ME3475 : IC Engine Lab

Experiment 1

ME21BTECH11001

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Aim:

To determine the spray cone angle of fuel at different injection pressures.

Theory:

The Schlieren technique is a visualization method used to detect density gradients in transparent media by capturing refractive index variations. It employs a collimated light source that produces a parallel beam, which, upon passing through a medium with density variations (such as air with temperature or pressure gradients), undergoes refraction. The resulting changes are recorded using an imaging system, generating images or videos that illustrate these variations.

In internal combustion (IC) engines, the Schlieren technique is applied to observe fuel spray dispersion within the combustion chamber. By capturing the fuel spray's behaviour at different injection pressures, this method provides insights into spray atomization and distribution. One key parameter obtained from these images is the spray cone angle, which represents the spread of the fuel spray as it exits the injector nozzle. Analysing the variation of the spray cone angle with different injection pressures aids in optimizing combustion efficiency, reducing emissions, and enhancing engine performance.

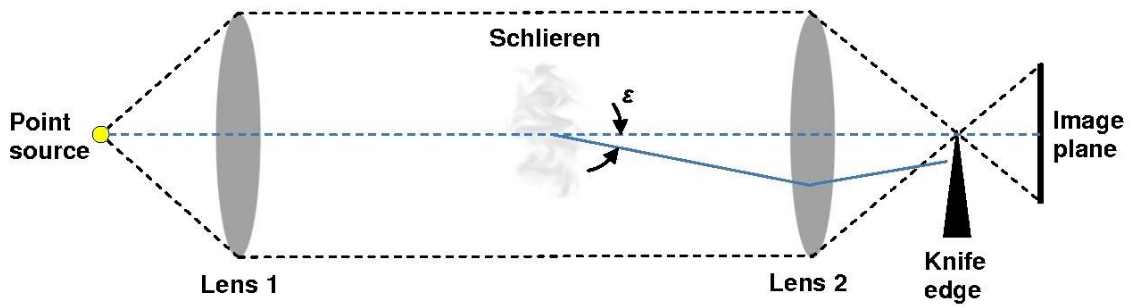
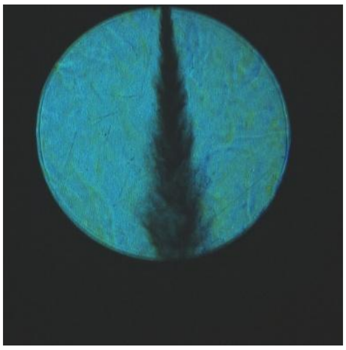


Fig: Experimental Setup

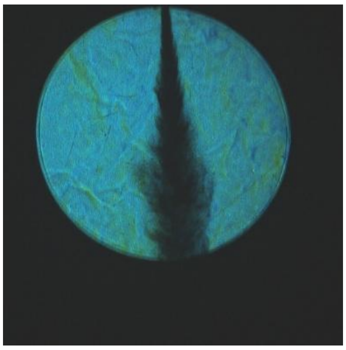
Procedure:

1. Set up a Schlieren optical system for analyzing fuel spray in an IC engine.
2. Assemble the necessary components: a light source, collimating optics for parallel light rays, a knife-edge or obstruction for contrast enhancement, and imaging optics.
3. Ensure a dark environment to improve image clarity.
4. Start the engine and maintain the chamber pressure at 3 bar.
5. Set the fuel injection pressure to 400 bar and initiate fuel injection.
6. Capture high-speed images of the fuel spray using a camera and transfer the data to a computer for analysis.
7. Use image processing software to isolate a complete cycle of fuel spray from the video sequence.
8. Save the extracted cycle as a video file with a frame rate of 1 frame per second for easier analysis.
9. Develop a MATLAB script to process the images and determine the spray cone angle.
10. Repeat the procedure for fuel injection pressures of 600 and 800 bar to study the effect of injection pressure on the spray cone angle.

