EFFECT OF SPIRES ON BOUNDARY LAYER GROWTH

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By

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CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF SPIRES ON BOUNDARY LAYER GROWTH**" submitted by SMRUTYUNJAYA TARAI & V.K ROHITH in partial fulfillment for the requirement for the award of Bachelor of Technology degree in Civil Engineering at National Institute of Technology, Rourkela, is an authentic work carried out by them under my supervision and guidance. To the best of my knowledge, the contents in this thesis, has not been submitted to any other University/Institute for the award of any degree or Diploma.

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ABSTRACT

The aim of the present work was to study the boundary layer thickness growth with vertical spires of varying heights and c/c spacing. In this study, it was observed that boundary layer thickness is affected by the presence of vertical spires in wind tunnel. Various spires of different heights 20, 30 and 40 cm with wall clearance of 2.5 cm were used to study their effects. The boundary layer thickness was in turn affected by the configuration of the spires. It was observed that boundary layer thickness increases with increase in height of the spires within the cross section of the wind tunnel and boundary layer thickness. Also, boundary layer thickness increases with decrease in c/c spacing of the spires. At a working section, the velocity profiles were plotted and boundary layer thickness in each case was calculated (the height from the surface to the point of 99 per cent of the main stream velocity). In this way the boundary layer thickness was calculated for different working sections.

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Chapter 1

INTRODUCTION

1.1 INTRODUCTION:

When a viscous fluid flows along a fixed impermeable wall or rigid surface, an essential condition is that velocity at any point on the wall or fixed surface is zero. The flow characteristics depend on the value of viscosity. If the boundary is stationary the velocity at the boundary is zero. Away from the boundary the velocity increases gradually due to which velocity variation occurs. The modifying effect appears to be restrained within narrow regions adjacent to solid surfaces. A boundary layer is thin layer of viscous fluid close to solid surface in which velocity of fluid on the stationary boundary increases from zero velocity to main stream velocity in direction normal to boundary.

To carry wind tunnel experiments it is necessary that the models should lie within the boundary layer zone. But in the wind tunnel the boundary layer thickness is very small so constant attempts have been made by researchers to increase the boundary layer thickness.

In the present work the first part of the experiment was to take the readings without any obstruction in the flow. With the readings the velocity profiles were drawn and growth of the boundary layer was found. In the later part of the experiment readings were taken in the presence of vertical spires of different sizes and dimension and the thickness of the boundary layer increased on comparison to the former.

1.2 BOUNDARY LAYER THICKNESS

Boundary layer thickness is defined as that distance from the surface where the local velocity equals 99% of the free stream velocity. The boundary layer thickness grows with the distance from the leading edge and it reaches a constant thickness.

1.3 VERTICAL SPIRES

This is the passive objects are mainly used as obstruction in wind tunnel so that generation of vortex and consequent turbulence takes place. Wooden vertical spires of different dimensions are used for the experiment purpose. Spires play an important role in the wind tunnel for the obstruction purpose so that generation of turbulence takes place which increases the thickness of Boundary layer.

Figure 1.1 VERTICAL SPIRES OF 20 CM SIZE

Chapter 2

LITERATURE SURVEY

LITERATURE SURVEY

1. G.I. Taylor (1915-1938): The statistical theory of turbulence, related to the scale and spectrum of turbulence is largely credited to G.I. Taylor in the period 1915-1938. Taylor noted that since velocities vary spatially as well as temporarily, correlation measurements can give an indication of the size of gusts or eddies
2. Von Karmann IN 1921 formulated a general equation from the conservation of momentum theory which can predict the boundary layer flow covers from laminar to turbulent regions. His equation contributes advancement in the prediction of drag caused by shear forces on a body.
3. Counihan (1969) used a model from simple geometric compositions made with rods and bars. The boundary layer was qualified by examining the following features: growth of structure and equilibrium of momentum.
4. A thick boundary layer can be produced through several different methods; the paper of Hunt and Fernholz (1975) lists ten possible methods of simulation of stable, unstable and neutral atmospheric conditions in various types of wind tunnel.
5. Ligrani et al. (1979, 1983) used streamlined spires with sharp-edged upstream and downstream blades. The total angle of the upstream blade was carefully adjusted for a fine-tuning of the fluctuation intensities. A cross barrier set downstream of the spires was used to increases the momentum deficit over that resulted from the spires alone.

Chapter 3

TEST APPARATUS

3.1 TELESCOPIC PROBE VELOCITY METER

The velocity, temperature and pressure sensors are measured with telescopic probe velocity meter. Inside the wind tunnel it measures the velocity from the surface longitudinally and in transverse direction. The sensor window must be fully exposed while using the probe and orientation should be faced upwards.

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Figure 3.1 TELESCOPIC PROBE VELOCITY METER

3.2 DIGITAL VELOCI CALICO MODEL A00TSI

The digital veloci calico model A00TSI is connected to the probe and from it we numerically note down the values of the velocity.

Figure 3.2 DIGITAL VELOCI CALICO MODEL A00TSI

3.3 VERTICAL SPIRES OF DIFFERENT SIZES

The formation of vortex and turbulence depends on the placement of vertical spires in different configuration.

