1	4.6	-0.4	0.55	13.6	-13.4	-0.18
-1.4	-13.4	0.31	4.6	1.6	0.64	13.6	-8.4	-0.25
-1.4	-10.4	0.5	4.6	6.6	-0.95	13.6	-3.4	1.13
-1.4	-8.4	0.04	4.6	11.6	-0.1	13.6	-0.9	0.64
-1.4	-5.4	-0.25	4.6	16.6	0	13.6	1.6	-0.06
-1.4	-3.4	0.8	7.6	-23.4	0	13.6	6.6	-0.1
-1.4	-0.9	-0.25	7.6	-18.4	0	13.6	11.6	0.1
-1.4	1.6	-0.4	7.6	-13.4	-0.38	13.6	16.6	0.1
-1.4	4.6	-0.45	7.6	-8.4	-0.75	16.6	-23.4	-0.2
-1.4	6.6	0.05	7.6	-3.4	-0.17	16.6	-18.4	-0.15
-1.4	11.6	-0.15	7.6	0.1	0.94	16.6	-13.4	-0.25
-1.4	16.6	0.1	7.6	1.6	0.32	16.6	-8.4	-0.87

Table A.5 continued……

VII			VIII			IX		
x	y	Z	x	y	z	x	y	z
16.6	-3.4	-0.65	25.6	1.6	1.05	34.6	16.6	0
16.6	-0.4	0.05	25.6	6.6	-0.3	37.6	-23.4	-0.38
16.6	1.6	0.32	25.6	11.6	-0.3	37.6	-18.4	-0.4
16.6	6.6	0.05	25.6	16.6	-0.17	37.6	-13.4	-0.5
16.6	11.6	-0.13	28.6	-23.4	-0.6	37.6	-8.4	-0.5
16.6	16.6	-0.05	28.6	-18.4	-0.45	37.6	-3.4	-0.85
19.6	-23.4	-0.2	28.6	-13.4	-0.48	37.6	1	0.42
19.6	-18.4	-0.3	28.6	-8.4	-2	37.6	2.6	-0.1
19.6	-13.4	-0.05	28.6	-3.4	-0.36	37.6	6.6	-0.19
19.6	-8.4	-0.8	28.6	1.6	-0.1	37.6	11.6	-0.2
19.6	-5.9	-1.8	28.6	6.6	-0.35	37.6	16.6	0
19.6	-3.4	-0.95	28.6	11.6	-0.18	40.6	-23.4	-0.3
19.6	-0.4	0.1	28.6	16.6	-0.16	40.6	-18.4	-0.3
19.6	1.1	0.75	31.6	-23.4	-0.47	40.6	-13.4	-0.4
19.6	4.6	-0.26	31.6	-18.4	-0.45	40.6	-8.4	-0.6
19.6	11.6	-0.1	31.6	-13.4	-0.37	40.6	-3.4	-0.35
19.6	16.6	0	31.6	-8.4	-0.87	40.6	0.9	0.52
22.6	-23.4	-0.35	31.6	-3.4	-0.9	40.6	2.6	-0.1
22.6	-18.4	-0.4	31.6	-0.4	0.1	40.6	6.6	-0.1
22.6	-13.4	-0.3	31.6	1.6	0	40.6	11.6	-0.1
22.6	-8.4	0	31.6	6.6	-0.28	40.6	16.6	0
22.6	-3.4	-0.46	31.6	11.6	-0.25	43.6	-23.4	-0.35
22.6	1.1	0.94	31.6	16.6	-0.18	43.6	-18.4	-0.38
22.6	3.6	-0.16	34.6	-23.4	-0.5	43.6	-13.4	-0.45
22.6	6.6	-0.3	34.6	-18.4	-0.4	43.6	-8.4	-0.4
22.6	11.6	-0.25	34.6	-13.4	-0.28	43.6	-3.4	0.1
22.6	16.6	-0.1	34.6	-8.4	0.2	43.6	-0.4	0.55
25.6	-23.4	-0.5	34.6	-3.4	-0.8	43.6	2	-0.77
25.6	-18.4	-0.5	34.6	0.1	0.5	43.6	6.6	-0.1
25.6	-13.4	-0.45	34.6	1.6	0.13	43.6	11.6	-0.15
25.6	-8.4	-0.25	34.6	6.6	-0.28	43.6	16.6	0
25.6	-3.4	0.42	34.6	11.6	-0.17			

Table A.6 Experimental data for aspect ratio 0.25 & angle of attack 25^0

I			II			III		
x	y	z	x	y	z	x	Y	z
-22.1	-24.23	0	-16.1	5.77	0.05	-7.1	-19.23	-0.2
-22.1	-19.23	-0.05	-16.1	10.77	0.15	-7.1	-14.23	-0.2
-22.1	-14.23	-0.05	-16.1	15.77	0.25	-7.1	-11.73	-0.2
-22.1	-9.23	-0.05	-13.1	-24.23	-0.05	-7.1	-9.23	-0.22
-22.1	-4.23	0	-13.1	-19.23	-0.1	-7.1	-6.23	0.75
-22.1	0.77	0	-13.1	-14.23	-0.1	-7.1	-3.93	0.05
-22.1	5.77	0.1	-13.1	-12.73	-1.1	-7.1	-1.73	0.21
-22.1	10.77	0.15	-13.1	-11.23	-1.35	-7.1	0.77	0.6
-22.1	15.77	0.25	-13.1	-9.23	-0.78	-7.1	5.77	-0.1
-19.1	-24.23	0	-13.1	-7.23	-1.3	-7.1	10.77	0.05
-19.1	-19.23	-0.05	-13.1	-4.23	-0.85	-7.1	15.77	0.2
-19.1	-14.23	-0.05	-13.1	-2.23	-0.05	-4.1	-24.23	-0.1
-19.1	-10.73	-1.53	-13.1	0.77	0	-4.1	-19.23	-0.25
-19.1	-9.23	-1.35	-13.1	5.77	-0.05	-4.1	-14.23	-0.25
-19.1	-6.73	-0.99	-13.1	10.77	0.1	-4.1	-9.23	-0.75
-19.1	-4.23	0	-13.1	15.77	0.25	-4.1	-6.73	0.19
-19.1	0.77	0.05	-10.1	-24.23	-0.1	-4.1	-4.43	1.2
-19.1	5.77	0.05	-10.1	-19.23	-0.2	-4.1	-2.23	-0.35
-19.1	10.77	0.25	-10.1	-14.23	-0.15	-4.1	0.77	-0.45
-19.1	15.77	0.3	-10.1	-11.73	-0.65	-4.1	5.77	-0.2
-16.1	-24.23	-0.05	-10.1	-9.23	-0.7	-4.1	10.77	0.05
-16.1	-19.23	-0.1	-10.1	-7.73	0.3	-4.1	15.77	0.19
-16.1	-14.23	-0.15	-10.1	-5.23	-0.25	-1.1	-24.23	-0.2
-16.1	-12.23	-2.2	-10.1	-4.23	-0.15	-1.1	-19.23	-0.25
-16.1	-10.23	-2	-10.1	-1.73	0.25	-1.1	-14.23	-0.35
-16.1	-8.23	-2.21	-10.1	0.77	0.15	-1.1	-9.23	-0.61
-16.1	-6.23	-1.55	-10.1	5.77	-0.05	-1.1	-6.73	-0.55
-16.1	-4.23	-0.7	-10.1	10.77	0	-1.1	-4.23	0.19
-16.1	-2.23	-0.05	-10.1	15.77	0.19	-1.1	-2.73	0.8
-16.1	0.77	0.1	-7.1	-24.23	-0.05	-1.1	-0.73	-1.1

Table A.6 continued……

IV			V			VI		
x	y	z	x	y	z	x	Y	z
-1.1	0.77	-1.2	7.9	-14.23	-0.35	13.9	15.77	0
-1.1	2.77	-0.15	7.9	-9.23	-0.33	16.9	-24.23	-0.39
-1.1	5.77	-0.25	7.9	-4.23	-0.4	16.9	-19.23	-0.39
-1.1	10.77	-0.1	7.9	-1.73	0	16.9	-14.23	-0.45
-1.1	15.77	0.09	7.9	-0.73	0.29	16.9	-9.23	-0.52
1.9	-24.23	-0.2	7.9	0.77	0.1	16.9	-4.23	-0.55
1.9	-19.23	-0.25	7.9	3.27	0.1	16.9	-1.73	-0.5
1.9	-14.23	-0.3	7.9	5.77	-0.35	16.9	0.77	0.05
1.9	-9.23	-0.3	7.9	10.77	-0.15	16.9	3.27	0.05
1.9	-6.73	0.05	7.9	15.77	0.05	16.9	5.77	0
1.9	-4.23	0.7	10.9	-24.23	-0.35	16.9	10.77	-0.35
1.9	-2.23	0.09	10.9	-19.23	-0.45	16.9	15.77	-0.05
1.9	0.77	-0.55	10.9	-14.23	-0.35	19.9	-24.23	-0.45
1.9	3.27	0.12	10.9	-9.23	-0.39	19.9	-19.23	-0.45
1.9	5.77	-0.3	10.9	-4.23	-0.45	19.9	-14.23	-0.45
1.9	10.77	-0.1	10.9	-0.73	-0.25	19.9	-9.23	-0.47
1.9	15.77	0.08	10.9	0.77	-0.4	19.9	-4.23	-0.55
4.9	-24.23	-0.3	10.9	5.77	-0.45	19.9	0.77	-0.35
4.9	-19.23	-0.3	10.9	10.77	-0.3	19.9	5.77	-0.45
4.9	-14.23	-0.26	10.9	15.77	0	19.9	10.77	-0.25
4.9	-9.23	-0.29	13.9	-24.23	-0.35	19.9	15.77	-0.05
4.9	-4.23	0.4	13.9	-19.23	-0.35	22.9	-24.23	-0.4
4.9	-2.23	0.65	13.9	-14.23	-0.37	22.9	-19.23	-0.45
4.9	0.77	-0.1	13.9	-9.23	-0.45	22.9	-14.23	-0.47
4.9	3.27	0.3	13.9	-4.23	-0.55	22.9	-9.23	-0.49
4.9	5.77	-0.35	13.9	-1.23	-0.27	22.9	-4.23	-0.48
4.9	10.77	-0.15	13.9	0.77	0.25	22.9	0.77	-0.35
4.9	15.77	0.05	13.9	3.27	-0.15	22.9	5.77	-0.29
7.9	-24.23	-0.35	13.9	5.77	-0.35	22.9	10.77	-0.3
7.9	-19.23	-0.35	13.9	10.77	-0.35	22.9	15.77	-0.05

