Design and manufacturing of a setup for the testing and evaluation of a motor vehicle's front fog lamps simulating fog effects using a filter

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In Partial Fulfillment
of the Requirements for the Degree of
Bachelors of Mechanical Engineering

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by

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Titled: "Design and manufacturing of a setup for the testing and evaluation of a motor vehicle's front fog lamps simulating fog effects using a filter." be accepted in partial fulfillment of the requirements for the award of BS Mechanical Engineering degree.

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ABSTRACT

Basic purpose of the project is to design and manufacture a laboratory mounted set up for testing and evaluating the performances of different fog lamps in foggy conditions, and achieving simulation of fog by designing a filter that behaves similar to fog. Main requirements while performing our experiment were to make sure no external light interferes with our work. To counter external light a structure would be constructed and covered with nylon fabric that would not allow the entrance of external light. Under these conditions, two experiments would be performed. One of them was to check the performance of fog lamps in artificial fog produced by the artificial fog machine, by measuring the luminance of light and the scattering and attenuation of light through the fog with lux meter. Second one would be related to recreation of fog effects using a filter (jute net) and performing experiment one. Net would serve us the purpose of artificial fog because it would work as attenuating medium. It would pass and reflect light simultaneously in the same way as fog does. Data obtained by this would be compared with the artificial fog results and analyzed. In the end, conclusions would be drawn about the performances of light and recommended testing protocol would be given.

Key words: Fog, Fog Simulation, Fog Lamps, Artificial Fog machine, Jute net.

PREFACE

Fog has proven to be a menace for vehicle drivers. Due to considerable number of deaths, because of fog, a need arose to design a set up that would help the society in determining the optimum lights while countering fog. We were financed by Hella KGaA Hueck & co to find out from different perspectives (theoretical and practical) as to what fog lamps would be best to use while driving in foggy conditions. This report is about our efforts and energies that we have put towards our goal. We are indebted to our parent company for the support they have provided to us, be it lights, finance or their technical support

ACKNOWLEDGMENTS

To thank individually, we would like to start off with Hella KGaA Hueck & Co for sponsoring our endeavor and helping us out with technical queries. Furthermore, we would like to thank our faculty supervisors Dr. Samiur Rahman Shah, Col. Naveed Hassan and Dr. Emaduddin for their sheer dedication and unparalleled support towards the team and the project. Finally, the team working at the Manufacturing Resource Center (MRC) in SMME Mr. Faisal and Mr. Irfan deserves an honorary mention for their dedicated assistance in workshop related to our project. In the end, there is a special thanks to our seniors who helped us in different stages of our project and mentored us throughout.

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Simulation of fog and evaluation of fog lamps

ORIGINALITY REPORT

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ABBREVIATIONS

NHA National Highway Authority

SSD Stopping Sight Distance

MRC Manufacturing Resource Center

dMT Braking Distance

V Design Speed

dPRT Driver perception-reaction distance

SAE Society of Automotive Engineering

TI Thermal Imagers

IR Infrared

EU European Union

NOMENCLATURE

k	Extinction Coefficient
V_{met}	Meteorological Visibility distance
$L_s(o)$	Luminance of the object
$L_s(d)$	Luminance at a distance 'd'
$d_{braking}$	Distance covered to bring the car to a full stop
V	Velocity
a	acceleration

CHAPTER 1:INTRODUCTION

One of the major reasons of accidents in winter season is fog. Fog is a major reason of poor visibility on roads. To counter this danger and increase the visibility on roads in these conditions, a set up is required to design to find out which lamps are best to use in foggy conditions. When there is a 2.5 degree temperature difference between dew-point temperature and the ambient temperature, fog appears.

Following are the effects of fog that are taken into account

1) Attenuation of light as it propagates.
2) How the path of light changes when it comes into contact with fog particles.

Fog of any type can be characterized using these two parameters. Taking into consideration these two effects, and the data we gathered from Pakistan meteorological department, we managed to produce the fog dominant in Pakistan.

Our laboratory set up would consist of a skeletal frame of steel pipes or some other suitable material, covered with fabric in such a way that no light enters or leave the skeletal frame. One unique thing about our structure is it will be made in such a way to operate easily in a laboratory. Using this setup, attenuation of light will be observed. Furthermore, we have selected jute net material to replicate the effects of attenuation and reflection of fog. For the measurement of light intensity, lux meter is used. Various fog lights will be tested under artificial fog conditions to determine which fog lamps perform better under fog conditions and the optimum height at which fog lamps perform better will also be determined. Frontal fog lamps are a popular option for driving in fog conditions and hence to improve them is our basic need to reduce accidents (Flannagan)

CHAPTER 2: LITERATURE REVIEW

This chapter of literature review covers the topics we had to study, the mathematical model and the concepts and research papers that laid the basis of our design and the methodology of our project.

2.1 Introduction to fog:

In order to have the knowhow of fog lamps performance, knowledge of interaction between fog and light particles is very necessary. Several journals and research papers were studied. Most of our time was spent on literature review through which we were able to learn how to replicate fog and how to characterize it.

2.2 Fog:

Fog is regarded as a phenomenon through which visibility of sight reduces to less then 1000 meters. (Yasmeen)

Fog formation can occur in two ways. First, the air is cooled to the dew point which leads to the formation of **fog** droplets. When the sun rises, the air and ground warm up. This leads to the air temperature being warmer than the dew point temperature, which **causes** the **fog** droplets to evaporate. (Editor)

Different types of fogs are present throughout the world. Some of them are:

1) Radiation fog
2) Ice fog
3) Advection fog
4) Steam fog
5) Industrial fog

Let us shed some light on the most prevailing types of fog

2.2.1 Advection fog:

Whenever moist air crosses a cool surface, temperature of the lower air falls below dew temperature and fog formation occurs. This type of fog is known as advection fog. (Service)

2.2.2 Radiation fog:

When long waves radiations are emitted by ground, it cools the surface. This phenomenon inverts the temperature. Moist air temperature reduces to below dew point and radiation fog produces. (Service)

2.3 Favourable conditions for fog:

Favourable conditions for the development of fog are

- Light wind
- Clear sky
- High moisture
- Lack of turbulence

Soil conditions also play an important role over the formation of fog eg: soil moisture, vegetation cover. (Yasmeen)

Environmental conditions required are:

- High polluted areas

They are also an important factor in the formation of fog, as they result in various reactions, producing different pollutants that lead to fog production.

2.4 Timeline of Fog in Pakistan:

November to February are considered as the most fog effected months in pakistan. We have made Punjab as the focal point of our fog testing due to its plainer areas. Fog occurs in Punjab in 2 phases: from November to December and then in the month of February. It can also be seen in other months, but it might not be that dense and it will not be concentrated. (Yasmeen)

Time line of fog is shown in image below:

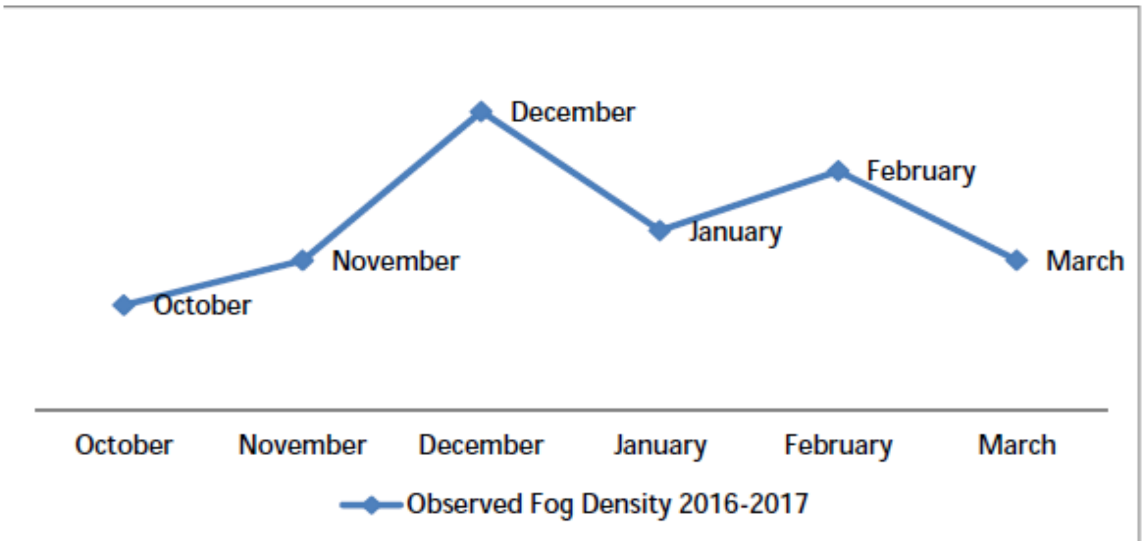

Figure 1 (Timeline of Fog in Pakistan)

This time line is valid for the year 2017

2.5 Replicating fog effects in laboratory:

In order to reproduce fog in laboratory settings, it is imperative to know on what factors it depends.

As we are well familiar that formation of fog depends on surface conditions. All the surface conditions were perfected in such a way to make sure that they give us the same results as that of real fog. Initially, we did two experiments. Major effect fog has is the reduction of visibility. The international definition of fog is less than a thousand km. We used an artificial fog machine to produce fog and in our first experiment we used charts to block the passage of light. For our 2nd experiment a tunnel covered with jute net will be used. Fog has implications for sensors such as Thermal Imagers (TI/FLIR) operating in the far-IR at wavelengths of about 10 μm which are better able to penetrate haze and some smokes because their particle size is smaller than the wavelength; the IR radiation is therefore not significantly deflected or absorbed by the particles. A visibility reduction is probably the most apparent symptom of air pollution. Visibility degradation is caused by the absorption and scattering of light by particles and gases in the atmosphere. Absorption of electromagnetic radiation by gases and particles is sometimes the cause of discolorations in the atmosphere but usually does not contribute very significantly to visibility degradation. Scattering by particulates impairs visibility much more readily. Visibility is reduced by significant scattering from particles between an observer and a distant object. The particles scatter light from the sun and the rest of the sky through the line of sight of the observer, thereby decreasing the contrast between the object and the background sky.