The thickness of the boundary layer will be less if the spacing between spires is increased as the formation of vortex and turbulence is less.

The boundary layer thickness is much greater if spacing between spires is decreased as the formation of vortex and generation of turbulence takes place in much effective way.

The main objective of putting these objects (spires) is for simulation purpose.

Different sizes of vertical strips (c/s 5 cm x 2 cm) used in the experiment are.

(i) 6 nos. of 20 cm height (ii) 6 nos. of 30 cm height, (iii) 6 nos. of 40 cm height

The vertical strips of heights 20 cm, 30 cm and 40 cm have been placed with varying central spacing of 10 cm c/c,8 cm c/c,6 cm c/c. The wall clearance in each case was kept 2.5 cm from both sides.

3.4 TROLLEY

The main purpose of the trolley in wind tunnel is used for changing the position of the velocity probe meter. It helps in a significant way by reducing the work load.

Figure 3.4 TROLLEY

Chapter 4

TEST PROCEDURE

4.1 PROCEDURE

1. For the growth of the Boundary layer in a wind tunnel we have to let the air flow through a set of passive devices such as spires in the beginning of the working section.

2. The vertical spires of heights 20 cm, 30 cm and 40 cm have been placed with central spacing of 10 cm c/c. and side distance of 2.5 cm on both sides.

3. 6 nos. of 20, 30 and 40cm vertical spires are used in the experiment.

4. In the first part of the experimental study, the objective was to determine the boundary layer thickness on the surface of the wind tunnel (plywood surface) without placing vertical spires.

5. In the second part of the experimental study, the objective was to determine the boundary layer growth on at the surface of the wind tunnel placing vertical spires.

6. The velocity data were taken at small intervals from the surface using a digital velocity calico model A00TSI. The procedure is repeated by placing the vertical spires at different sections.

7. The distance of telescopic probe velocity meter were marked at 0.5m, 1.2m, 2 m, 3.5m, and 4 m from the vertical spires. For the different cases of vertical spires same sections were used. Velocity profile at every section is plotted and the boundary layer thickness (height from the surface up to 99% of the main stream velocity) was obtained.

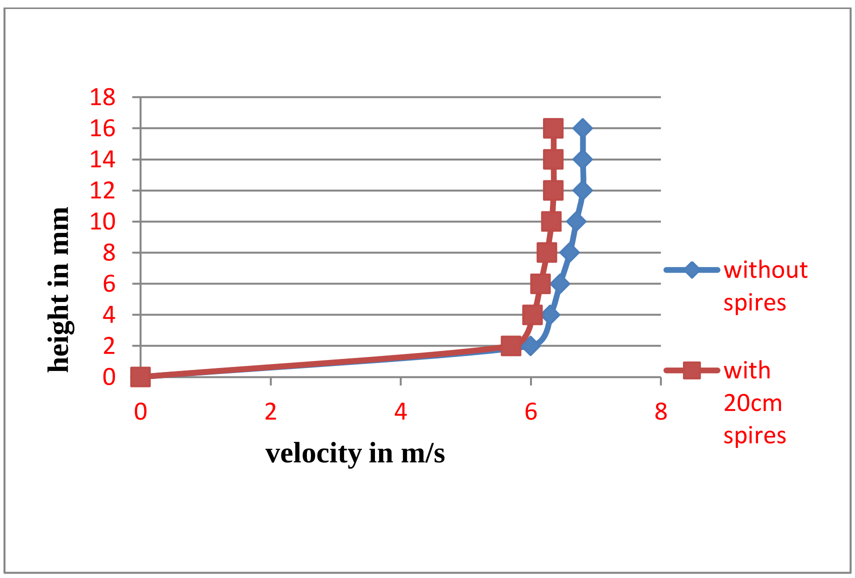
Chapter 5

VARIATION OF VELOCITY PROFILE AND BOUNDARY LAYER THICKNESS

5.1.1 VELOCITY PROFILE AT 1.2 m AWAY FROM SPIRES WHEN 20 cm HEIGHT OF SPIRES USED

Velocity with 20cm spires in m/s	Velocity without spires in m/s	Height from the surface
0	0	0
5.7	6	2
6.03	6.3	4
6.15	6.45	6
6.25	6.6	8
6.32	6.7	10
6.35	6.8	12
6.35	6.8	14

Table 5.1.1.1: Velocity profile of 20 cm spires and without spires at distance 1.2 m away the spires