Table A.7 Experimental data for aspect ratio 0.20 & angle of attack 15^0

I			II			III		
x	y	z	x	y	z	x	Y	z
-30.07	-23.24	0.1	-18.07	-23.24	0.02	-9.07	-10.74	-0.8
-30.07	-18.24	0.05	-18.07	-18.24	-0.07	-9.07	-8.24	-0.7
-30.07	-13.24	0.05	-18.07	-13.24	0.05	-9.07	-5.24	1.4
-30.07	-8.24	0.07	-18.07	-10.74	0	-9.07	-3.24	1.43
-30.07	-3.24	0.14	-18.07	-8.24	0.95	-9.07	-0.74	0.5
-30.07	1.76	0.25	-18.07	-6.24	-1.7	-9.07	1.76	-0.73
-30.07	6.76	0.3	-18.07	-3.24	-1.08	-9.07	4.26	-0.25
-30.07	11.76	0.35	-18.07	-0.74	0.15	-9.07	6.76	0
-30.07	16.76	0.47	-18.07	1.76	0.13	-9.07	11.76	0.05
-27.07	-23.24	0.05	-18.07	6.76	0.2	-9.07	16.76	0.2
-27.07	-18.24	0.06	-18.07	11.76	0.2	-6.07	-23.24	-0.25
-27.07	-13.24	0.05	-18.07	16.76	0.35	-6.07	-18.24	-0.3
-27.07	-10.74	-0.08	-15.07	-23.24	-0.05	-6.07	-13.24	-0.33
-27.07	-8.24	-0.9	-15.07	-18.24	-0.1	-6.07	-10.74	-0.43
-27.07	-5.74	0	-15.07	-13.24	-0.15	-6.07	-8.24	-0.4
-27.07	-3.24	0.15	-15.07	-10.74	0.1	-6.07	-5.74	0.1
-27.07	1.76	0.2	-15.07	-8.24	0.9	-6.07	-3.24	1.25
-27.07	6.76	0.3	-15.07	-6.74	1.7	-6.07	-1.74	0.6
-27.07	11.76	0.35	-15.07	-5.24	-0.3	-6.07	-0.24	0.2
-27.07	16.76	0.5	-15.07	-3.24	-0.15	-6.07	1.76	0.21
-24.07	-23.24	0.05	-15.07	-0.74	0.2	-6.07	4.26	0.34
-24.07	-18.24	0	-15.07	0.76	0.86	-6.07	6.76	0.1
-24.07	-13.24	-0.04	-15.07	4.26	0.1	-6.07	11.76	0
-24.07	-10.24	-1.9	-15.07	6.76	0.2	-6.07	16.76	0.15
-24.07	-8.54	-2.84	-15.07	11.76	0.2	-3.07	-23.24	-0.4
-24.07	-5.74	-1.7	-15.07	16.76	0.3	-3.07	-18.24	-0.4
-24.07	-3.24	-0.74	-12.07	-23.24	-0.15	-3.07	-13.24	-0.66
-24.07	1.76	0.15	-12.07	-18.24	-0.2	-3.07	-10.74	-0.35
-24.07	6.76	0.25	-12.07	-13.24	-0.2	-3.07	-8.24	-0.36
-24.07	11.76	0.35	-12.07	-10.74	-1	-3.07	-5.74	0.3
-24.07	16.76	0.35	-12.07	-8.24	0.4	-3.07	-3.24	1.46
-21.07	-23.24	0	-12.07	-5.74	1.62	-3.07	-0.74	0.33
-21.07	-18.24	-0.05	-12.07	-4.74	0.95	-3.07	1.76	0.5
-21.07	-13.24	-0.1	-12.07	-3.24	0.75	-3.07	4.26	-0.05
-21.07	-10.74	-0.75	-12.07	-0.74	0.45	-3.07	6.76	-0.1
-21.07	-9.74	-0.7	-12.07	1.26	0.95	-3.07	11.76	-0.05
-21.07	-7.74	-3.06	-12.07	1.76	0.57	-3.07	16.76	0.05
-21.07	-5.24	-2.7	-12.07	4.26	0.1	-0.07	-23.24	-0.55
-21.07	-3.24	-1.57	-12.07	6.76	0.1	-0.07	-18.24	-0.54
-21.07	-0.74	-0.48	-12.07	11.76	0.15	-0.07	-15.74	-0.95
-21.07	1.76	0.13	-12.07	16.76	0.25	-0.07	-13.24	-1.9
-21.07	6.76	0.2	-9.07	-23.24	-0.2	-0.07	-10.74	-2.2
-21.07	11.76	0.25	-9.07	-18.24	-0.1	-0.07	-8.24	-1.6
-21.07	16.76	0.45	-9.07	-13.24	-0.16	-0.07	-5.74	-1

Table A.7 continued......

IV			V			VI		
x	y	Z	x	y	z	x	y	z
-0.07	-3.24	0.35	8.93	-3.24	-0.95	17.93	-0.74	-0.15
-0.07	-1.24	1.15	8.93	-0.74	0.25	17.93	1.76	0.82
-0.07	0.76	0.55	8.93	1.26	1.4	17.93	4.26	0.35
-0.07	1.76	0.65	8.93	1.76	0.74	17.93	6.76	-0.35
-0.07	4.26	0.2	8.93	4.26	-0.4	17.93	11.76	-0.3
-0.07	6.76	-0.2	8.93	6.76	-0.36	17.93	16.76	-0.1
-0.07	11.76	-0.15	8.93	11.76	-0.27	20.93	-23.24	-0.4
-0.07	16.76	0.05	8.93	16.76	-0.05	20.93	-18.24	-0.75
2.93	-23.24	-0.67	11.93	-23.24	-0.47	20.93	-15.74	0
2.93	-18.24	-0.54	11.93	-18.24	-0.47	20.93	-13.24	0
2.93	-15.74	-0.85	11.93	-15.74	-1.67	20.93	-10.74	-0.75
2.93	-13.24	-1.3	11.93	-13.24	-1.7	20.93	-8.24	-1.09
2.93	-10.74	-2.2	11.93	-10.74	-1.1	20.93	-5.74	-0.66
2.93	-8.24	-2.25	11.93	-8.24	-0.95	20.93	-3.24	-0.4
2.93	-5.74	-1.6	11.93	-5.74	-0.87	20.93	-0.74	0.1
2.93	-3.24	-0.3	11.93	-3.24	-0.5	20.93	2.26	1.34
2.93	-0.74	1.15	11.93	-0.74	0.6	20.93	4.26	0.5
2.93	1.76	-0.1	11.93	1.26	1.73	20.93	6.76	-0.35
2.93	4.26	-0.25	11.93	4.26	-0.2	20.93	11.76	-0.35
2.93	6.76	-0.26	11.93	6.76	-0.35	20.93	16.76	-0.15
2.93	11.76	-0.2	11.93	11.76	-0.33	23.93	-23.24	-0.4
2.93	16.76	-0.05	11.93	16.76	-0.1	23.93	-18.24	-0.4
5.93	-23.24	-0.65	14.93	-23.24	-0.4	23.93	-15.74	-0.57
5.93	-18.24	-0.6	14.93	-18.24	-0.4	23.93	-13.24	-1.22
5.93	-15.74	-0.25	14.93	-15.74	-1.35	23.93	-10.74	-0.66
5.93	-13.24	-0.65	14.93	-13.24	-1.98	23.93	-8.24	-0.7
5.93	-10.74	-0.73	14.93	-10.74	-1.84	23.93	-5.74	-0.28
5.93	-8.24	-1.54	14.93	-8.24	-1.3	23.93	-3.24	-0.05
5.93	-5.74	-1.6	14.93	-5.74	-1.35	23.93	-0.74	0.55
5.93	-3.24	-0.8	14.93	-3.24	-1.05	23.93	1.76	1.45
5.93	-0.74	0.5	14.93	-0.74	0.3	23.93	2.76	1.8
5.93	0.26	0.85	14.93	1.76	1.24	23.93	6.76	-0.32
5.93	1.76	0.5	14.93	4.26	0.3	23.93	11.76	-0.35
5.93	4.26	0.06	14.93	6.76	-0.3	23.93	16.76	-0.15
5.93	6.76	-0.35	14.93	11.76	-0.3	26.93	-23.24	-0.45
5.93	11.76	-0.22	14.93	16.76	-0.1	26.93	-18.24	-0.65
5.93	16.76	0	17.93	-23.24	-0.4	26.93	-15.74	-1.75
8.93	-23.24	-0.5	17.93	-18.24	-0.5	26.93	-13.24	-1.8
8.93	-18.24	-0.45	17.93	-15.74	-0.35	26.93	-10.74	-1.4
8.93	-15.74	-0.6	17.93	-13.24	-0.55	26.93	-7.74	-0.2
8.93	-13.24	-0.43	17.93	-10.74	-1.27	26.93	-5.74	0.05
8.93	-10.74	-0.25	17.93	-8.24	-1.35	26.93	-3.24	0.2
8.93	-8.24	-0.35	17.93	-5.74	-1.15	26.93	-0.74	0.8
8.93	-5.74	-0.96	17.93	-3.24	-1.05	26.93	1.26	1.2