2.6 Visibility criteria:

Visibility for a very small source of light is referred as point source. It reflects a complex interaction of many factors that includes size and luminance of the source, the luminance of the ambient back ground (Goettl). A small particle of spectrum sandwiched between ultraviolet and infrared radiations is light (Ryer)

The main parameter that characterizes fog is visibility. The meteorological visibility distance $Vmet$ is one such factor and it depends upon the density of the fog. As it is defined earlier that any meteorological phenomenon that reduces visibility below 1000 meters is fog. So $Vmet < 1000\ m$. But it was studied that for dense fog conditions the visibility range decreases and thi distance is reduced further to $Vmet < 400\ m$.

2.7 A balance between safety, mobility and environmental considerations:

Furthermore, for the design of tunnel and how the person should be able to stop the car within safe distance speed limits were also studied. A speed limit is based on both safety and mobility considerations and increasingly also on environmental considerations. The general framework for speed limits is the responsibility of the national government. Generally, local and regional road authorities determine the speed limit on a road. The current general speed limits vary across EU Member States. Also, the application of variable speed limits related to traffic and weather conditions vary across EU Member States

Safety is only one element that affects what speed limit is applied. Also the effects on travel time, mobility must be considered. Setting limits aims to meet the optimum total cost by balancing safety and mobility consequences. There may be a different optimum for different roads depending on their accident rate and their function for mobility. What the optimum is, is largely determined by the method and assumptions that are applied to calculate the costs of road accidents and mobility loss, and increasingly also the costs of air pollution and noise. This, in the end, is a political decision. Assessment frameworks have been proposed to support these decisions. Some administrations are now proposing that the "balance" between safety and mobility should be judged from a more ethical standpoint. This requires that an upper limit is put on the injury risk that could occur on the road (e.g. virtually eliminating the chance of a fatality occurring). The speed limit and the design of the road infrastructure would then be matched to ensure that the injury risk was not exceeded. (Commision)

2.8 Thickness of Fog:

There is a great variance in the thickness of fog during the foggy weather. Sometimes the fog is less dense and the visibility distance is greater and sometimes the fog is dense and the visibility distance is very small. So in our project we are going to consider the thickness of fog. And artificial fog will be produced by the artificial fog machine using different concentrations of glycol and fog will be simulated using different mediums. For less dense fog and dense fog we are going to use different mediums as simulating medium of fog.

2.9 Mathematical Model:

Our Mathematical model is based on the Beer Lambert extinction model which is based on the absorbance, transmittance and attenuation of light through a medium. Here in our project the medium is fog through which the incoming light from the fog lamps propagates

The meteorological visibility distance $Vmet$ is a convenient unit and is related to the extinction coefficient k: (Romain Gallen)

$$Vmet = 3/k \qquad (1)$$

Visibility in fog depends upon many factors. One such is the extinction coefficient, which describes how visibility decreases in fog conditions. We can calculate the extinction coefficient using Beer-Lambert extinction model, (Romain Gallen)

$$L(d) = Ls(0)e^{-kd} \qquad (2)$$

Here $Ls(0)$ is the luminance of the object, k is the extinction coefficient, d the observation distance.

For better approximation, we can use two light sources which will give the estimated value of k as:

$$k = \frac{\ln\left(\frac{LiLj\,(0)}{Lj\,Li(0)}\right)}{dj - di}$$

Since both the light sources are the same

$$Li(0) = Lj\,(0)$$

$$\Rightarrow k = \frac{ln\,(Li/Lj\,)}{dj - di} \quad (3)$$

The extinction coefficient and the meteorological visibility distance can be calculated from the application of Beer Lambert principle on a Transmissiometer. A transmissiometer is an instrument that contains two parts. A transmission unit and a receiver unit. The transmission unit contains a light source which throws a beam of light towards the receiver. This beam of light is straightened using a convex lens on its way to the receiver. Whereas the receiver unit contains a photodetector and another convex lens for converging the incoming beam of light from the transmitter unit to the photodetector. Then the unknowns i.e the extinction coefficient and the visibility distance can be found from the application of the Beer Lambert equation.

The quantities like visibility and extinction coefficient are to be calculated using the formulae from eq (1),(2) and(3):

Table 1 (Fog Parameters and their calculation for a single Light source)

Quantity	*Relation Used*
Visibility (Vmet)	$Vmet = 3/k$
Extinction Coefficient (k)	$Ls(d) = Ls(0)e^{-kd}$

Table 2 (Fog parameters and their calculations for two Light sources)

Quantity	*Relation Used*
Visibility (Vmet)	$Vmet = 3/k$
Extinction Coefficient (k)	$k = \frac{ln\,(Li/Lj)}{dj - di}$

The Back reflectance is caused by the fog because fog is an opaque object so it reflects back the light coming from the headlights and the fog lamps. This back reflectance can affect the visibility on the road and can cause problems for the driver. This back reflectance can be measured by using a Lux meter. And thus this value must be taken into consideration while manufacturing fog lamps of a car.

It sums up the literature review

CHAPTER 3: METHODOLOGY

The project is divided into 2 sections. In the first section, design and manufacturing of a tunnel. And in the second section experimentation is done

3.1 Design calculations of light tunnel:

The first step was to determine the dimensions of the tunnel to be manufactured and since our objective was to design a laboratory mounted setup so we have to make sure the tunnel is not so large and can be incorporated in a laboratory easily.

As our objective is to evaluate the performance of fog lamps, so its width was taken to be 3m so a car can be placed inside easily with some room besides for the surroundings. Also the height was taken to be 1.5m which is just above the average height of a car and the length of the tunnel was taken to be 4 m so that a car would be placed inside and there would be room for fog to be scattered ahead of it for the evaluation of fog lamps

Parametric Analysis:

The parameters for the design of light tunnel are then:

Table 3 (Tunnel sizing parameters)

Parameter	*Dimension*
Tunnel length	*4m*
Tunnel width	*3m*
Tunnel height	*1.5m*

3.2 Material of tunnel:

We have to select the material of the tunnel keeping in mind the cost and strength of the material.After several visit to the market,and through search from the internet we have decided to select mild steel.PVC was another choice for the material but we decided to neglect this choice because it wasn’t as strong as mild steel.

3.3 Structure of Tunnel:

Our tunnel will have a skeletal frame structure. This structure will be covered with a nylon fabric to make sure no external light affect our experiment.

The solidworks model of our tunnel is given in the figure (Flannagan)

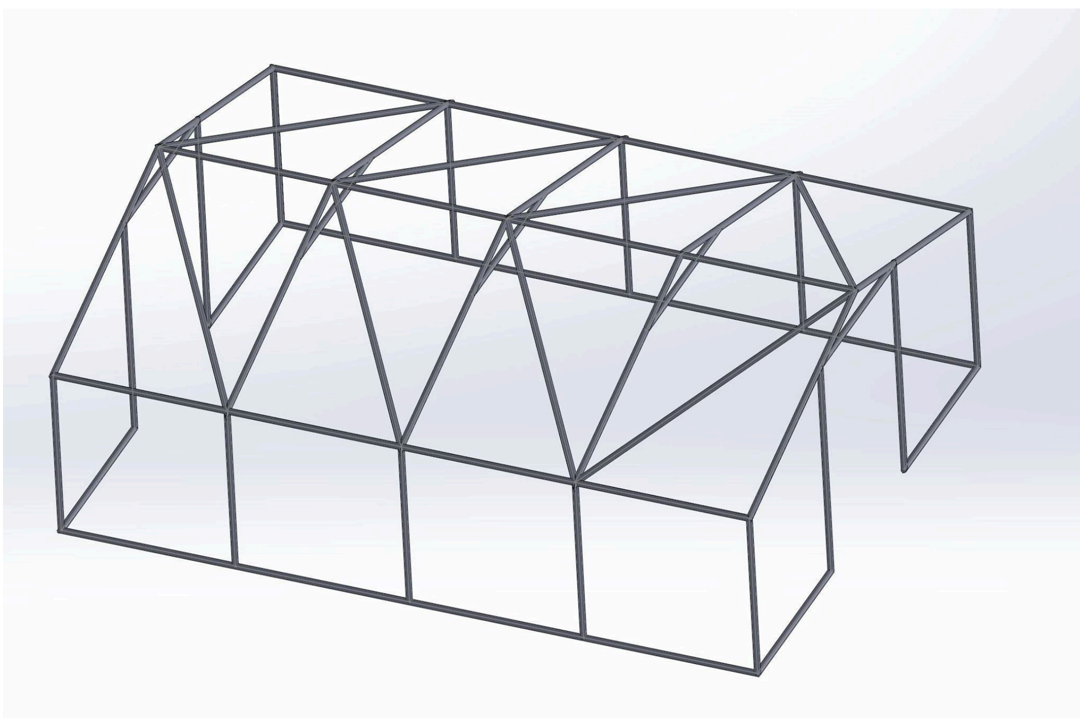

Figure 2 (CAD model of the tunnel)

The tunnel will be grounded to the pavement by tying it to iron rods hammered into the pavement, which increased its stability considerably.