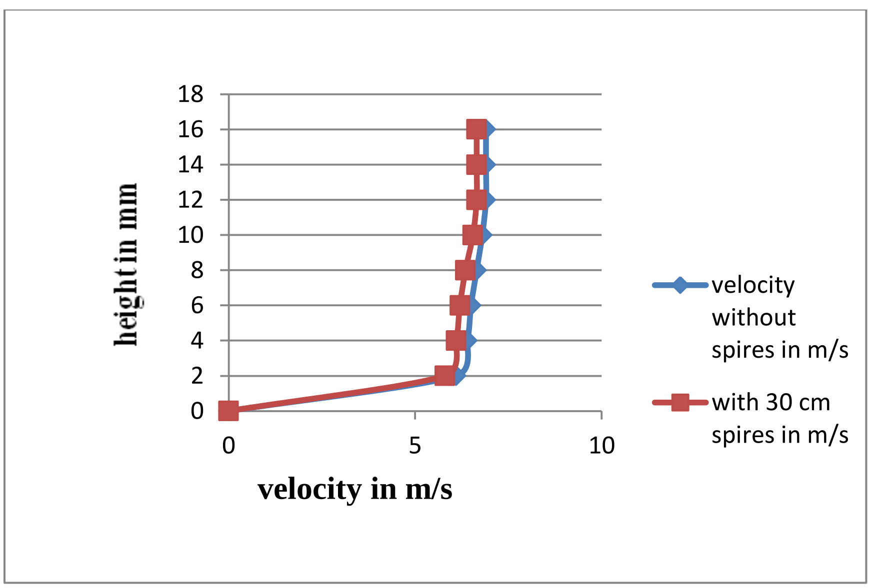


Graph 5.1.1.1: Velocity profile of 20 cm spire and without spire at distance 1.2 m away from the spires

5.1.2 VELOCITY PROFILE AT 2 m AWAY FROM THE SPIRES WHEN 30 cm HEIGHT OF SPIRES ARE USED

Velocity with 30cm spires in m/s	Velocity without spires in m/s	Height from the surface
0	0	0
5.8	6.1	2
6.1	6.4	4
6.2	6.5	6
6.35	6.65	8
6.55	6.8	10
6.65	6.9	12
6.65	6.9	14

Table 5.1.2.1: Velocity profile of 30 cm spires and without spires at distance 2 m away from the spires

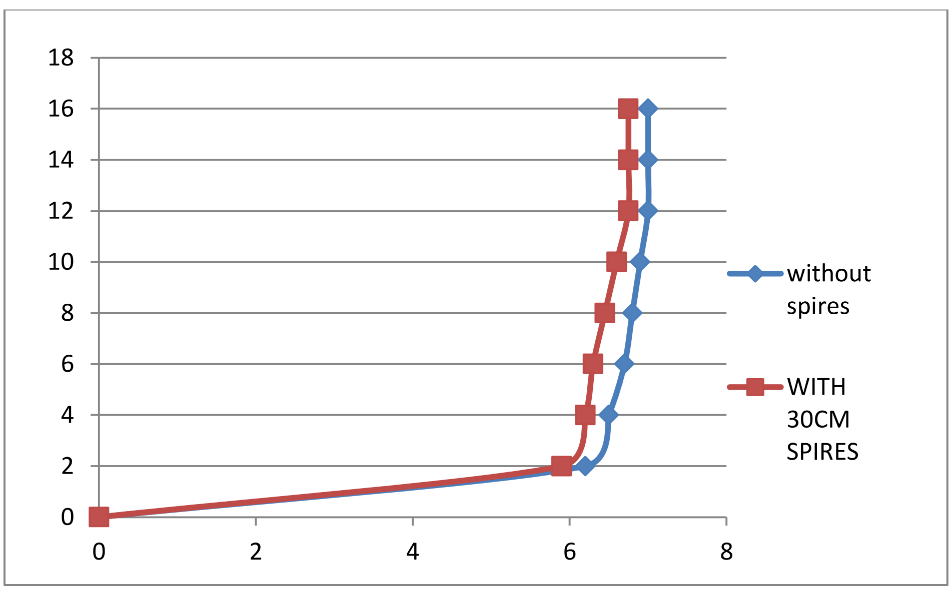


Graph 5.1.2.1: Velocity profile of 30 cm spire and without spire at distance 2 m away from the spires

5.1.3 VELOCITY PROFILE AT 4 m AWAY WHEN 40 cm HEIGHT OF SPIRES ARE USED.

Velocity with 40cm spires in m/s	Velocity without spires in m/s	Height from the surface
0	0	0
5.9	6.2	2
6.2	6.5	4
6.3	6.7	6
6.45	6.8	8
6.6	6.9	10
6.75	7	12
6.75	7	14

Table 5.1.3.1: Velocity profile of 40 cm spires and without spires at distance 4 m away from the spires.