Table A.7 continued......

VII			VIII			IX		
x	y	Z	x	y	z	x	y	z
26.93	2.26	0.65	35.93	4.26	-0.15	47.93	4.26	0.1
26.93	4.26	0.3	35.93	6.76	0.45	47.93	6.76	-0.1
26.93	6.76	-0.21	35.93	11.76	-0.2	47.93	11.76	-0.2
26.93	11.76	-0.25	35.93	16.76	0	47.93	16.76	-0.04
26.93	16.76	-0.16	38.93	-23.24	-0.5	50.93	-23.24	-0.6
29.93	-23.24	-0.45	38.93	-18.24	-0.55	50.93	-18.24	-0.4
29.93	-18.24	-0.35	38.93	-14.74	-0.25	50.93	-13.24	-0.38
29.93	-15.74	-1.06	38.93	-13.24	0.25	50.93	-8.24	0.16
29.93	-13.24	-1.35	38.93	-10.74	0.05	50.93	-3.24	0.15
29.93	-10.74	-1.8	38.93	-8.24	-0.15	50.93	1.76	1.05
29.93	-8.24	-1.34	38.93	-5.74	-0.05	50.93	4.26	-0.2
29.93	-5.74	-1.25	38.93	-3.24	0	50.93	6.76	0.1
29.93	-3.24	-0.9	38.93	-0.74	0.15	50.93	11.76	-0.18
29.93	-0.74	-0.2	38.93	1.76	0.3	50.93	16.76	-0.05
29.93	1.76	0.3	38.93	4.26	-0.15	53.93	-23.24	-0.67
29.93	3.76	0.6	38.93	6.76	0.3	53.93	-18.24	-0.6
29.93	6.76	-0.22	38.93	11.76	-0.2	53.93	-13.24	-0.55
29.93	11.76	-0.22	38.93	16.76	0	53.93	-8.24	-0.54
29.93	16.76	-0.15	41.93	-23.24	-0.53	53.93	-3.24	-0.45
32.93	-23.24	-0.45	41.93	-18.24	-0.4	53.93	1.76	-0.3
32.93	-20.24	-0.95	41.93	-13.24	-0.97	53.93	4.26	-0.55
32.93	-18.24	-0.65	41.93	-8.24	-0.57	53.93	6.76	-0.2
32.93	-15.74	0.1	41.93	-3.24	-0.5	53.93	11.76	-0.2
32.93	-13.24	-0.2	41.93	1.76	-0.4	53.93	16.76	-0.1
32.93	-10.74	-1.2	41.93	5.26	0.45	56.93	-23.24	-0.7
32.93	-8.24	-1.05	41.93	6.76	0.05	56.93	-18.24	-0.65
32.93	-5.74	-1.05	41.93	11.76	-0.15	56.93	-13.24	-0.38
32.93	-3.24	-1	41.93	16.76	-0.05	56.93	-8.24	-0.55
32.93	-0.74	-0.4	44.93	-23.24	-0.6	56.93	-3.24	-0.5
32.93	1.76	0.06	44.93	-18.24	-0.33	56.93	1.76	-0.2
32.93	4.26	0.05	44.93	-14.24	0.24	56.93	4.26	0.3
32.93	6.76	-0.21	44.93	-8.24	-0.4	56.93	6.76	-0.04
32.93	11.76	-0.21	44.93	-3.24	-0.3	56.93	11.76	-0.15
32.93	16.76	-0.05	44.93	1.76	0.1	56.93	16.76	0
35.93	-23.24	-0.5	44.93	5.76	0.6	59.93	-23.24	-0.7
35.93	-18.24	-1.4	44.93	6.76	-0.1	59.93	-18.24	-0.65
35.93	-15.74	-0.5	44.93	11.76	-0.15	59.93	-13.24	-0.67
35.93	-13.24	0.6	44.93	16.76	-0.05	59.93	-8.24	-0.5
35.93	-10.74	-0.2	47.93	-23.24	-0.65	59.93	-3.24	-0.46
35.93	-8.24	-0.58	47.93	-18.24	-0.4	59.93	1.76	-0.04
35.93	-5.74	-0.5	47.93	-13.24	0.34	59.93	4.26	0.3
35.93	-3.24	-0.48	47.93	-8.24	-0.04	59.93	6.76	-0.1
35.93	-0.74	-0.2	47.93	-3.24	0	59.93	11.76	-0.18
35.93	1.76	0.5	47.93	1.76	0.7	59.93	16.76	0

Table A.8 Experimental data for aspect ratio 0.20 & angle of attack 20^0

I			II			III		
x	y	z	x	y	z	x	Y	z
-29.74	-24.28	0.05	-20.74	-11.78	-1	-11.74	-11.78	-1.1
-29.74	-19.28	0.05	-20.74	-9.28	-1.04	-11.74	-9.28	0.5
-29.74	-14.28	0.06	-20.74	-7.78	-3.4	-11.74	-6.78	1.95
-29.74	-9.28	0.1	-20.74	-6.28	-3.35	-11.74	-4.28	0.3
-29.74	-4.28	0.1	-20.74	-4.28	-2.1	-11.74	-1.78	-0.75
-29.74	0.72	0.2	-20.74	-1.78	-1.68	-11.74	0.72	-0.1
-29.74	5.72	0.25	-20.74	0.72	-0.45	-11.74	2.22	0.8
-29.74	10.72	0.35	-20.74	5.72	0.15	-11.74	5.72	0.15
-29.74	15.72	0.4	-20.74	10.72	0.25	-11.74	10.72	0.14
-26.74	-24.28	0.05	-20.74	15.72	0.4	-11.74	15.72	0.05
-26.74	-19.28	0.05	-17.74	-24.28	-0.05	-8.74	-24.28	-0.2
-26.74	-14.28	0.03	-17.74	-19.28	-0.1	-8.74	-19.28	-0.2
-26.74	-11.78	-1.1	-17.74	-14.28	-0.1	-8.74	-14.28	0.05
-26.74	-9.28	-1.63	-17.74	-11.78	-0.15	-8.74	-11.78	-0.8
-26.74	-6.78	-1.5	-17.74	-9.28	0.4	-8.74	-9.28	-0.5
-26.74	-4.28	-0.74	-17.74	-6.28	-1.6	-8.74	-6.78	1.15
-26.74	0.72	0.15	-17.74	-4.28	-1.55	-8.74	-4.28	1.8
-26.74	5.72	0.3	-17.74	-1.78	-2	-8.74	-2.28	1
-26.74	10.72	0.35	-17.74	0.72	-0.65	-8.74	-1.78	0.06
-26.74	15.72	0.4	-17.74	5.72	0.25	-8.74	0.72	0.15
-23.74	-24.28	0	-17.74	10.72	0.3	-8.74	3.22	1.3
-23.74	-19.28	0.03	-17.74	15.72	0.4	-8.74	5.72	0.25
-23.74	-14.28	0	-14.74	-24.28	-0.1	-8.74	10.72	0.1
-23.74	-11.78	-1.76	-14.74	-19.28	-0.1	-8.74	15.72	0.2
-23.74	-10.28	-2.43	-14.74	-14.28	-1.3	-5.74	-24.28	-0.2
-23.74	-8.78	-3.1	-14.74	-11.78	0.7	-5.74	-19.28	-0.3
-23.74	-6.28	-2.5	-14.74	-9.28	-0.2	-5.74	-14.28	-0.15
-23.74	-4.28	-1.9	-14.74	-6.78	1.6	-5.74	-11.78	-0.2
-23.74	-1.78	-0.8	-14.74	-5.28	-0.54	-5.74	-9.28	-0.3
-23.74	0.72	0.15	-14.74	-1.78	-1.85	-5.74	-6.78	0.76
-23.74	3.22	0.25	-14.74	0.72	0.1	-5.74	-4.28	1.95
-23.74	5.72	0.2	-14.74	5.72	0.15	-5.74	-2.28	1
-23.74	10.72	0.3	-14.74	10.72	0.2	-5.74	0.72	0.55
-23.74	15.72	0.4	-14.74	15.72	0.35	-5.74	3.22	0
-20.74	-24.28	0.05	-11.74	-24.28	-0.1	-5.74	5.72	-0.3
-20.74	-19.28	0	-11.74	-19.28	-0.15	-5.74	10.72	-0.05
-20.74	-14.28	-0.05	-11.74	-14.28	-0.4	-5.74	15.72	0.15

Table A.8 continued......