Figure 3 (Tunnel)

3.4 FEM Analysis:

A FEM Analysis was done on the tunnel on Solidworks before manufacturing to make sure whether it is sustainable or not.

3.4.1 Vertical Displacement:

A uniformly distributed load 744.8N was exerted on the tunnel throughout and the displacement was found to be negligible as can be seen from the figure

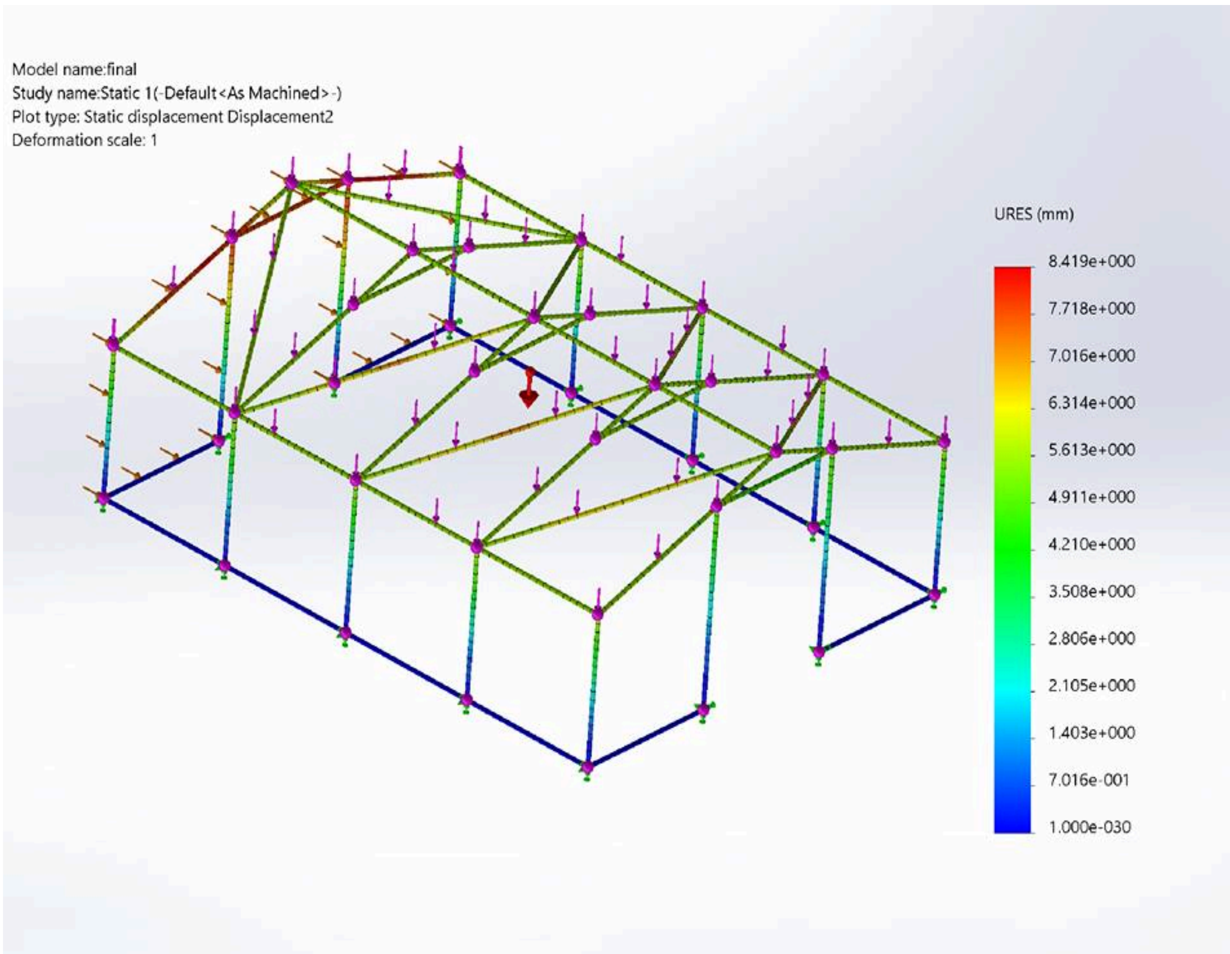

Figure 4 (FEM Analysis displacement)

3.4.2 z-Displacement:

Also the force due to aerodynamic drag was exerted on the sides of the tunnel to incorporate the effects of Aerodynamic drag due to the average wind velocity of Islamabad that is 10 m/s (weatherspark). And the displacement in the z direction due to this drag was also found to be negligible as can be seen from the figure

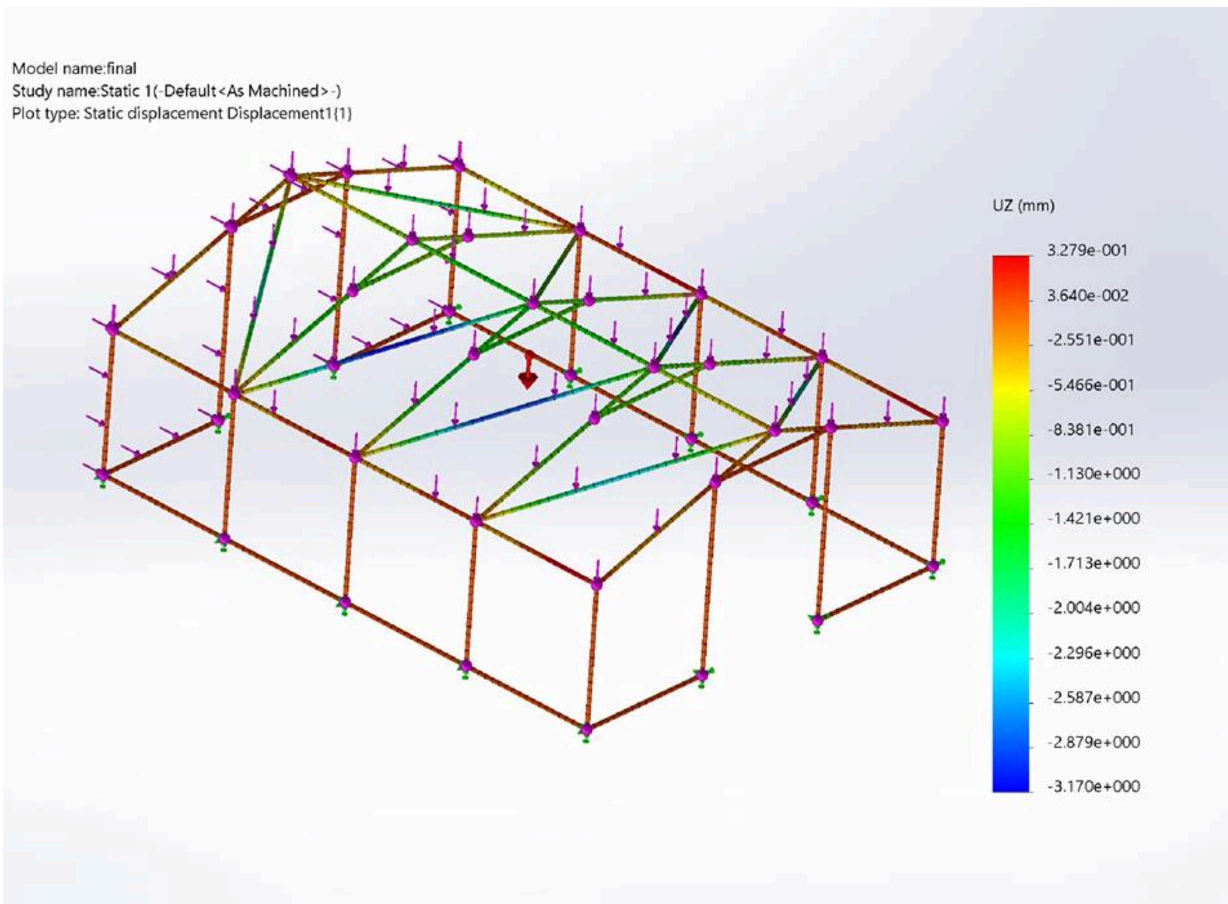

Figure 5 (FEM Analysis z displacement)

3.4.3 Factor of Safety:

The minimum factor of safety due to all the applied loads was in safe range and as can be seen from the figure the minimum factor of safety of our design was 2.47 which means all the loads are under the fracture stress and hence our design was good to go towards the manufacturing stage