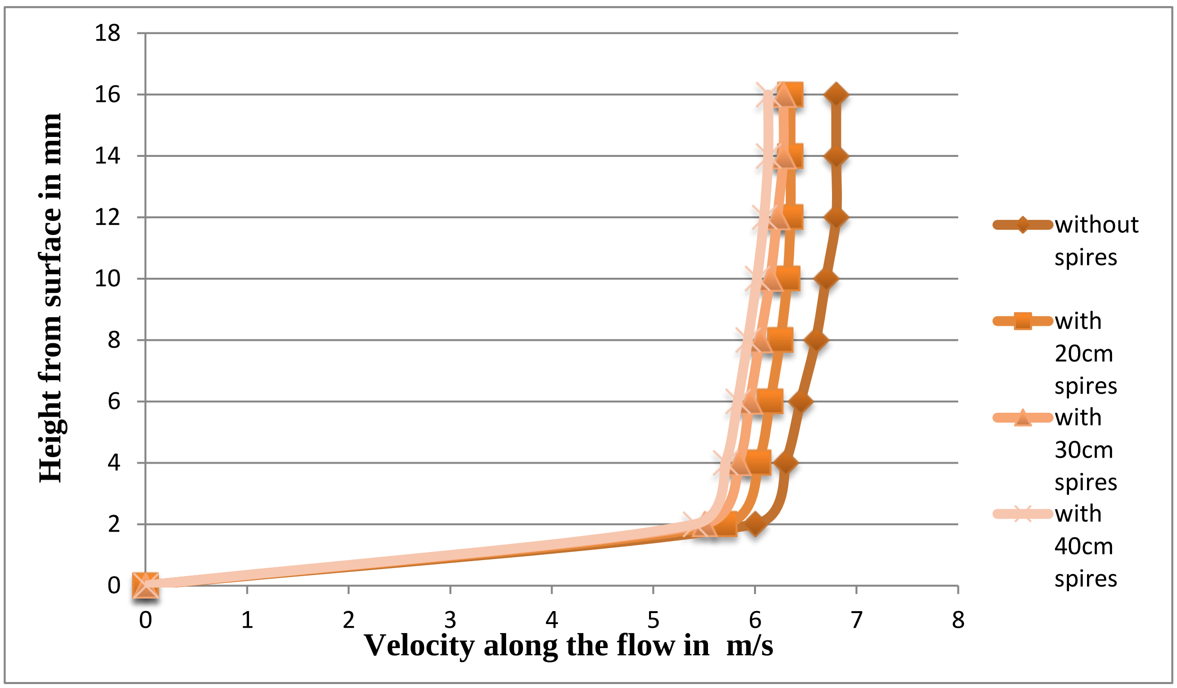


Graph 5.1.3.1: Velocity profile of 40 cm spire and without spire at distance 4 m away from the spires

5.1.4 VELOCITY PROFILE OF DIFFERENT SPIRES AT 1.2 m AWAY FROM SPIRES

With 40cm spires in m/s	With 30 cm spires in m/s	With 20cm spires in m/s	Without spires in m/s	Height from the surface in mm
0	0	0	0	0
5.41	5.5	5.7	6	2
5.71	5.84	6.03	6.3	4
5.83	6.05	6.15	6.45	6
5.93	6.15	6.25	6.6	8
6.02	6.22	6.32	6.7	10
6.09	6.28	6.35	6.8	12
6.13	6.28	6.35	6.8	14
6.13	6.28	6.35	6.8	16

Table 5.1.4.1: Velocity profile of different spires at 1.2 m away from the spires

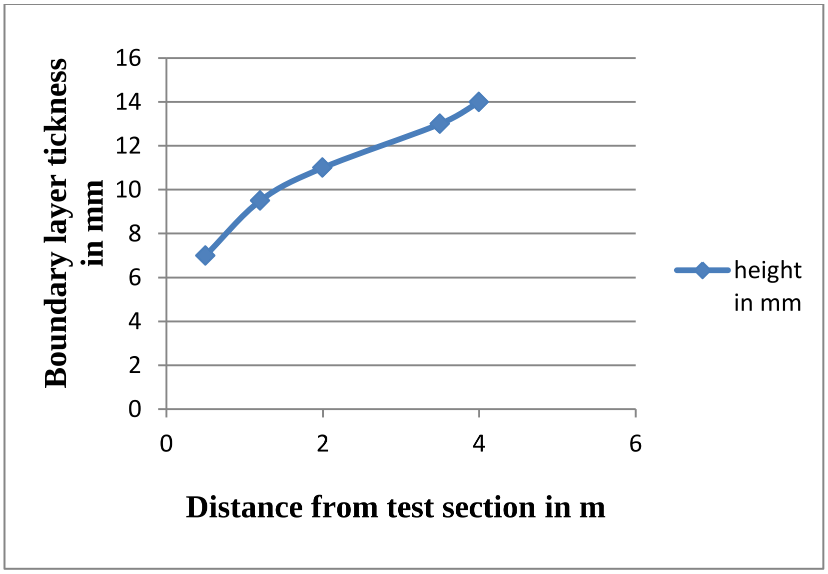


Graph 5.1.4.1: Velocity profiles of different spires at 1.2 m away from the spires

5.2.1 VARIATION OF BOUNDARY LAYER THICKNESS ALONG THE FLOW FROM THE BEGINNING OF TEST SECTION IF SPIRE HEIGHT IS 20 cm

Distance from the test section in m	Boundary layer thickness in mm
0.5	7
1.2	9.5
2	11
3.5	13
4	14

Table 5.2.1.1: Variation of Boundary layer thickness along the flow with vertical spire height 30 cm