IV			V			VI		
x	y	z	x	y	z	x	y	z
-2.74	-24.28	-0.2	3.26	-1.78	0.5	12.26	-24.28	-0.5
-2.74	-19.28	-0.3	3.26	0.72	-0.56	12.26	-21.78	-1.78
-2.74	-16.78	-1.45	3.26	3.22	-0.3	12.26	-19.28	-1.7
-2.74	-14.28	-1.5	3.26	5.72	-0.15	12.26	-16.78	-1.45
-2.74	-11.78	-0.35	3.26	10.72	-0.1	12.26	-14.28	0.05
-2.74	-9.28	-0.1	3.26	15.72	0	12.26	-11.78	-0.35
-2.74	-6.78	0	6.26	-24.28	-0.45	12.26	-9.28	-1.15
-2.74	-4.28	1.4	6.26	-19.28	-0.65	12.26	-6.78	-1.9
-2.74	-1.28	0.66	6.26	-16.78	-0.26	12.26	-4.28	-0.9
-2.74	0.72	0.65	6.26	-14.28	-0.76	12.26	-1.78	0.72
-2.74	3.22	0.1	6.26	-11.78	-2.47	12.26	0.72	1.45
-2.74	5.72	0.15	6.26	-9.28	-2.26	12.26	3.22	1.2
-2.74	10.72	-0.05	6.26	-6.78	-1.2	12.26	5.72	-0.27
-2.74	15.72	0.05	6.26	-4.28	-0.3	12.26	8.22	-0.1
0.26	-24.28	-0.4	6.26	-1.78	0.6	12.26	10.72	-0.25
0.26	-19.28	-1.1	6.26	-0.78	1	12.26	15.72	-0.1
0.26	-16.78	-1.5	6.26	0.72	0	15.26	-24.28	-1.15
0.26	-14.28	-2	6.26	3.22	0.05	15.26	-21.78	-1.76
0.26	-11.78	-2.2	6.26	5.72	0.3	15.26	-19.28	-2.2
0.26	-9.28	-1.3	6.26	8.22	-0.15	15.26	-16.78	-2
0.26	-6.78	-0.85	6.26	10.72	-0.15	15.26	-14.28	-0.9
0.26	-4.28	0.5	6.26	15.72	-0.05	15.26	-11.78	-0.5
0.26	-2.78	0.85	9.26	-24.28	-0.5	15.26	-9.28	-1.5
0.26	-0.78	-0.45	9.26	-19.28	-0.55	15.26	-6.78	-2.6
0.26	0.72	0.1	9.26	-16.78	-0.2	15.26	-4.28	-1.7
0.26	3.22	0.7	9.26	-14.28	0.05	15.26	-1.78	0.6
0.26	5.72	0.2	9.26	-11.78	-1.15	15.26	0.72	1.8
0.26	10.72	-0.1	9.26	-9.28	-1.8	15.26	3.22	0.75
0.26	15.72	0.05	9.26	-6.78	-1.6	15.26	5.72	0
3.26	-24.28	-0.4	9.26	-4.28	-0.1	15.26	8.22	-0.3
3.26	-19.28	-0.95	9.26	-1.78	0.85	15.26	10.72	-0.25
3.26	-16.78	-0.7	9.26	0.72	1.4	15.26	15.72	-0.15
3.26	-14.28	-1.25	9.26	3.22	0.6	18.26	-24.28	-1.2
3.26	-11.78	-2.7	9.26	5.72	0.5	18.26	-21.78	-0.9
3.26	-9.28	-2	9.26	8.22	-0.1	18.26	-19.28	-1.1
3.26	-6.78	-1.2	9.26	10.72	-0.2	18.26	-16.78	-1.4
3.26	-4.28	-0.95	9.26	15.72	-0.1	18.26	-14.28	-0.9

Table A.8 continued……

VII			VIII			IX		
x	y	z	x	y	z	x	y	z
18.26	-11.78	-0.6	24.26	0.72	0.35	33.26	-24.28	-0.6
18.26	-9.28	-1.35	24.26	3.22	0.2	33.26	-21.78	-1.05
18.26	-6.78	-0.75	24.26	5.72	-0.05	33.26	-19.28	-1
18.26	-4.28	0.3	24.26	10.72	-0.35	33.26	-17.28	-0.2
18.26	-1.78	1.15	24.26	15.72	-0.28	33.26	-14.28	-1.34
18.26	-0.78	1.6	27.26	-24.28	-0.3	33.26	-11.78	-1.5
18.26	0.72	1	27.26	-21.78	-0.7	33.26	-9.28	-0.55
18.26	3.22	-0.75	27.26	-19.28	-0.75	33.26	-6.78	-0.1
18.26	5.72	-0.9	27.26	-16.78	-0.25	33.26	-4.28	-0.05
18.26	10.72	-0.3	27.26	-14.28	-0.8	33.26	-1.78	1.03
18.26	15.72	-0.15	27.26	-11.78	-0.75	33.26	0.72	1.85
21.26	-24.28	-1.2	27.26	-9.28	-1.5	33.26	3.22	0.6
21.26	-21.78	-0.46	27.26	-6.78	-1.4	33.26	5.72	-0.38
21.26	-19.28	0	27.26	-4.28	-0.15	33.26	10.72	0.2
21.26	-16.78	-0.85	27.26	-1.78	0.05	33.26	15.72	-0.1
21.26	-14.28	-1.2	27.26	0.72	1.16	36.26	-24.28	-0.75
21.26	-11.78	-1	27.26	3.22	0.95	36.26	-21.78	-1.2
21.26	-9.28	-0.93	27.26	5.72	0.3	36.26	-19.28	-0.3
21.26	-6.78	-0.05	27.26	8.22	-0.7	36.26	-16.78	0.1
21.26	-4.28	0.1	27.26	10.72	-1.04	36.26	-14.28	-0.46
21.26	-1.78	0.6	27.26	15.72	-0.21	36.26	-11.78	-1.36
21.26	0.72	0.24	30.26	-24.28	-0.55	36.26	-9.28	-1.44
21.26	3.22	-0.5	30.26	-21.78	-0.7	36.26	-6.78	-1.57
21.26	5.72	-1.04	30.26	-19.28	-1.3	36.26	-4.28	-0.4
21.26	8.22	-0.32	30.26	-16.78	-1.05	36.26	-1.78	0.8
21.26	10.72	-0.3	30.26	-14.28	-1.54	36.26	0.72	0.7
21.26	15.72	-0.25	30.26	-11.78	-0.65	36.26	3.22	-0.05
24.26	-24.28	-2.16	30.26	-9.28	-0.05	36.26	5.72	-0.34
24.26	-21.78	-2.15	30.26	-6.78	-0.54	36.26	10.72	-0.4
24.26	-19.28	-0.7	30.26	-4.28	-0.3	36.26	15.72	-0.15
24.26	-16.78	-0.4	30.26	-1.78	0.7	39.26	-24.28	-0.5
24.26	-14.28	-1.05	30.26	0.72	1.6	39.26	-21.78	-2.1
24.26	-11.78	-1.95	30.26	3.22	0.6	39.26	-19.28	-0.47
24.26	-9.28	-1.9	30.26	5.72	-0.3	39.26	-16.78	0.3
24.26	-6.78	-0.65	30.26	8.22	-1.15	39.26	-14.28	0.2
24.26	-4.28	-0.4	30.26	10.72	-0.4	39.26	-11.78	-0.27
24.26	-1.78	0.05	30.26	15.72	-0.1	39.26	-9.28	-1.3