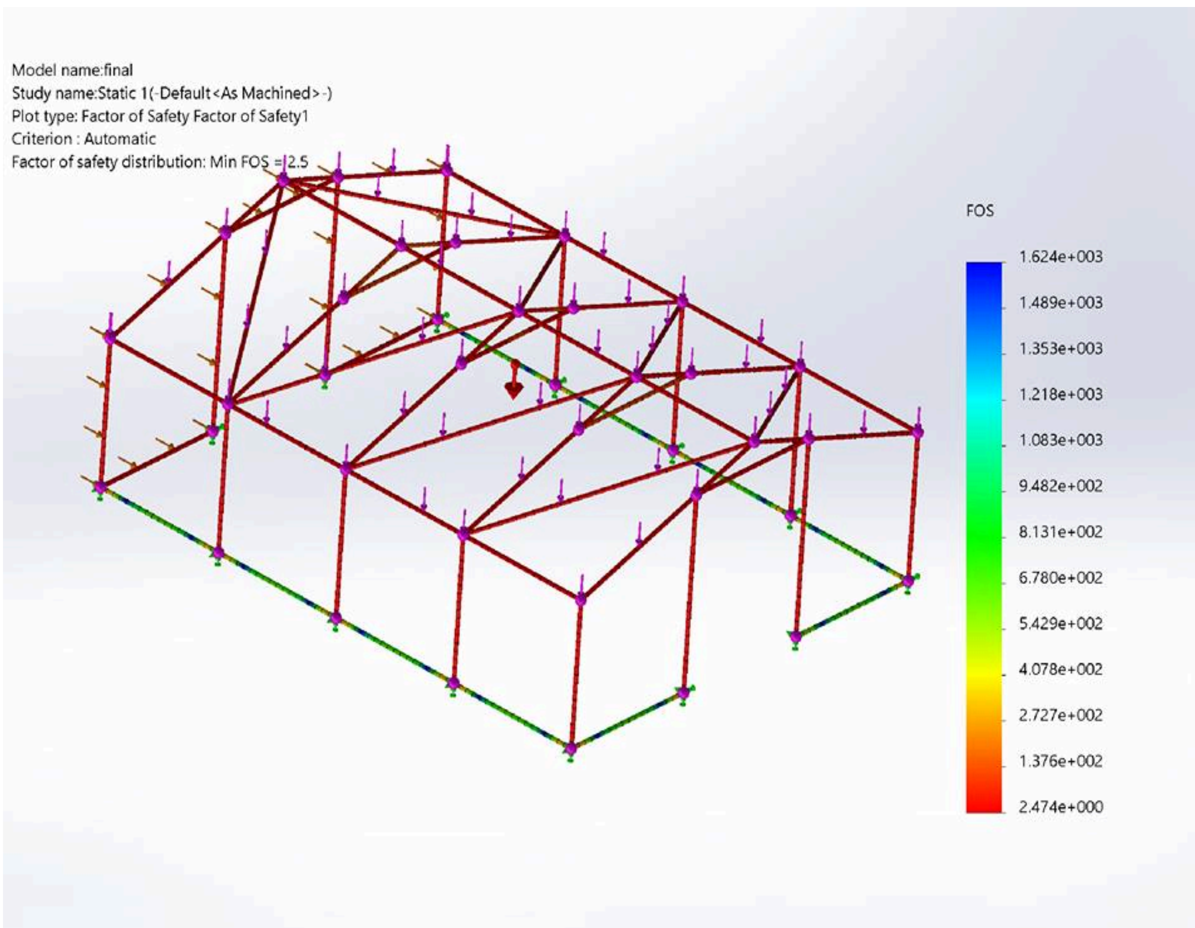

Figure 6 (FEM Analysis Factor of safety)

3.5 Nylon Fabric Cover:

A cover was made from Nylon to cover the tunnel to make sure no external light enters the tunnel during experimentation so that fog lamps can be evaluated without any errors.

Figure 7 (Tunnel covered with Nylon fabric)

3.6 Fog Machine:

The Second part of the project is the production of fog and manufacturing of light fixture on which different for lights are to be mounted.Fog machine was provided from SMME lab. A solution of Glycerin and water will be used in this machine to produce fog of sufficient density.

Figure 8(Artificial Fog Machine)

3.7 Badminton Net:

Badminton net was used as a possible medium to replicate fog effects. A Badminton net made up of nylon was used first with the intent of simulating fog and results were noted. However the results weren't satisfying which allowed us to pursue further options in search of amedium capable of simulating fog.

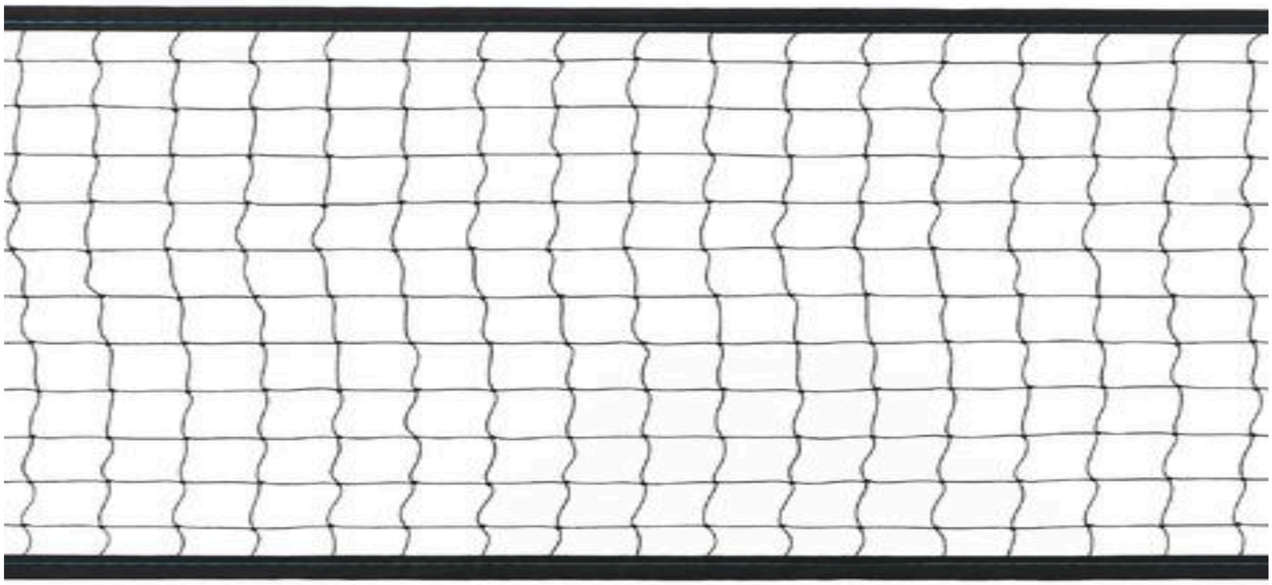

Figure 9 (Badminton Net)

3.8 Jute rope net:

For recreating and replicating effects of fog, Jute net was used. Results of attenuation and scattering of light were determined from lux meter and were compared with the results of attenuation and scattering by using fog machine.Furthermore jute net rope was recommended by hella and pakistan meteorological department to test different fog lights. Jute net was used to recreate the scattering effects of fog because physical obstacles scatter light and does not let it to be transmitted.

Moreover in order to consider the varaince in the thickness of fog we used two different kinds of jute net. One with smaller spacing for simulating dense fog and one with a larger spacing for simulating less dense fog

Figure 10 (Jute net with less spacing)

And jute net with large spacing with larger visibility distance was used to simulate less dense fog.

Figure 11 (Jute net with large spacing)

3.9 Lux meter:

Parameters like visibility, fog attenuation measurements and extinction coefficients will be measured using lux meter. When light encounters a surface, it can either reflected away or refracted through to material beneath. This process attenuates it intensity. (Ryer)

And it can be measured by lux meter. A lux meter is a photodetector that not only detects light but also measures the luminance of light. It has two parts. One is a light sensor and the other one is a digital meter that measures the luminance. It has different ranges and it can be calibrated by selecting its range by pressing the range button. Aim the light directly at its light sensor to measure the luminance and press the hold button to freeze the reading for ease of measurement during experiment.

Figure 12 (Lux meter)

3.10 Light Fixture:

A light fixture was also made so that the fog lamps can be clamped on it for experimentation. It is made with an adjustable height so experiment was performed at different heights and the height at which the fog lamps gave the optimum results will be used for the rest of experimentation. The height from the ground that gave the eoptimum results was found out to be 57cm. And all the experiments were performed at this height. Moreovert the light fixture consist of a swithchboard that takes power from a battery and delivers power to the fog lamps.

Figure 13 (Light fixture)

3.11 Experiment 1:

Fog machine will be used in this experiment to create fog in the tunnel. The purpose of this experiment is to observe the beam patterns of different fog lights and determine the best fog light that gives the best visibility and vision for the driver in Fog conditions. Furthermore the aim of the experiment is also to determine at what height the fog lights should be installed to ensure the maximum visibility for the driver. It can be determined by placing lights at different height each time and analyzing the beam patterns on the grid and attenuation of light from lux meter. Using data from the grid, Isolux diagrams can be plotted using a surface-fitting method, where luminance (measured in lux)will be plotted as a function of space(x,y) coordinates. The height at which the scattering and attenuation of light beam is minimum will be the most appropriate height for Fog lights in Automobiles. It is of utmost importance that vehicle light system be aimed properly to fetch the maximum efficiency. Poorly aimed light not only annoy traffic but also cause accidents. (VISUAL HEADLIGHT AIMING PROCEDURE)
Moreover the results of this experiment will act as a standard for the second experiment in which we will recreate the fog effects using a filter

3.12 Experiment 2:

In this experiment,badminton net,Jute net and other net materials will be used to replicate the effect of fog in light beam. But the properties of Jute resembles most with the fog (Arfin Jahan 1) so we are going to use it as our replicating medium. (Placeholder1)
When light comes in contact with the jute net, some of it will be reflected and refracted.This will allow the scattering and attenuation of light which will again be measured from the beam patterns in the grid and lux meter readings.The purpose of this experiment is to determine the best material for the rope that could give similar scattering of light beam and attenuation as with the fog machine.

In the end the results of this experiment will be compared with the results of the first and it is expected that the jute net results should approximate the results of artificial fog as the optical properties of jute resembles to fog.