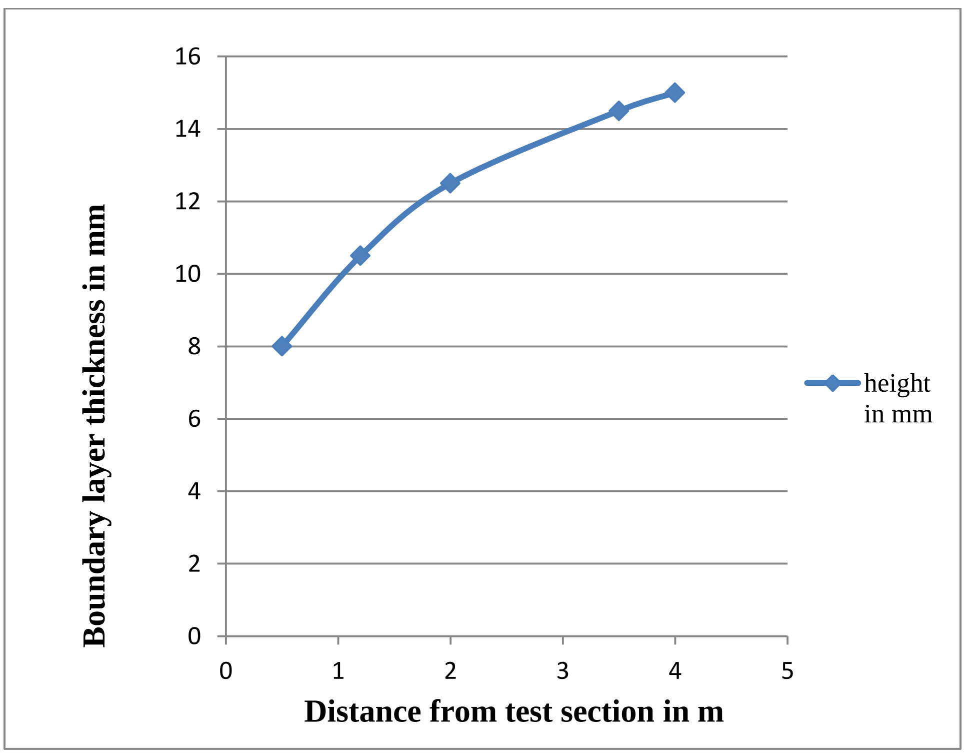


Graph 5.2.1.1: Variation of boundary layer thickness along the flow from the beginning of the test section when 20 cm spires are placed

5.2.2 VARIATION OF BOUNDARY LAYER THICKNESS ALONG THE FLOW FROM THE BEGINNING OF TEST SECTION IF SPIRE HEIGHT IS 30 cm

Distance from the test section in m	Boundary layer thickness in mm
0.5	8
1.2	10
2	11.5
3.5	14
4	15

Table 5.2.2.1: Variation of Boundary layer thickness along the flow with vertical spire height 30 cm

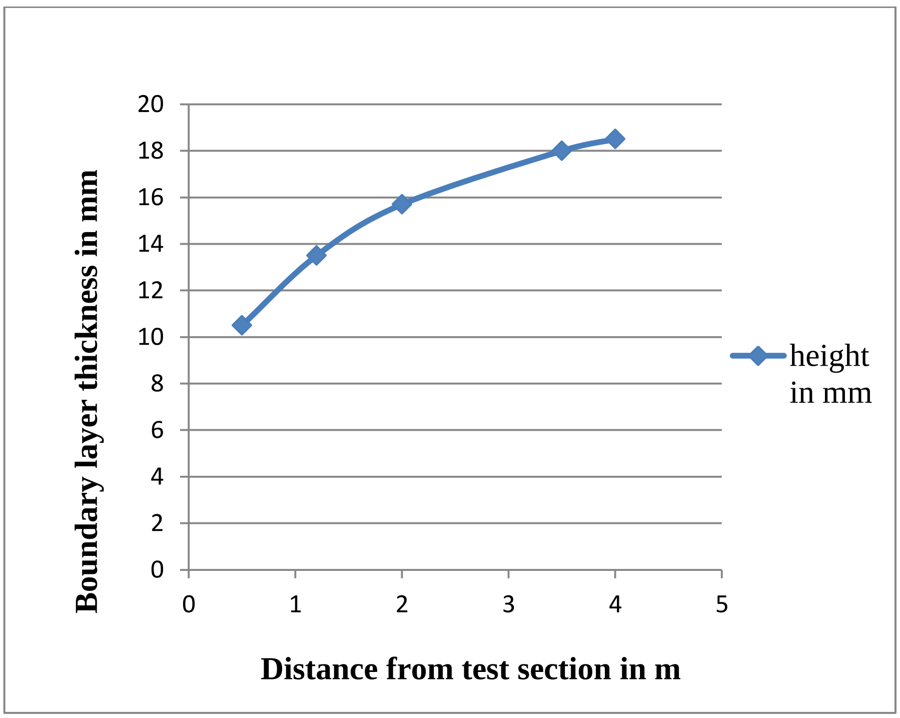


Graph 5.2.2.1variation of boundary layer thickness along the flow from the beginning of the test section when 30 cm spires are placed

5.2.3 VARIATION OF BOUNDARY LAYER THICKNESS ALONG THE FLOW FROM THE BEGINNING OF TEST SECTION IF SPIRE HEIGHT IS 40 cm

Distance from the test section in m	Boundary layer thickness in mm
0.5	10.5
1.2	13.5
2	15.7
3.5	18
4	18.5

Table 5.2.3.1: Variation of Boundary layer thickness along the flow with vertical spire height 40 cm