Table A.8 continued……

X			XI			XII		
x	y	Z	x	y	z	x	y	z
39.26	-6.78	-1.46	48.26	-14.28	0	57.26	15.72	0
39.26	-4.28	-0.56	48.26	-9.28	-0.6	60.26	-24.28	-0.8
39.26	-1.78	0.25	48.26	-4.28	-1.15	60.26	-19.28	-0.3
39.26	0.72	0.5	48.26	-1.78	0.35	60.26	-14.28	-0.85
39.26	3.22	-0.25	48.26	0.72	0	60.26	-9.28	-0.7
39.26	5.72	-1	48.26	3.22	-0.15	60.26	-4.28	-0.4
39.26	8.22	-0.28	48.26	5.72	0.1	60.26	0.72	0.05
39.26	10.72	-0.2	48.26	10.72	-0.2	60.26	5.72	-0.2
39.26	15.72	-0.1	48.26	15.72	0	60.26	10.72	-0.17
42.26	-24.28	-0.15	51.26	-24.28	-0.35	60.26	15.72	0
42.26	-21.78	-1.05	51.26	-19.28	-0.7	63.26	-24.28	-0.8
42.26	-19.28	-1.87	51.26	-14.28	0.1	63.26	-19.28	-0.8
42.26	-16.78	-0.5	51.26	-9.28	-0.4	63.26	-14.28	-0.44
42.26	-14.28	0.1	51.26	-4.28	-0.5	63.26	-9.28	-0.54
42.26	-11.78	0.15	51.26	0.72	0.73	63.26	-4.28	-0.26
42.26	-9.28	-0.5	51.26	3.22	0.72	63.26	0.72	0.15
42.26	-6.78	-1.1	51.26	4.72	0.3	63.26	5.72	0
42.26	-4.28	-0.85	51.26	10.72	-0.2	63.26	10.72	-0.15
42.26	-1.78	0.45	51.26	15.72	-0.05	63.26	15.72	0.05
42.26	0.72	0.64	54.26	-24.28	-0.7	66.26	-24.28	-0.56
42.26	3.22	0.95	54.26	-19.28	-0.75	66.26	-19.28	0
42.26	5.72	0.34	54.26	-13.78	0.3	66.26	-14.28	-0.15
42.26	10.72	-0.05	54.26	-9.28	-0.15	66.26	-9.28	-0.2
42.26	15.72	-0.05	54.26	-4.28	0.05	66.26	-4.28	0.15
45.26	-24.28	-0.65	54.26	1.72	1.2	66.26	0.72	0.7
45.26	-19.28	-0.3	54.26	5.72	-0.21	66.26	5.72	-0.1
45.26	-14.28	-0.22	54.26	10.72	-0.2	66.26	10.72	-0.05
45.26	-9.28	-0.2	54.26	15.72	-0.1	66.26	15.72	0
45.26	-4.28	-0.7	57.26	-24.28	-0.7	69.26	-24.28	-0.76
45.26	-1.78	0.53	57.26	-19.28	-0.4	69.26	-19.28	-0.5
45.26	0.72	0.45	57.26	-14.28	-0.15	69.26	-14.28	-0.54
45.26	3.22	0.14	57.26	-9.28	-0.05	69.26	-9.28	-0.1
45.26	5.72	0	57.26	-4.28	0.5	69.26	-4.28	0.1
45.26	10.72	-0.1	57.26	0.72	0.86	69.26	0.72	-0.13
45.26	15.72	0	57.26	3.22	0	69.26	5.72	-0.02
48.26	-24.28	-0.55	57.26	5.72	0.4	69.26	10.72	-0.05
48.26	-19.28	-0.15	57.26	10.72	-0.2	69.26	15.72	0.1

Table A.9 Experimental data for aspect ratio 0.20 & angle of attack 25^0

I			II			III		
x	y	z	x	y	z	x	y	z
-31.33	-25.28	0.1	-22.33	-5.28	-1.95	-13.33	2.22	0.63
-31.33	-20.28	0.1	-22.33	-2.78	-1.2	-13.33	4.72	0.05
-31.33	-15.28	0.05	-22.33	-0.28	0.1	-13.33	9.72	0.12
-31.33	-10.28	0.1	-22.33	4.72	0.2	-13.33	14.72	0.25
-31.33	-5.28	0.15	-22.33	9.72	0.27	-10.33	-25.28	-0.12
-31.33	-0.28	0.2	-22.33	14.72	0.41	-10.33	-20.28	-0.3
-31.33	4.72	0.3	-19.33	-25.28	0	-10.33	-15.28	-0.38
-31.33	9.72	0.3	-19.33	-20.28	-0.1	-10.33	-12.78	-0.02
-31.33	14.72	0.4	-19.33	-16.78	-0.75	-10.33	-10.28	0.5
-28.33	-25.28	0.05	-19.33	-12.78	-1.45	-10.33	-7.28	1.95
-28.33	-20.28	0.05	-19.33	-12.28	-1.35	-10.33	-5.48	0.3
-28.33	-14.28	-0.71	-19.33	-10.28	-3.42	-10.33	-2.78	-0.2
-28.33	-11.78	-0.2	-19.33	-7.78	-3.3	-10.33	-0.28	-0.29
-28.33	-10.28	-0.45	-19.33	-5.28	-2.05	-10.33	1.72	0.49
-28.33	-7.78	-0.25	-19.33	-2.78	-1.5	-10.33	4.72	0.27
-28.33	-5.28	0.15	-19.33	-0.28	0.1	-10.33	9.72	0.05
-28.33	-0.28	0.2	-19.33	4.72	0.15	-10.33	14.72	0.17
-28.33	4.72	0.25	-19.33	9.72	0.19	-7.33	-25.28	-0.29
-28.33	9.72	0.3	-19.33	14.72	0.39	-7.33	-20.28	-0.33
-28.33	14.72	0.4	-16.33	-25.28	-0.05	-7.33	-17.78	-0.58
-25.33	-25.28	0	-16.33	-20.28	-0.1	-7.33	-15.28	-1.2
-25.33	-20.28	0	-16.33	-15.28	-0.23	-7.33	-12.78	-0.7
-25.33	-16.78	-0.75	-16.33	-12.78	-0.7	-7.33	-10.28	0.09
-25.33	-15.28	-1.75	-16.33	-10.28	-0.1	-7.33	-7.78	1.6
-25.33	-12.78	-2.25	-16.33	-8.48	-1.55	-7.33	-5.28	1.74
-25.33	-10.28	-2.2	-16.33	-5.28	-0.8	-7.33	-3.88	0.65
-25.33	-7.78	-1.99	-16.33	-2.78	-0.71	-7.33	-1.78	0.1
-25.33	-5.28	-1.45	-16.33	0.42	0.8	-7.33	-0.28	-0.15
-25.33	-2.78	-0.45	-16.33	4.72	0.1	-7.33	2.22	0.6
-25.33	-0.28	0.2	-16.33	9.72	0.19	-7.33	3.22	0.9
-25.33	4.72	0.25	-16.33	14.72	0.3	-7.33	4.72	0.4
-25.33	9.72	0.29	-13.33	-25.28	-0.1	-7.33	9.72	-0.05
-25.33	14.72	0.35	-13.33	-20.28	-0.2	-7.33	14.72	0.1
-22.33	-25.28	-0.05	-13.33	-15.28	-0.25	-4.33	-25.28	-0.28
-22.33	-20.28	0	-13.33	-12.78	0.01	-4.33	-20.28	-0.4
-22.33	-17.28	-1.1	-13.33	-9.58	1	-4.33	-17.78	-1.6
-22.33	-15.28	-2.55	-13.33	-7.28	-0.41	-4.33	-15.28	-1.9
-22.33	-13.78	-3.25	-13.33	-5.28	-0.47	-4.33	-12.78	-1.7
-22.33	-11.78	-3.31	-13.33	-2.78	-0.25	-4.33	-10.28	-0.3
-22.33	-10.28	-3.55	-13.33	-0.28	0.19	-4.33	-7.78	0.3
-22.33	-7.78	-2.55	-13.33	0.72	0.74	-4.33	-4.28	1.8

Table A.9 continued......