CHAPTER 4: RESULTS AND DISCUSSIONS

t was studied that the visibility distance increases with luminance. So in order to verify that we have conducted a series of experiments on different fog lamps including the Hella Incaandescent and the Hella LED 24V on both the artificial fog and the potential mediums for simulating fogs including Jute net and badminton net but Jute net gives the most closest results as that of fog. And from the results we reached the conclusion that jute net is the best medium to replicate fog effects. A graph was plotted between meteorological visibility distance and luminance to verify the inference. And the trend of graph was the same as in the research paper. (Romain Gallen)

4.1 Artificial Fog Results:

The first experiment was conducted on artificial fog generated using an artificial fog machine using a solution of glycol and water. Thickness of fog was varied using different concentrations of glycol to achieve varying visibility distance and different values of luminance were recorded using lux meter. Different Fog lamps were tested and the results were plotted

4.1.1 Hella LED:

Hella LED 24V gave different values of luminance as the thickness of fog was varied and the following trend was achieved between meteorological visibility distance and the luminance

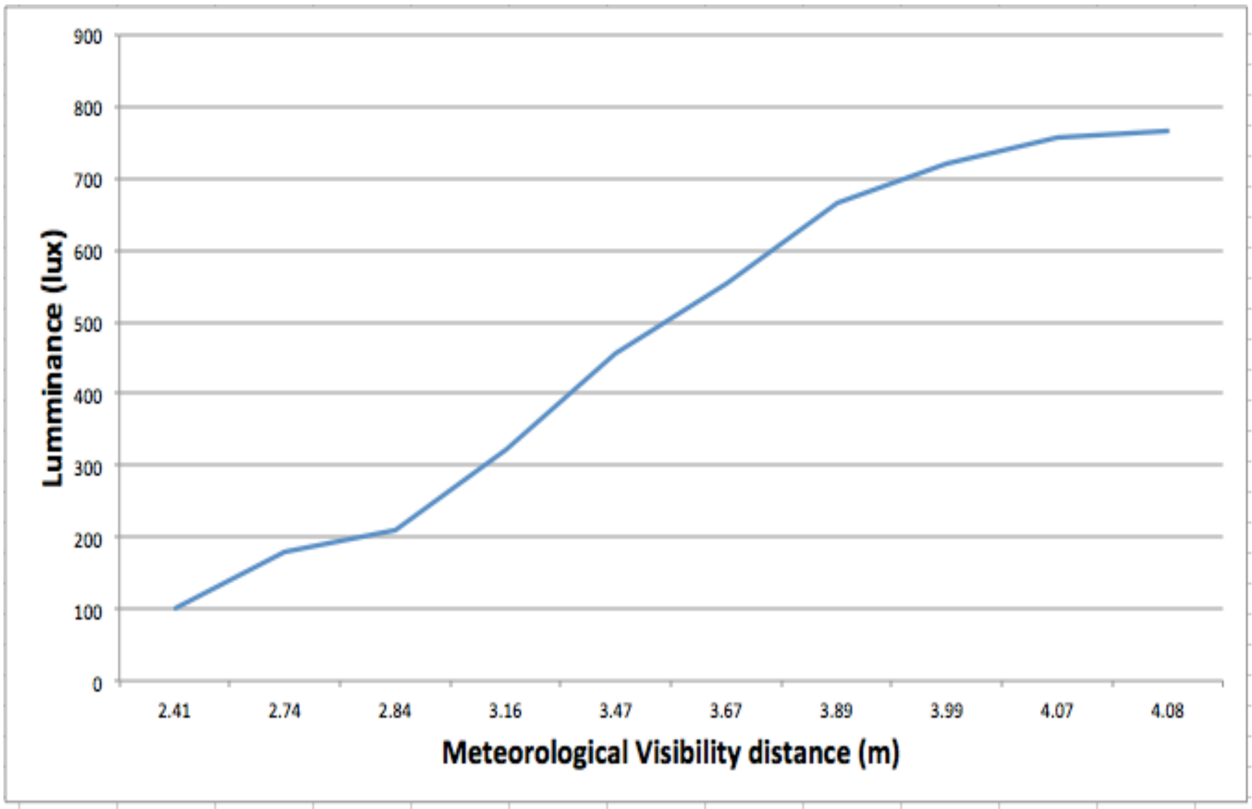

Figure 14 (Hella LED on Artificial Fog)

4.1.2 Hella Incandescent:

Similarly Hella Incandescent gave different values of luminance as the thickness of fog was varied and the following trend was achieved between meteorological visibility distance and the luminance

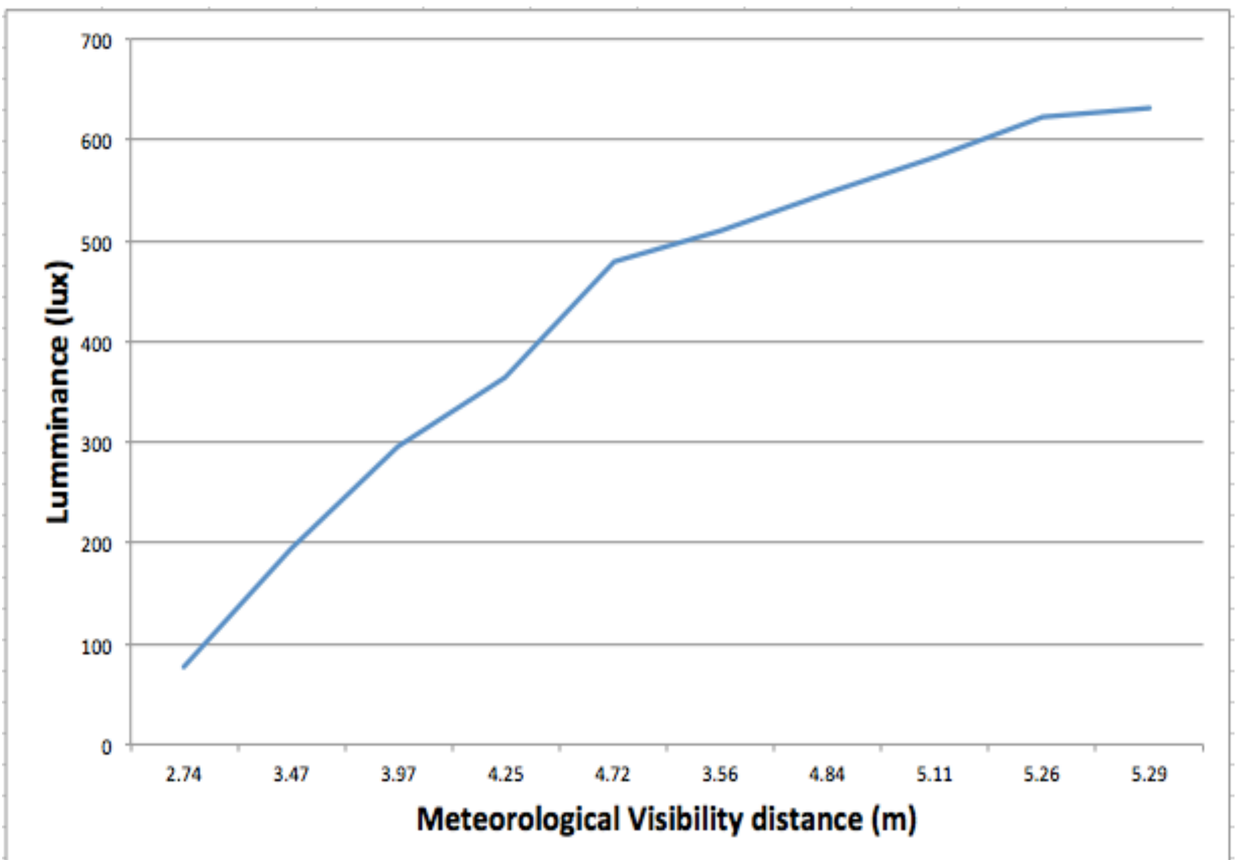

Figure 15 (Hella Incandescent on Artificial Fog)

4.2 Badminton net results:

Before performing our experiment we performed a rough experiment on badminton net just to check whether it can be used as a replicating medium for fog or not. In this experiment Badminton net was placed in front of Hella LED 24V and lux meter was used to measure the readings of luminance and the results were plotted on matlab. But as seen in the graph the results don't follow the trend of the graph in the research paper. So it eliminated our hypothesis to use badminton net as a simulating medium for fog.