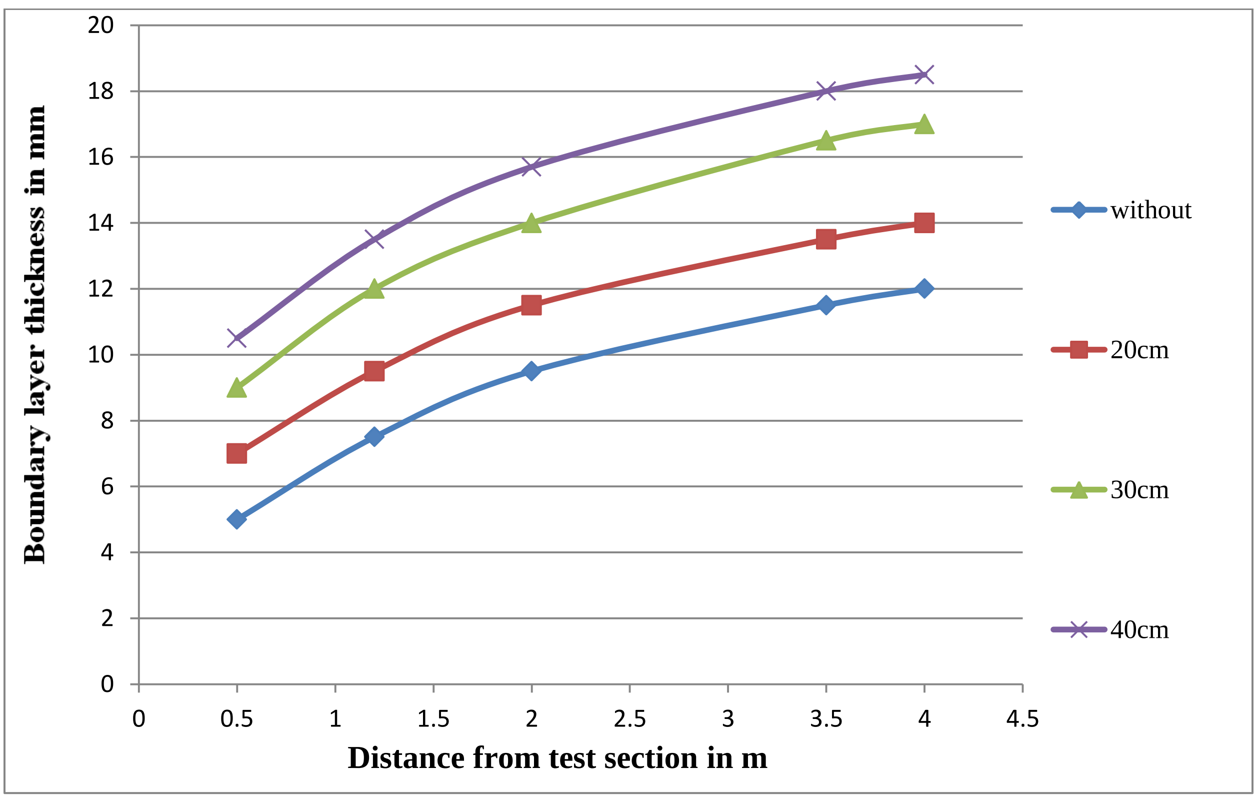


Graph 5.2.3.1: Variation of boundary layer thickness along the flow from the beginning of the test section when 40 cm spires are placed

5.2.4 COMPARISON OF BOUNDARY LAYER THICKNESS ALONG THE FLOW WITH DIFFERENT SIZE OF VERTICAL SPIRES AND WITHOUT SPIRES

Distance from the test section in m	Thickness without spires in mm	Thickness with 20 cm spires in mm	Thickness with 30 cm spires in mm	Thickness with 40 cm spires in mm
0.5	5	7	8	10.5
1.2	7.5	9.5	10	13.5
2	9.5	11	11.5	15.7
3.5	11.5	13	14	18
4	12	14	15	18.5