IV			V			VI		
x	y	Z	x	y	z	x	y	z
-4.33	-2.28	0.25	4.67	-15.28	-0.65	10.67	14.72	-0.15
-4.33	-0.28	0	4.67	-12.78	-0.85	13.67	-25.28	-0.1
-4.33	2.22	0.41	4.67	-10.28	-1.1	13.67	-22.28	-0.85
-4.33	3.22	0.8	4.67	-7.78	-1.11	13.67	-20.28	-2.05
-4.33	4.72	-0.2	4.67	-5.28	0.1	13.67	-17.78	-2.45
-4.33	9.72	-0.15	4.67	-2.78	0.7	13.67	-15.28	-1.9
-4.33	14.72	0.05	4.67	-0.28	-0.8	13.67	-12.78	-1.55
-1.33	-25.28	-0.37	4.67	2.22	-0.81	13.67	-10.28	-1.75
-1.33	-20.28	-0.45	4.67	4.72	-0.29	13.67	-7.78	-1.71
-1.33	-17.78	-1.5	4.67	9.72	-0.25	13.67	-5.28	-1.3
-1.33	-15.28	-2.35	4.67	14.72	-0.05	13.67	-2.78	0.2
-1.33	-12.78	-2.05	7.67	-25.28	-0.65	13.67	-0.28	1.4
-1.33	-10.28	-1.69	7.67	-20.28	-0.65	13.67	0.72	1.8
-1.33	-7.78	-0.55	7.67	-17.78	-0.55	13.67	2.22	1.08
-1.33	-5.28	0.95	7.67	-15.28	-0.2	13.67	4.72	-0.1
-1.33	-2.78	0.73	7.67	-12.78	-0.51	13.67	7.22	-1.51
-1.33	-0.78	-0.83	7.67	-10.28	-0.9	13.67	9.72	-0.8
-1.33	0.72	-0.45	7.67	-7.78	-0.95	13.67	14.72	-0.1
-1.33	2.22	0.15	7.67	-5.28	-0.25	16.67	-25.28	-0.39
-1.33	4.22	0.75	7.67	-2.78	0.9	16.67	-22.78	-0.5
-1.33	6.72	-0.1	7.67	-0.28	0.1	16.67	-20.28	-0.65
-1.33	9.72	-0.1	7.67	2.22	0.95	16.67	-17.78	-1.41
-1.33	14.72	0	7.67	4.72	0.4	16.67	-15.28	-1.95
1.67	-25.28	-0.51	7.67	7.22	0.1	16.67	-12.78	-1.45
1.67	-20.28	-0.7	7.67	9.72	-0.25	16.67	-10.28	-1.65
1.67	-17.78	-0.75	7.67	14.72	-0.05	16.67	-7.78	-1.5
1.67	-15.28	-1.21	10.67	-25.28	-0.4	16.67	-5.28	-1.1
1.67	-12.78	-1.45	10.67	-21.78	-0.55	16.67	-2.78	0.2
1.67	-10.28	-1.6	10.67	-20.28	-1.3	16.67	-0.28	1.55
1.67	-7.78	-1.3	10.67	-17.78	-1.5	16.67	2.22	0.55
1.67	-5.28	0.25	10.67	-15.28	-1.35	16.67	4.72	0
1.67	-3.78	0.65	10.67	-12.78	-1.47	16.67	7.22	-0.85
1.67	-2.28	-0.03	10.67	-10.28	-1.8	16.67	9.72	-0.15
1.67	-0.28	-1.25	10.67	-7.78	-1.8	16.67	14.72	-0.2
1.67	2.22	-0.9	10.67	-5.28	-0.75	19.67	-25.28	-0.8
1.67	4.72	-0.2	10.67	-2.78	0.7	19.67	-22.78	-0.49
1.67	9.72	-0.2	10.67	-0.28	1.95	19.67	-20.28	-0.1
1.67	14.72	0	10.67	2.22	0.95	19.67	-17.78	-0.45
4.67	-25.28	-0.65	10.67	4.72	0.05	19.67	-15.28	-0.4
4.67	-20.28	-0.65	10.67	7.22	-0.85	19.67	-12.78	-1.1
4.67	-17.78	-0.59	10.67	9.72	-0.35	19.67	-10.28	-1.26

Table A.9 continued……

VII			VIII			IX		
x	y	z	x	y	z	x	y	z
19.67	-7.78	-1.25	25.67	4.72	-0.45	34.67	-22.78	-0.41
19.67	-5.28	-0.9	25.67	7.22	-0.27	34.67	-20.28	-1.79
19.67	-2.78	0.05	25.67	9.72	-0.9	34.67	-17.78	-1.7
19.67	-0.28	1.6	25.67	12.22	-0.05	34.67	-15.28	-1.2
19.67	0.72	2.05	25.67	14.72	0	34.67	-12.78	-0.85
19.67	2.22	0.9	28.67	-25.28	-0.62	34.67	-10.28	-0.45
19.67	4.72	0.11	28.67	-22.78	-0.25	34.67	-7.78	-0.55
19.67	7.22	-0.25	28.67	-20.28	-1.25	34.67	-5.28	-0.7
19.67	9.72	0.1	28.67	-17.78	-0.7	34.67	-2.78	-0.43
19.67	14.72	-0.2	28.67	-15.28	-1.55	34.67	-0.28	0.67
22.67	-25.28	-0.45	28.67	-12.78	-1.26	34.67	2.22	1.7
22.67	-22.78	-1.5	28.67	-10.28	-1.25	34.67	4.72	0.7
22.67	-20.28	-0.61	28.67	-7.78	-0.8	34.67	7.22	-0.05
22.67	-17.78	-0.05	28.67	-5.28	-0.15	34.67	9.72	-0.2
22.67	-15.28	-0.8	28.67	-2.78	0.6	34.67	14.72	-0.1
22.67	-12.78	-0.8	28.67	-0.28	1.3	37.67	-25.28	-0.55
22.67	-10.28	-0.85	28.67	2.22	0.35	37.67	-22.78	-0.35
22.67	-7.78	-0.92	28.67	4.72	-0.26	37.67	-20.28	-0.55
22.67	-5.28	-0.59	28.67	7.22	-0.1	37.67	-17.78	-0.1
22.67	-2.78	0.5	28.67	9.72	-0.05	37.67	-15.28	-0.45
22.67	-2.28	1.79	28.67	12.22	0.4	37.67	-12.78	-0.41
22.67	0.72	2.39	28.67	14.72	-0.1	37.67	-10.28	0
22.67	2.22	1.45	31.67	-25.28	-0.45	37.67	-7.78	0.05
22.67	4.72	0.65	31.67	-22.78	-0.65	37.67	-5.28	-0.05
22.67	7.22	0.31	31.67	-20.28	-0.95	37.67	-2.78	-0.15
22.67	9.72	-0.65	31.67	-17.78	-1.45	37.67	-0.28	0.45
22.67	12.22	-1.1	31.67	-15.28	-1.6	37.67	1.72	1.25
22.67	14.72	-0.15	31.67	-12.78	-1.51	37.67	4.72	-0.1
25.67	-25.28	0.19	31.67	-10.28	-1.41	37.67	7.22	-0.3
25.67	-22.78	-0.4	31.67	-7.78	-1.35	37.67	9.72	0.1
25.67	-20.28	-1.45	31.67	-5.28	-1.01	37.67	14.72	-0.1
25.67	-17.78	-0.35	31.67	-2.78	-0.05	40.67	-25.28	-0.35
25.67	-15.28	-0.45	31.67	-0.28	0.65	40.67	-22.78	-0.47
25.67	-12.78	-0.6	31.67	0.72	1	40.67	-20.28	0.04
25.67	-10.28	-0.5	31.67	2.22	0.55	40.67	-17.78	0.55
25.67	-7.78	-0.6	31.67	4.72	0.15	40.67	-16.28	0.75
25.67	-5.28	-0.35	31.67	7.22	-0.4	40.67	-15.28	0.36
25.67	-2.78	0.5	31.67	9.72	-0.4	40.67	-12.78	-0.15
25.67	-0.28	2.05	31.67	12.22	-0.25	40.67	-11.78	-0.22
25.67	0.72	2.35	31.67	14.72	-0.1	40.67	-10.28	-0.02
25.67	2.22	1.2	34.67	-25.28	-0.45	40.67	-7.78	0.25

Table A.9 continued……

X			XI			XII		
x	y	z	x	y	z	x	y	z
40.67	-5.28	0.47	49.67	-25.28	-0.65	58.67	-25.28	-0.75
40.67	-2.78	0.75	49.67	-20.28	-0.55	58.67	-20.28	-0.65
40.67	-0.28	0.9	49.67	-17.28	-0.19	58.67	-15.28	-0.35
40.67	2.22	0.6	49.67	-15.28	-0.55	58.67	-10.28	-0.45
40.67	4.72	0	49.67	-10.28	-0.27	58.67	-5.28	-0.45
40.67	7.22	-0.1	49.67	-7.78	0.15	58.67	-0.28	-0.45
40.67	9.72	-0.15	49.67	-5.28	-0.05	58.67	2.72	0.35
40.67	14.72	-0.05	49.67	-2.78	-0.35	58.67	4.72	0.15
43.67	-25.28	-0.55	49.67	-0.28	-0.2	58.67	9.72	-0.15
43.67	-22.78	-0.8	49.67	1.22	0.5	58.67	14.72	-0.05
43.67	-20.28	-0.35	49.67	2.22	0.01	61.67	-25.28	-0.8
43.67	-17.78	0.8	49.67	4.72	-0.15	61.67	-20.28	-0.69
43.67	-15.28	0.6	49.67	7.22	-0.07	61.67	-15.28	-0.3
43.67	-12.78	0.25	49.67	9.72	-0.2	61.67	-10.28	-0.45
43.67	-10.28	1.45	49.67	14.72	-0.05	61.67	-5.28	-0.25
43.67	-7.78	-0.55	52.67	-25.28	-0.7	61.67	-0.28	-0.05
43.67	-5.28	-0.35	52.67	-20.28	-0.6	61.67	3.72	0.6
43.67	-2.78	0.55	52.67	-16.88	-0.2	61.67	7.22	-0.09
43.67	-0.28	0.55	52.67	-15.28	-0.59	61.67	9.72	-0.1
43.67	2.22	0.8	52.67	-12.78	-0.55	61.67	14.72	0
43.67	4.72	-0.3	52.67	-10.28	-0.55	64.67	-25.28	-0.85
43.67	7.22	-0.13	52.67	-5.28	-0.15	64.67	-20.28	-0.85
43.67	9.72	-0.1	52.67	-2.78	-0.15	64.67	-15.28	-0.65
43.67	14.72	-0.05	52.67	-0.28	-0.05	64.67	-10.28	-0.35
46.67	-25.28	-0.6	52.67	2.22	1.2	64.67	-5.28	-0.2
46.67	-22.78	-0.45	52.67	4.72	0.2	64.67	-0.28	0.35
46.67	-20.28	-0.55	52.67	7.22	-0.25	64.67	2.22	0.45
46.67	-17.78	0.05	52.67	9.72	-0.2	64.67	4.72	-0.15
46.67	-15.28	-0.2	52.67	14.72	-0.1	64.67	9.72	-0.1
46.67	-12.78	-0.4	55.67	-25.28	-0.75	64.67	14.72	0.05
46.67	-10.28	-0.55	55.67	-20.28	-0.65	67.67	-25.28	-0.8
46.67	-7.78	-0.22	55.67	-15.28	-0.45	67.67	-20.28	-0.75
46.67	-5.28	-0.45	55.67	-10.28	-0.5	67.67	-15.28	-0.48
46.67	-2.78	-0.45	55.67	-5.28	-0.55	67.67	-10.28	-0.65
46.67	-0.28	-0.2	55.67	-0.28	0.15	67.67	-5.28	-0.53
46.67	2.22	-0.15	55.67	1.72	1	67.67	-0.28	-0.3
46.67	4.72	-0.18	55.67	4.72	-0.35	67.67	4.72	-0.23
46.67	7.22	-0.25	55.67	7.22	-0.05	67.67	9.72	-0.05
46.67	9.72	-0.2	55.67	9.72	-0.15	67.67	14.72	0.05
46.67	14.72	-0.1	55.67	14.72	-0.05			