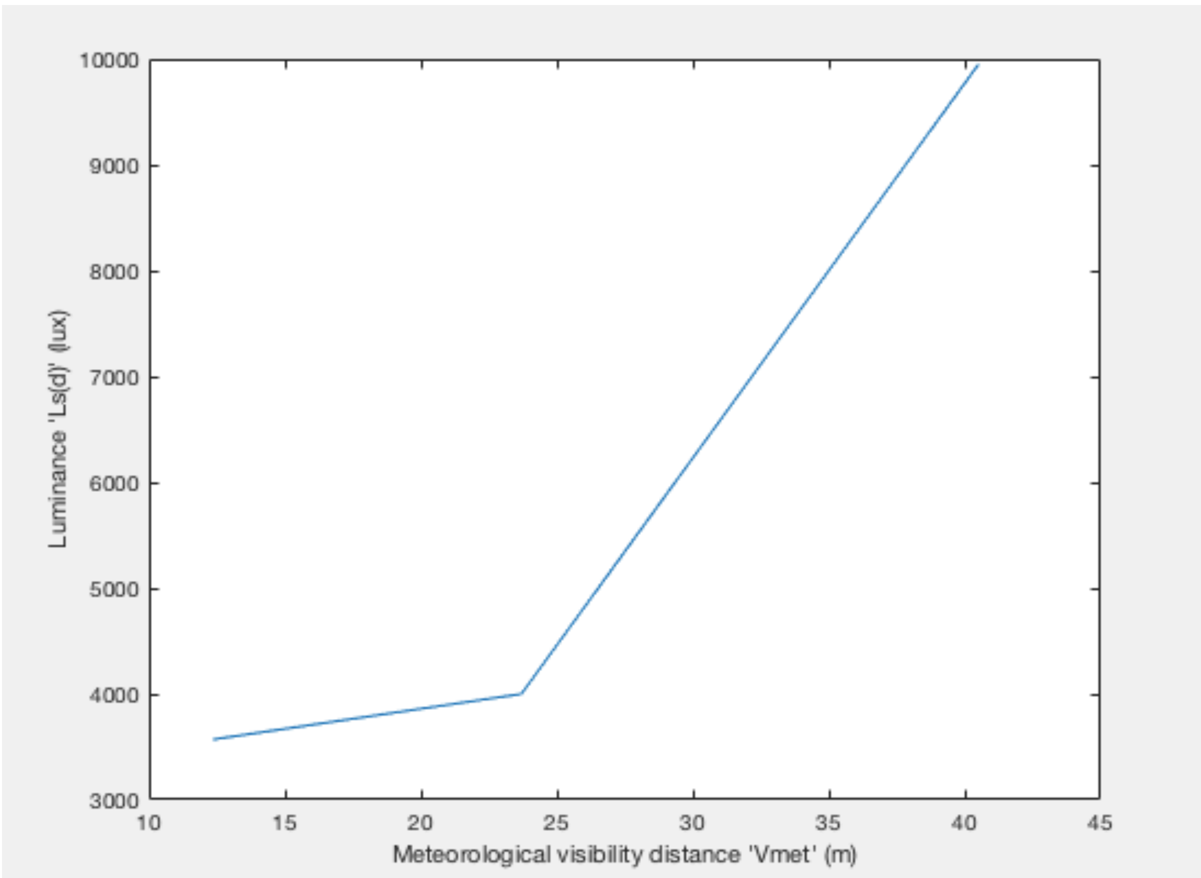

Figure 16 (Hella LED on badminton net)

4.3 Jute Net Results:

Similarly the same experiment was performed on jute net and the thickness of jute net was varied using two different kinds of jute nets. One with a large spacing and one with a small spacing. And different layers of the net was used to vary thickness of the simulated fog.

4.3.1 Hella LED:

Hella LED 24V gave different values of luminance as the thickness of fog was varied and the following trend was achieved between meteorological visibility distance and the luminance

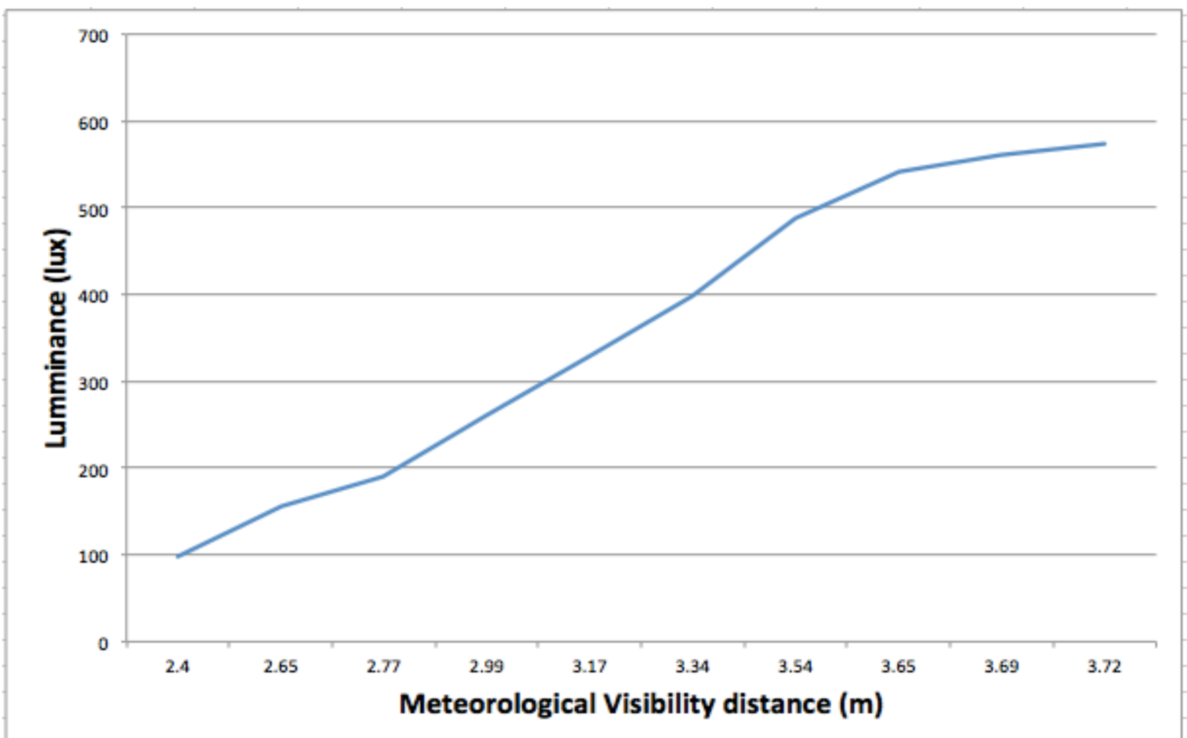

Figure 17 (Hella LED on Jute Net)

4.3.2 Hella Incandescent:

Similarly Hella Incandescent gave different values of luminance as the thickness of fog was varied and the following trend was achieved between meteorological visibility distance and the luminance

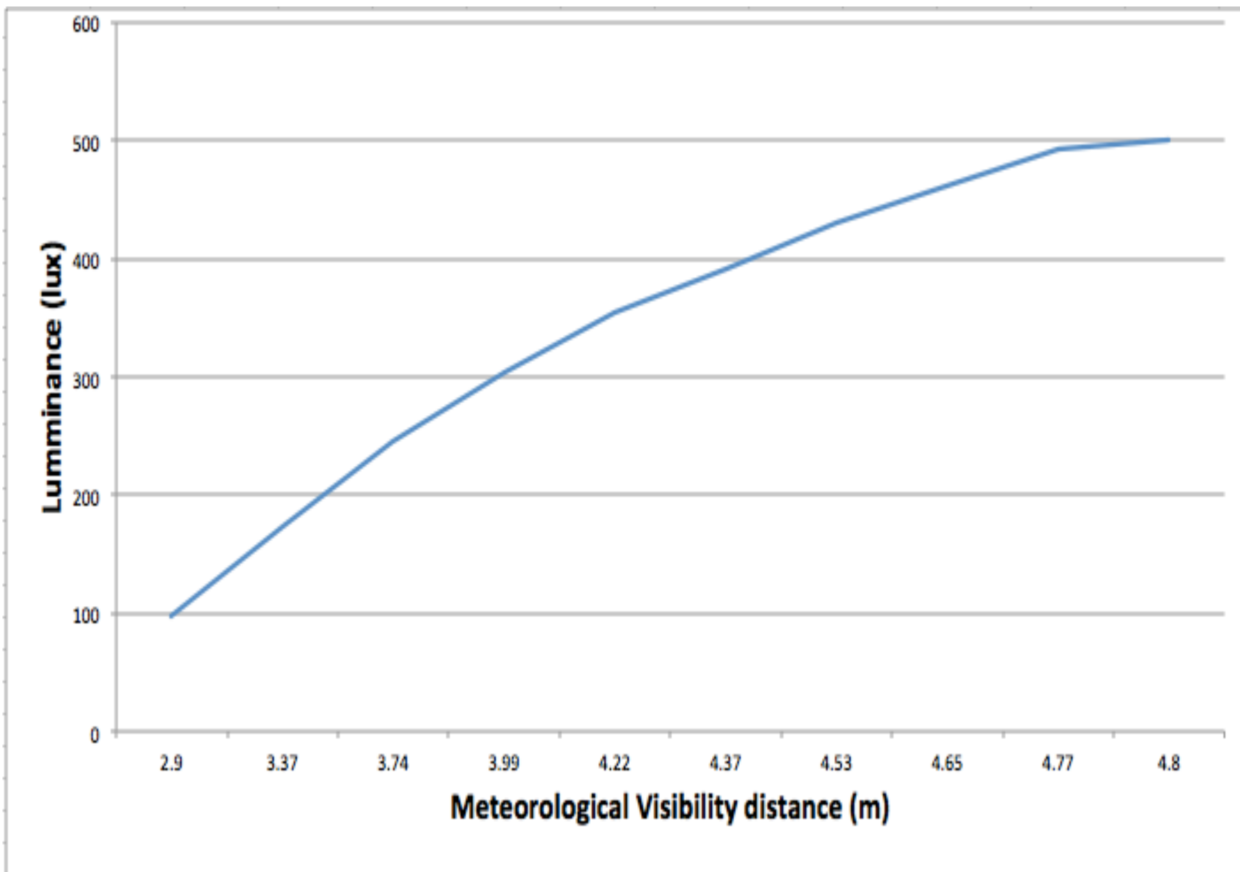

Figure 18 (Hella Incandescent on Jute Net)

4.4 Comparison between Artificial fog and Jute Net:

From the above results it was concluded that both the jute net and artificial fog gave almost similar results with 10-15 percentage difference which occurred due to random errors and personal errors during experimentation. However the trend of the graph between luminance and the visibility distance was the same as can be seen in the graphs

4.4.1 Hella Incandescent:

The similarity can be seen in the graphs, which shows that jute net is a good medium to simulate fog.