Table 5.2.4.1: Comparison of boundary layer thickness with and without spires

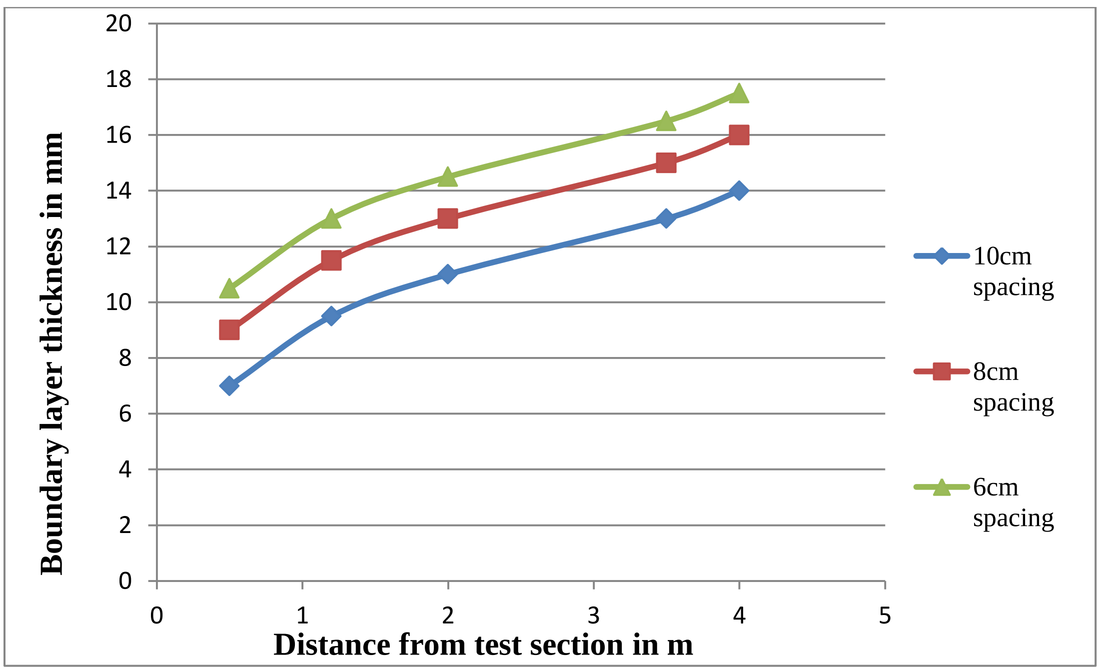


Graph 5.2.4.1: Comparison of boundary layer thickness with and without spires

5.2.5 VARIATION OF BOUNDARY LAYER THICKNESS OF 20 cm HEIGHT SPIRES IF SPACING BETWEEN SPIRES ARE CHANGED

Distance from test section in m	Thickness with10cm C/C spacing in mm	Thickness with8cm C/C spacing in mm	Thickness with6cm C/C spacing in mm
0.5	7	9	10.5
1.2	9.5	11.5	13
2	11	13	14.5
3.5	13	15	16.5
4	14	16	17.5

Table 5.2.5.1: Variation of boundary layer thickness of 20cm height spires if spacing is changed

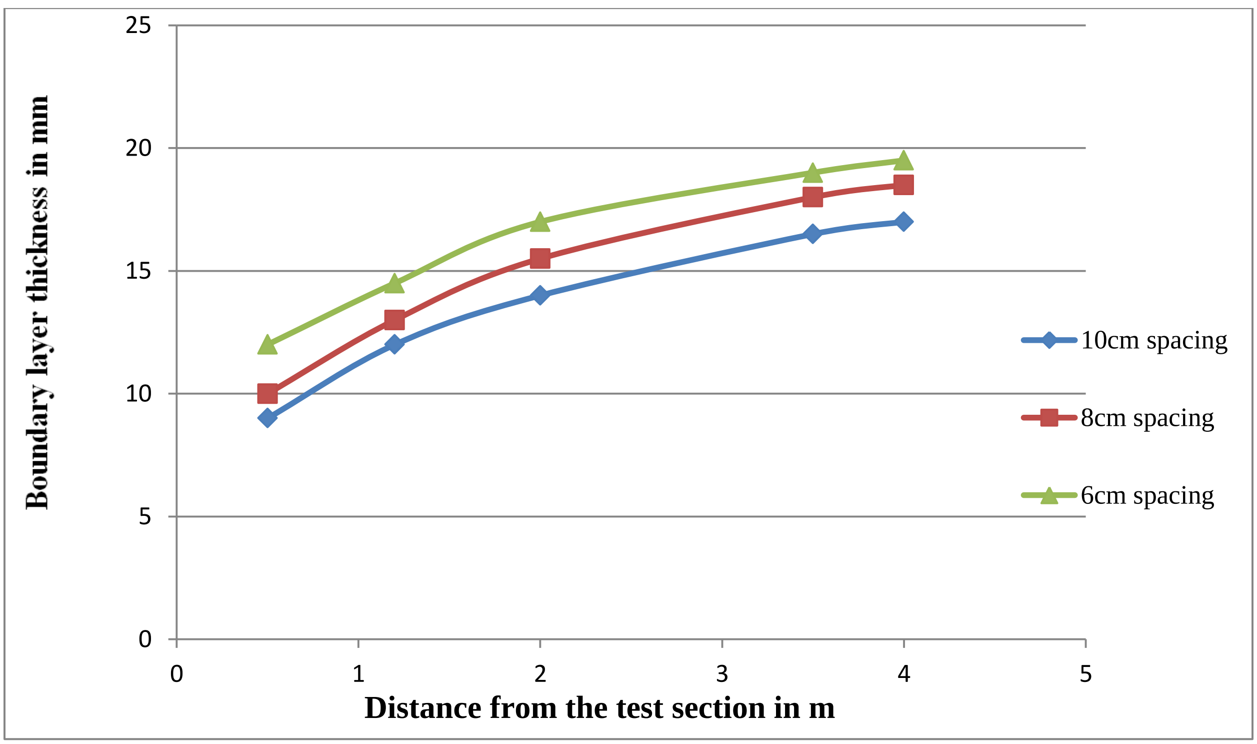


Graph 5.2.5.1: Variation of boundary layer thickness of 20cm height spires if spacing is changed

5.2.6VARIATION OF BOUNDARY LAYER THICKNESS OF 30 cm HEIGHT SPIRES IF SPACING BETWEEN SPIRES ARE CHANGED

Distance from test section in m	Thickness with10cm C/C spacing in mm	Thickness with8cm C/C spacing in mm	Thickness with6cm C/C spacing in mm
0.5	9	10	12
1.2	12	13	14.5
2	14	15.5	17
3.5	16.5	18	19
4	17	18.5	19.5