EXPERIMENTAL DATA RELATED TO VARIATION OF STRENGTH OF VORTEX

This appendix contains the experimental data collected in River engineering laboratory, Water Resources Development & Management Department, Indian Institute of Technology, Roorkee, India. The data presented here have been used in chapter 4 of this thesis. The fig. B.1 indicates the sign convention and axes used.

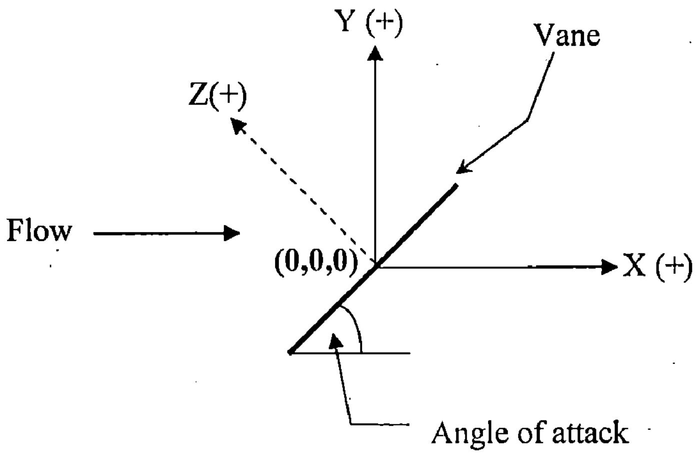

Fig. B.1 Definition sketch of origin for three dimensional velocity measurement

Origin = Middle bottom edge of vane at initial bed level

Table B.1

3D Velocity components for submerged vanes with aspect ratio 0.33 and α = 15°

x	y	z	Vx	Vy	Vz
27.24	-12	2.5	23.72	9.28	-0.64
27.24	-8	2.5	23.85	10.16	-0.82
27.24	-4	2.5	22.75	11.65	-0.89
27.24	0	2.5	22.93	12.26	-1.82
27.24	4	2.5	18.55	9.44	0.77
27.24	8	2.5	18.97	8.26	0.87
27.24	12	2.5	20.42	9	0.09
27.24	-12	6.5	24.09	6.85	-1.55
27.24	-8	6.5	25.14	7.04	-1.9
27.24	-4	6.5	24.26	6.41	-1.81
27.24	0	6.5	21.36	2.39	-0.95
27.24	4	6.5	23.35	5.83	0.54
27.24	8	6.5	23.36	7.03	0.11
27.24	12	6.5	21.93	7.03	0.08
27.24	-12	10.5	24.02	9.27	-1
27.24	-8	10.5	23.8	9.21	-0.57
27.24	-4	10.5	23.82	9.78	-0.89
27.24	0	10.5	24.73	9.15	-0.99
27.24	4	10.5	23.65	7.63	-0.14
27.24	8	10.5	24.13	8.76	0.38
27.24	12	10.5	22.95	8.24	0.53
27.24	-12	14.5	24.16	7.39	-0.4
27.24	-8	14.5	23.39	8.04	-0.34
27.24	-4	14.5	23.03	8.12	-0.35
27.24	0	14.5	23	6.22	-0.09
27.24	4	14.5	23.54	5.77	0.2
27.24	8	14.5	24	8.06	0.33
27.24	12	14.5	23.77	7.34	0.29

Table B.2

3D Velocity components for submerged vanes with aspect ratio 0.33 and α = 20°

x	y	z	Vx	Vy	Vz
29.4	-12	2.5	23.31	3.49	-0.47
29.4	-8	2.5	23.77	5.23	-0.65
29.4	-4	2.5	25.41	7	-1.12
29.4	0	2.5	26.18	10.07	-2.01
29.4	4	2.5	22.65	13.14	-0.57
29.4	8	2.5	15.17	6.3	1.07
29.4	12	2.5	18.81	7.17	0.13
29.4	-12	6.5	26.62	6.17	-0.48
29.4	-8	6.5	26.84	5.34	-1.2
29.4	-4	6.5	27.27	5.22	-1.88
29.4	0	6.5	25.78	3.79	-4.21
29.4	4	6.5	19.65	-3.16	-1.97
29.4	8	6.5	25.59	4.83	1.74
29.4	12	6.5	27.29	5.29	0.42
29.4	-12	10.5	27.79	5.02	-1.34
29.4	-8	10.5	27.34	5.23	-1.26
29.4	-4	10.5	27.56	4.9	-1.81
29.4	0	10.5	28.27	3.71	-1.71
29.4	4	10.5	27.35	2.38	-0.81
29.4	8	10.5	26.62	3.53	0.29
29.4	12	10.5	26.2	3.69	0.45
29.4	-12	14.5	25.61	2.92	-0.55
29.4	-8	14.5	27.23	1.93	-0.85
29.4	-4	14.5	27.02	2.06	-0.65
29.4	0	14.5	26.63	1.23	-0.51
29.4	4	14.5	27.29	0.87	-0.05
29.4	8	14.5	26.69	1.24	0.56
29.4	12	14.5	25.88	1.35	0.41

Table B.3

3D Velocity components for submerged vanes with aspect ratio 0.33 and α = 25°

x	y	z	Vx	Vy	Vz
26.8	-12	2.5	21.97	7.64	-0.44
26.8	-8	2.5	22.28	8.91	-1.14
26.8	-4	2.5	23.71	7.24	-1.37
26.8	0	2.5	23.53	10.85	-2.93
26.8	4	2.5	16.13	9.87	-1.42
26.8	8	2.5	14.29	9.64	2.11
26.8	12	2.5	17.5	6.92	2.85
26.8	-12	6.5	25.12	6.82	-1.48
26.8	-8	6.5	24.27	7.61	-2.17
26.8	-4	6.5	24.5	7.87	-1.97
26.8	0	6.5	22.98	6.33	-3.27
26.8	4	6.5	16.31	-0.39	-2.62
26.8	8	6.5	19.31	3.51	1.63
26.8	12	6.5	19.36	4.59	1.87
26.8	-12	10.5	24.51	6.53	-1.75
26.8	-8	10.5	24.8	6.27	-1.9
26.8	-4	10.5	24.87	5.71	-2
26.8	0	10.5	24.93	5.91	-1.84
26.8	4	10.5	23.22	5.26	-0.78
26.8	8	10.5	23.93	5.76	-0.05
26.8	12	10.5	23.86	5.64	0.13
26.8	-12	14.5	23	3.88	-0.81
26.8	-8	14.5	24.3	4.41	-1.24
26.8	-4	14.5	23.92	3.05	-1.11
26.8	0	14.5	24.38	3.48	-0.85
26.8	4	14.5	23.58	2.52	-1.25
26.8	8	14.5	23.63	2.26	0.3
26.8	12	14.5	22.34	1.55	0.27

Table B.4

3D Velocity components for submerged vanes with aspect ratio 0.25 and α = 15

x	y	z	Vx	Vy	Vz
27.24	s	2.5	24.68	4.9	-0.64
27.24	-8	2.5	25.06	7.61	-1.01
27.24	-4	2.5	26.13	8.16	-1.2
27.24	0	2.5	26.39	11.28	-0.77
27.24	4	2.5	22.34	13.52	1.86
27.24	8	2.5	18.49	8.07	-1.66
27.24	12	2.5	19.54	8.44	-0.66
27.24	-12	6.5	25.24	6.17	-1.57
27.24	-8	6.5	26.28	6.67	-1.82
27.24	-4	6.5	24.96	6.22	-1.98
27.24	0	6.5	23.08	3.88	-4.42
27.24	4	6.5	17.92	-3.42	-2.26
27.24	8	6.5	20.09	7.55	1.55
27.24	12	6.5	22.75	6.67	0.33
27.24	-12	10.5	26.18	4.38	-1.56
27.24	-8	10.5	25.85	6.32	-1.1
27.24	-4	10.5	25.59	5.21	-1.13
27.24	0	10.5	25.58	6.13	-1.6
27.24	4	10.5	25.66	5.05	-0.46
27.24	8	10.5	23.96	5.69	0.14
27.24	12	10.5	25.62	7.85	0.42
27.24	-12	14.5	23.22	3.7	-0.12
27.24	-8	14.5	25.13	5.63	-0.76
27.24	-4	14.5	24.37	3.57	-0.17
27.24	0	14.5	24.66	3.68	-0.56
27.24	4	14.5	25.07	4.48	-0.28
27.24	8	14.5	23.88	4.21	0.65
27.24	12	14.5	24.97	6.28	0.44