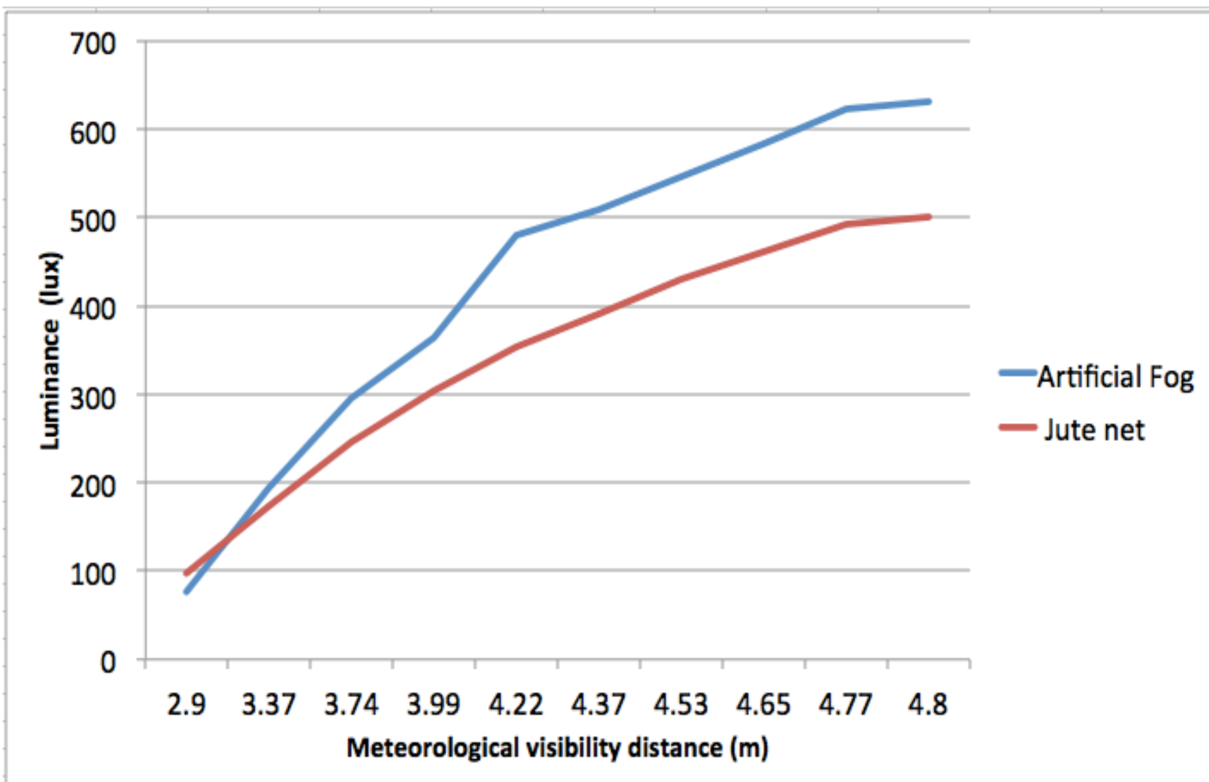

Figure 19 (Artificial Fog and Jute net Comparison on Hella Incandescent)

4.4.2 Hella LED:

Similarly Hella LED 24V gave approximately similar results on both artificial fog and jute net as seen in the graphs.

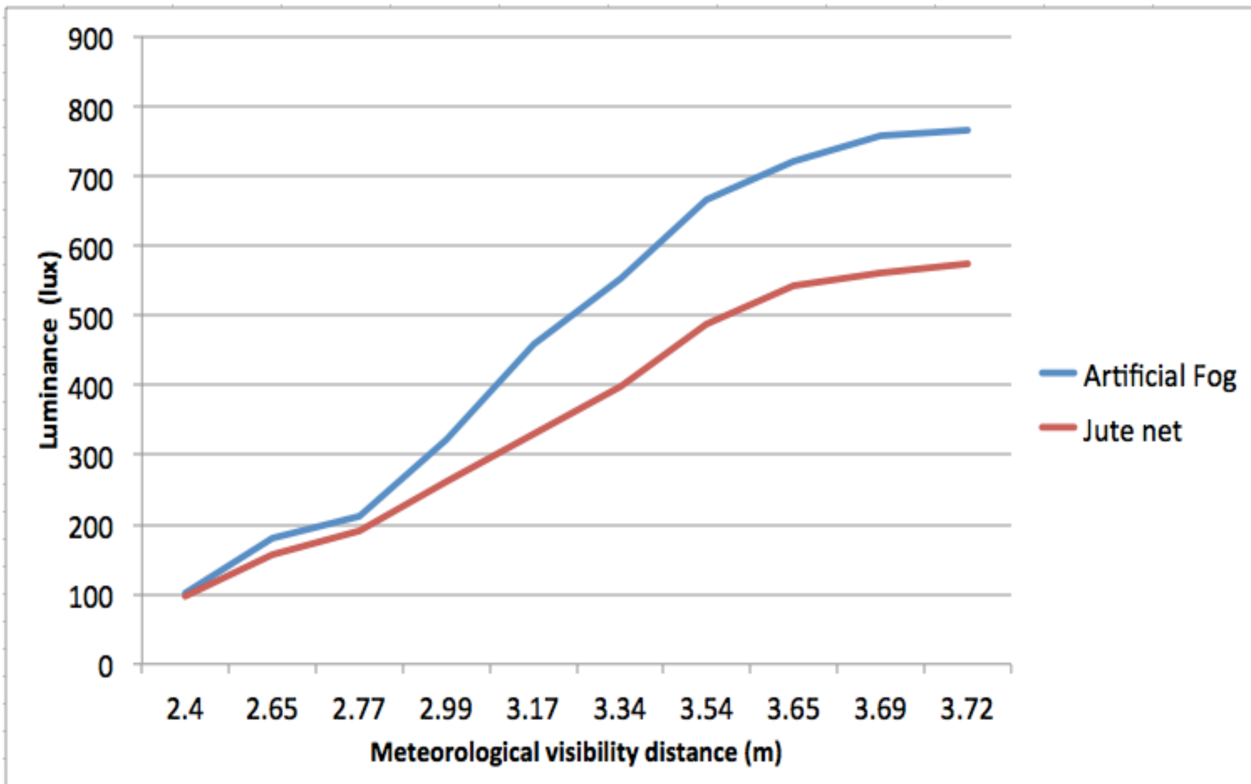

Figure 20 (Artificial Fog and Jute net comparison on Hella LED)

4.5 Fog Lamps Comaparison:

From the above graphs we can evaluate the performance of fog lamps and it can be clearly seen that Hella LED 24V gives better visibility in fog than the Hella Incandescent fog lamp.

4.5.1 Artificial Fog:

Hella LED gives better results on artificial fog than Hella Incandescent

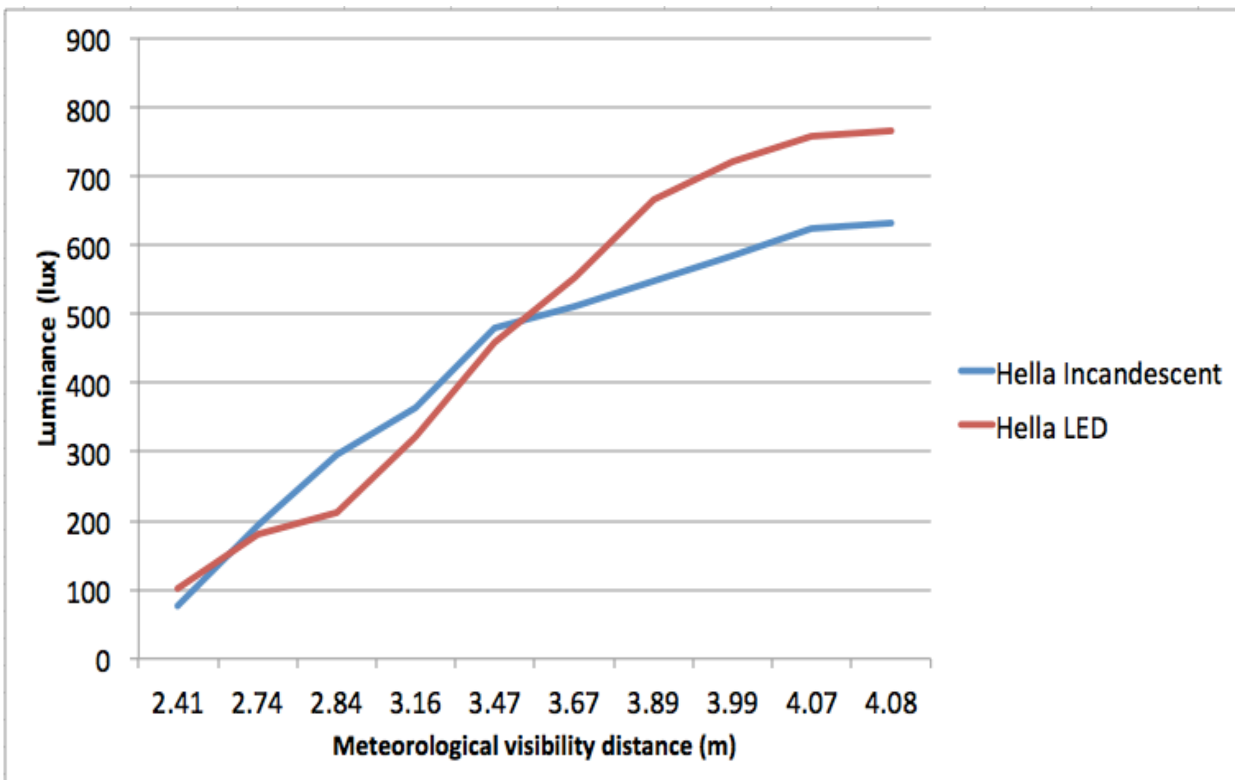

Figure 21 (Fog Lamps comparison on Artificial Fog)