Table 5.2.6.1: Variation of boundary layer thickness of 30cm height spires if spacing is changed

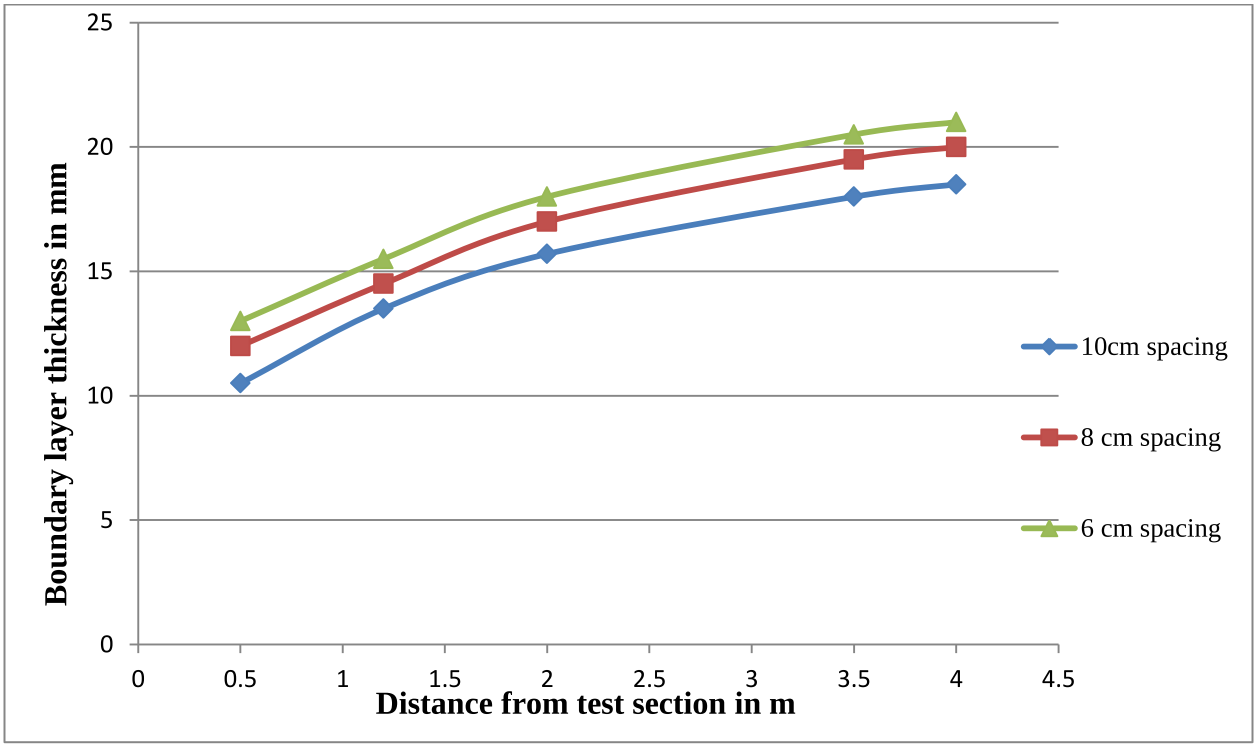


Graph 5.2.6.1: Variation of boundary layer thickness of 30cm height spires if spacing is changed

5.2.7 VARIATION OF BOUNDARY LAYER THICKNESS OF 40 cm HEIGHT SPIRES IF SPACING BETWEEN SPIRES ARE CHANGED

Distance from test section in m	Thickness with10cm C/C spacing in mm	Thickness with8cm C/C spacing in mm	Thickness with6cm C/C spacing in mm
0.5	10.5	12	13
1.2	13.5	14.5	15.5
2	15.7	17	18
3.5	18	19.5	20.5
4	18.5	20	21

Table 5.2.7.1: Variation of boundary layer thickness of 40cm height spires if spacing is changed



Graph 5.2.7.1: Variation of boundary layer thickness of 40cm height spires if spacing is changed

Chapter 6

RESULT AND DISCUSSION

RESULT AND DISCUSSION

1. From the above graphs and tables we can conclude that boundary layer thickness increases if objects like spires are used along the flow of air. Mainly this occurs due to the formation of vortex and turbulence.

2. It was observed that boundary layer thickness increases on increasing the height of spires within the cross section of wind tunnel. This is due to the change in the viscosity of the fluid.

3. Boundary layer thickness increases on decreasing the spacing between the spires.

4. From the graph it was observed that velocity along the flow decreases with increasing height of the spires and increasing the spacing between the spires

5. There is significant change in the velocity profile when spires of the different sizes are used in the wind tunnel. Velocity profile is closer towards the ordinate axis when the spires are used.

Chapter 7

CONCLUSION

7 CONCLUSION

1. The increase in growth of boundary layer was achieved by placing the vertical spires at the beginning of the working section.
2. The mean velocity profiles obtained through the simulation of the boundary layer designed for the wind tunnel showed good agreement with the results for the expected power law curve.
3. With increase in the height of spire the thickness of Boundary layer also increased.
4. The effective formation of vortex is less when the spacing between the spires is increased.
5. So the boundary layer thickness will be less as comparison to those spires where spacing is less.

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