Table B.5

3D Velocity components for submerged vanes with aspect ratio 0.25 and α = 20°

x	y	Z	Vx	Vy	Vz
29.4	-12	2.5	22.38	3.8	-1.19
29.4	-8	2.5	23.42	5.3	-1.4
29.4	-4	2.5	23.65	6.61	-1.69
29.4	0	2.5	22.65	8.84	-3.26
29.4	4	2.5	16.48	11.33	2.63
29.4	8	2.5	15.86	12.63	2.37
29.4	12	2.5	18.19	7.45	-0.75
29.4	-12	6.5	24.11	3.22	-1.42
29.4	-8	6.5	24.42	3.97	-1.84
29.4	-4	6.5	23.01	2.37	-2.48
29.4	0	6.5	19.73	-0.47	-3.74
29.4	4	6.5	20.45	-4	-0.83
29.4	8	6.5	19.25	2.66	1.72
29.4	12	6.5	21.83	5.38	0.76
29.4	-12	10.5	24.59	4.62	-1.38
29.4	-8	10.5	24.45	4.88	-1.33
29.4	-4	10.5	25.18	4.66	-1.67
29.4	0	10.5	24.61	3.28	-1.51
29.4	4	10.5	24.45	2.03	-0.79
29.4	8	10.5	25.08	2.81	-0.09
29.4	12	10.5	22.88	3.68	0.71
29.4	-12	14.5	23.75	4.75	-0.6
29.4	-8	14.5	24.7	2.91	-1.06
29.4	-4	14.5	24.37	1.74	-1.11
29.4	0	14.5	24.19	1.55	-0.76
29.4	4	14.5	23.65	1.62	-0.17
29.4	8	14.5	24.3	2.5	-0.05
29.4	12	14.5	23.57	2.97	0.21

Table B.6

3D Velocity components for submerged vanes with aspect ratio 0.25 and α = 25

x	y	z	Vx	Vy	Vz
29.1	-12	2.5	22.23	8.01	-0.9
29.1	-8	2.5	22.15	9.53	-1.09
29.1	-4	2.5	20.73	9.84	-1.26
29.1	0	2.5	21.7	12.98	-2.88
29.1	4	2.5	15.62	16.59	-2.15
29.1	8	2.5	15.61	15.62	4.86
29.1	12	2.5	14.61	7.86	-1.18
29.1	-12	6.5	22.76	6.56	-1.66
29.1	-8	6.5	22.88	6.23	-1.53
29.1	-4	6.5	22.31	7.37	-1.65
29.1	0	6.5	22.79	6.4	-2.45
29.1	4	6.5	22.02	6.1	-3.3
29.1	8	6.5	18.23	-0.04	-3.74
29.1	12	6.5	21.77	7.34	1.5
29.1	-12	10.5	23.3	7.03	-1.27
29.1	-8	10.5	23.18	6.48	-1.36
29.1	-4	10.5	23.48	5.96	-1.93
29.1	0	10.5	22.87	4.84	-2.13
29.1	4	10.5	23.77	2.76	-0.84
29.1	8	10.5	23.73	4.24	0.87
29.1	12	10.5	22.49	6.68	1.01
29.1	-12	14.5	22.61	5.1	-0.5
29.1	-8	14.5	23.58	6.8	-1.09
29.1	-4	14.5	21.77	3.17	-1.29
29.1	0	14.5	21.77	2.42	-1.02
29.1	4	14.5	21.47	1.25	-0.18
29.1	8	14.5	22.72	3.59	0.39
29.1	12	14.5	21.62	3.44	1.04

Table B.7

3D Velocity components for submerged vanes with aspect ratio 0.20 and α = 15°

x	y	z	Vx	Vy	Vz
32.07	-12	2.5	21.18	4.44	-0.86
32.07	-8	2.5	22.34	4.48	-1.1
32.07	-4	2.5	21.63	5.84	-0.77
32.07	0	2.5	22.63	8.97	-0.97
32.07	4	2.5	15.92	10.83	1.55
32.07	8	2.5	14.78	3.28	-1.33
32.07	12	2.5	15.9	4.06	-0.86
32.07	-12	6.5	22.2	3.25	-0.88
32.07	-8	6.5	22.73	4.12	-1.76
32.07	-4	6.5	22.88	5.81	-2.3
32.07	0	6.5	21.94	5.13	-2.49
32.07	4	6.5	17.04	-3.04	-2.1
32.07	8	6.5	17.98	1.83	2.89
32.07	12	6.5	17.24	5.49	0.9
32.07	-12	10.5	23.09	3.83	-0.53
32.07	-8	10.5	22.23	4.79	-1.06
32.07	-4	10.5	22.71	4.91	-1.49
32.07	0	10.5	22.77	3.42	-1.61
32.07	4	10.5	22.97	2.39	-0.95
32.07	8	10.5	22.98	4.24	0.39
32.07	12	10.5	23.32	5.68	1.2
32.07	-12	14.5	22.68	2.82	-0.58
32.07	-8	14.5	21.87	2.08	-0.24
32.07	-4	14.5	22.4	1.75	-0.95
32.07	0	14.5	23.24	3.24	-0.69
32.07	4	14.5	22.45	2.22	-0.18
32.07	8	14.5	22.3	2.46	0.55
32.07	12	14.5	22.13	2.53	0.5

Table B.8

3D Velocity components for submerged vanes with aspect ratio 0.20 and α = 20°

x	y	z	Vx	Vy	Vz
31.74	-12	2.5	23.96	4.07	-0.46
31.74	-8	2.5	24	4.1	-1.25
31.74	-4	2.5	24.14	4.39	-1.13
31.74	0	2.5	26.11	10.58	-3.22
31.74	4	2.5	11.47	3.98	-0.25
31.74	8	2.5	14.25	3.23	5.34
31.74	12	2.5	18.36	4.47	-0.92
31.74	-12	6.5	24.08	1.98	-1.4
31.74	-8	6.5	24.4	2.51	-2.11
31.74	-4	6.5	23.33	2.79	-2.6
31.74	0	6.5	23.69	2.18	-3.96
31.74	4	6.5	18.89	-5.57	-2.43
31.74	8	6.5	18.18	1.99	3.43
31.74	12	6.5	20.37	6.03	1.04
31.74	-12	10.5	24.92	3.54	-1.43
31.74	-8	10.5	25.22	3.45	-1.53
31.74	-4	10.5	24.93	3.63	-1.86
31.74	0	10.5	25.18	3.36	-1.5
31.74	4	10.5	24.37	-0.72	-1.08
31.74	8	10.5	24.84	2.4	0.67
31.74	12	10.5	23.49	3.35	0.9
31.74	-12	14.5	24.23	1.74	-0.68
31.74	-8	14.5	24.02	1.53	-0.8
31.74	-4	14.5	24.05	1.59	-1.09
31.74	0	14.5	23.87	-1.08	-0.81
31.74	4	14.5	23.02	-1.51	-0.21
31.74	8	14.5	23.61	-1.02	0.62
31.74	12	14.5	23.03	-0.36	0.94

Table B.9

3D Velocity components for submerged vanes with aspect ratio 0.20 and α = 25

x	y	z	Vx	Vy	Vz
21.33	-12	2.5	23.4	3.99	-0.89
21.33	-8	2.5	23.28	5.73	-0.63
21.33	-4	2.5	26.05	11.11	-2.7
21.33	0	2.5	23.18	9.5	-3.22
21.33	4	2.5	16.18	9.98	-1.81
21.33	8	2.5	17.59	13.13	7.66
21.33	12	2.5	15.61	5.29	-0.44
21.33	-12	6.5	22.92	3.1	-1.48
21.33	-8	6.5	24.16	3.25	-2.34
21.33	-4	6.5	23.97	3.96	-2.63
21.33	0	6.5	21.2	1.15	-4.1
21.33	4	6.5	18.58	-4.84	-3.6
21.33	8	6.5	20.57	3.72	4.69
21.33	12	6.5	19.59	5.62	0.21
21.33	-12	10.5	25.08	3.26	-1.36
21.33	-8	10.5	25.01	2.43	-1.72
21.33	-4	10.5	25.14	3.21	-2.08
21.33	0	10.5	25.45	1.07	-1.97
21.33	4	10.5	25.56	-1.18	-1.02
21.33	8	10.5	25.92	1.6	0.84
21.33	12	10.5	24.34	3.02	0.98
21.33	-12	14.5	23.56	2.56	-0.94
21.33	-8	14.5	23.71	0.66	-0.73
21.33	-4	14.5	24.12	2.05	-0.89
21.33	0	14.5	25.49	3.63	-1.09
21.33	4	14.5	24.98	0.9	-0.34
21.33	8	14.5	24.23	0.71	0.26
21.33	12	14.5	24.44	3.49	0.32