4.5.2 Jute Net:

Similarly Hella LED 24V gave the better performance under simulated fog conditions (weatherspark)

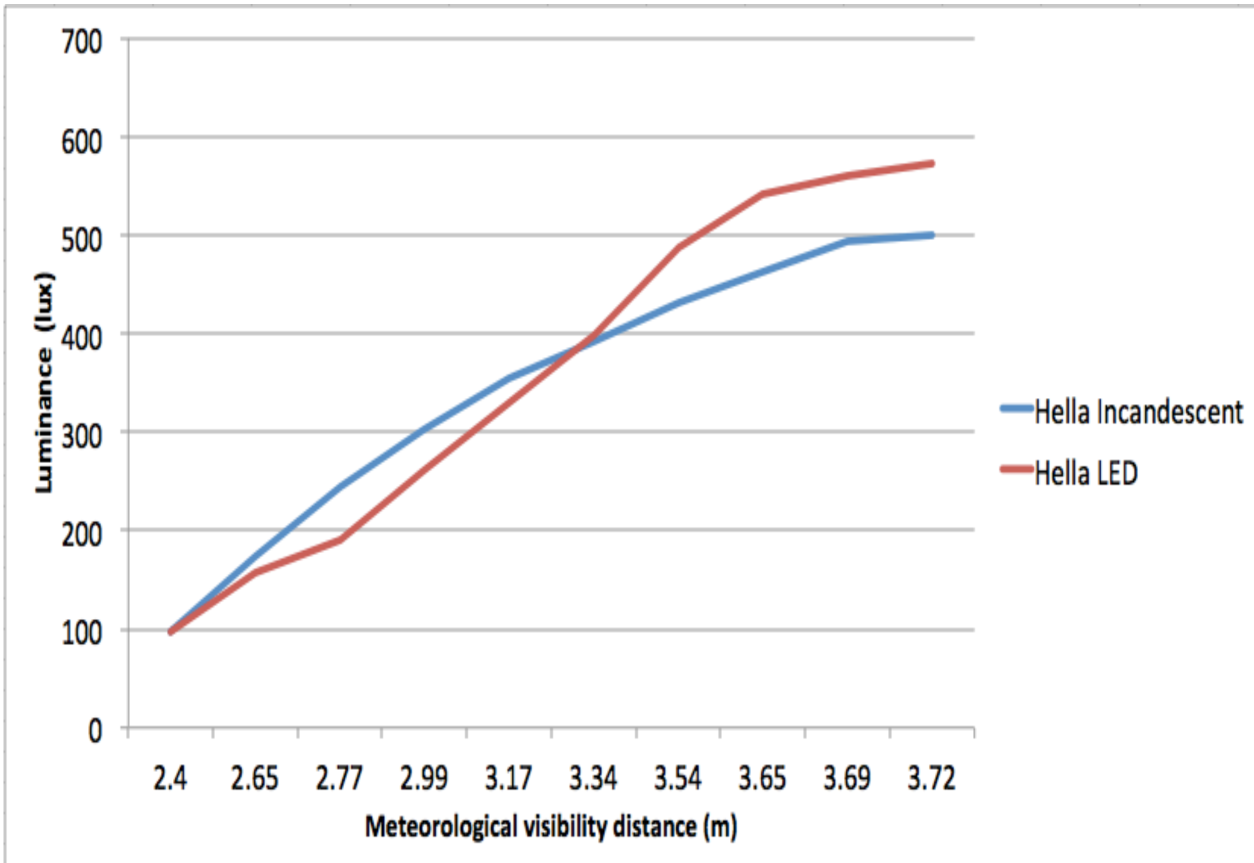

Figure 22 (Fog lamps comparison on Jute net)

4.6 Results:

So from the results it is clear that badminton net cannot be used as a replicating medium for fog but instead Jute net can be used to simulate fog effects in a laboratory.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

So from all the research and literature review done on our project and the methodology developed for our project. We finally achieved fog simulation by using Jute net and we were able to give a solution for both the dense fog and less dense fog by using two different jute nets, one with large spacing for less dense fog and one with small spacing for the dense fog. All results were taken as plots between visibility distance and luminance and compared with the research paper and the artificial fog results to reach the conclusion that jute net is the best solution for simulating fog in a laboratory.

Moreover our other objective was to test different fog lamps provided to us by Hella. And by conducting experiments we have reached the conclusion that Hella LED 24V gives the best performance under fog conditions than the Hella incandescent 12V. However Hella incandescent also gives suitable performance in fog but if you have to make a choice from these two fog lamps than it is recommended to use Hella LED.

Further our project is based on experimentation a lot and we are simulating fog and trying to get the same results as that of artificial fog. Due to variations in weather frequently and unpredictability of the weather, it is very difficult to perform experimentation on natural fog. However the density of the fog will vary continuously and will affect the results and every time we will get different results. That's why for better approximation of results we use artificial fog machine as it generates artificial fog continuously keeping its density same.

For future recommendations we will like to suggest that the experimentation be performed on natural fog and results of those conducted on natural fog be used to in simulating fog effects. However it is very difficult to achieve but anything is possible with good planning

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APPENDIX I: MATLAB CODE

```
>>data=xlsread('fle'); %reading experimental values stored in an excel file

>> x=data(:,1); %storing first column of excel file i.e meterorological visibility distance

>> y=data(:,2); %storing second column i.e luminance in variable y

>> plot(x,y); %plotting graph of Vmet vs. luminance
```

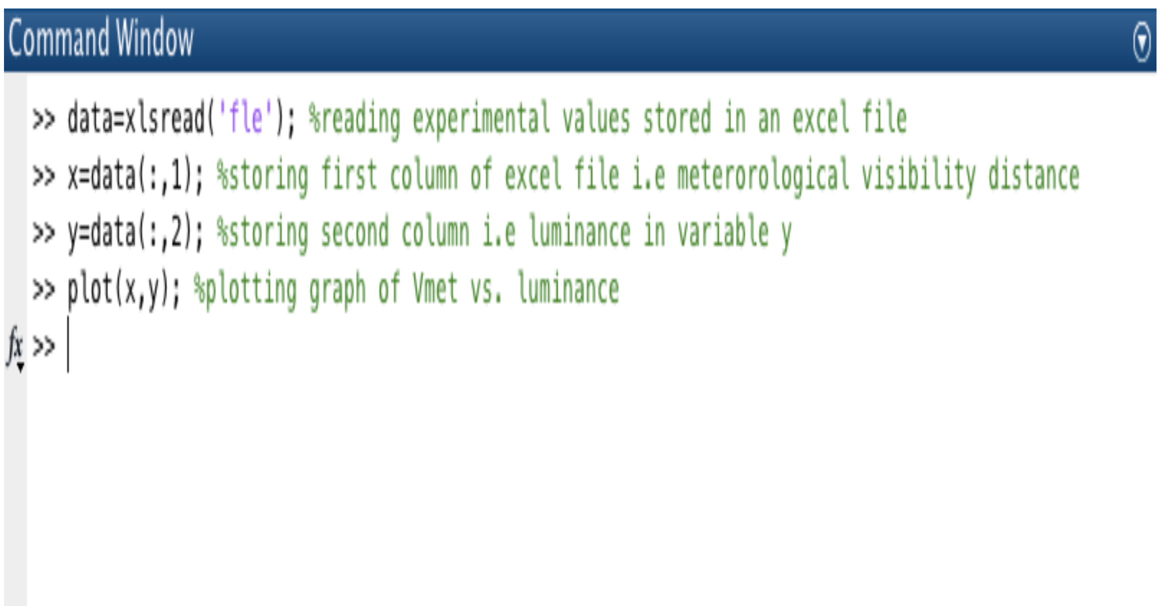

Figure 23 (Matlab Code)

APPENDIX II: EXPERIMENTAL READINGS

Table 4 (Hella LED Artificial Fog)

Ls(o)	d	Ls(d)	Vmet
14490	4	101.1	2.41
14490	4	180.2	2.74
14490	4	210.9	2.84
14490	4	323.3	3.16
14490	4	457.6	3.47
14490	4	553.1	3.67
14490	4	664.7	3.89
14490	4	720.3	3.99
14490	4	758.5	4.07
14490	4	765.9	4.08

Table 5 (Hella LED Jute net)

Ls(o)	d	Ls(d)	Vmet
14490	4	97.3	2.4
14490	4	156.7	2.65
14490	4	190.5	2.77
14490	4	261.8	2.99
14490	4	330.3	3.17
14490	4	398.4	3.34
14490	4	487.6	3.54
14490	4	541.9	3.65
14490	4	561.3	3.69
14490	4	573.2	3.72

Table 6 (Hella Incandescent Artificial Fog)

Ls(o)	d	Ls(d)	Vmet
6100	4	76.6	2.74
6100	4	193.3	3.47
6100	4	296.6	3.97
6100	4	363.33	4.25
6100	4	480	4.72
6100	4	510	3.56
6100	4	546.6	4.84
6100	4	583.33	5.11
6100	4	623.33	5.26
6100	4	631.2	5.29

Table 7 (Hella Incandescent Jute Net)

Ls(o)	d	Ls(d)	Vmet
6100	4	97.6	2.9
6100	4	173.8	3.37
6100	4	245.6	3.74
6100	4	303.2	3.99
6100	4	354.7	4.22
6100	4	391.6	4.37
6100	4	430.7	4.53
6100	4	462.4	4.65
6100	4	493.1	4.77
6100	4	501.2	4.8