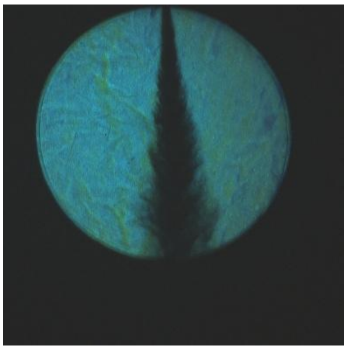
Actual Images:



400 bar



600 bar



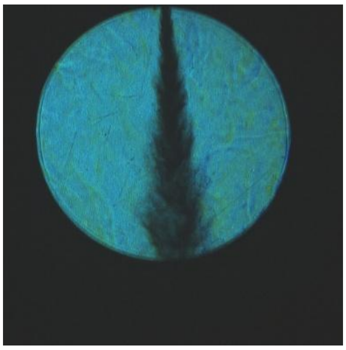
800 bar

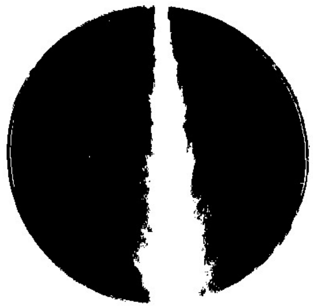
MATLAB Code:

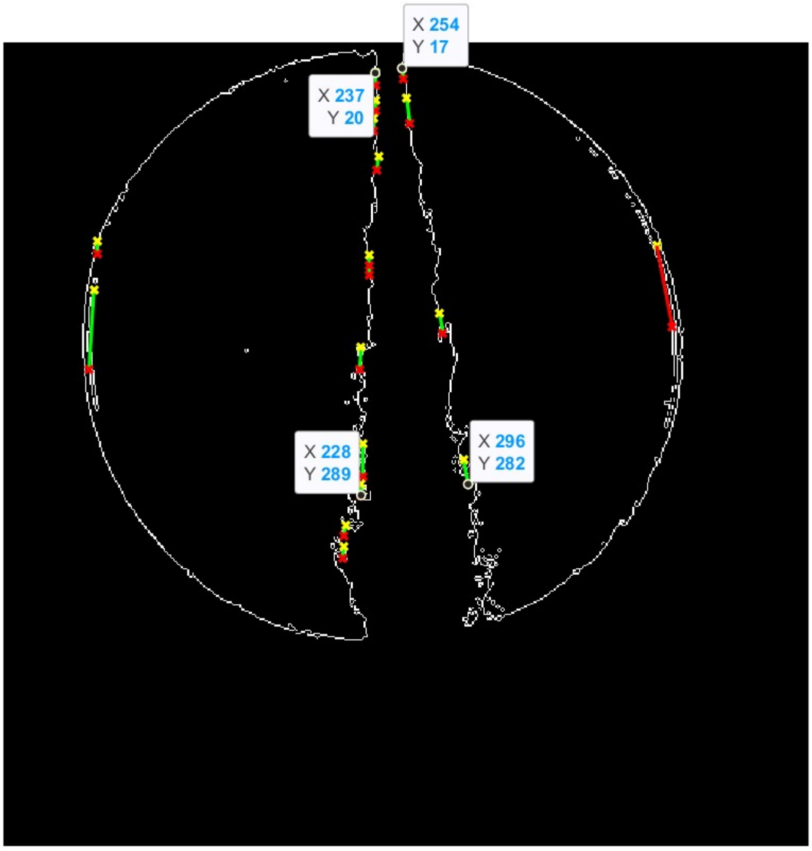
```
clc % Clear the command window
RGB = imread("800_1.jpg"); % Read the RGB image
imshow(RGB) % Display the RGB image

% Convert the RGB image to grayscale
I = im2gray(RGB);

% Binarize the grayscale image
BW = imbinarize(I);

% Invert the binary image
BW = ~BW;

% Display the inverted binary image
imshow(BW)

% Detect edges in the inverted binary image using the Sobel operator
BW = edge(BW,'sobel');

% Perform Hough transform on the edge-detected image
[H,theta,rho] = hough(BW);

% Identify peaks in the Hough transform accumulator array
P = houghpeaks(H,5,'threshold',ceil(0.3*max(H(:))));

% Detect lines in the image using the Hough peaks
lines = houghlines(BW,theta,rho,P,'FillGap',5,'MinLength',7);

% Display the original binary image with detected lines overlayed


figure, imshow(BW), hold on

% Initialize variable to store the length of the longest line segment
max_len = 0;

% Iterate through each detected line
for k = 1:length(lines)
   % Extract endpoints of the line
   xy = [lines(k).point1; lines(k).point2];

   % Plot the line
   plot(xy(:,1),xy(:,2),'LineWidth',2,'Color','green');

   % Plot the endpoints of the line
   plot(xy(1,1),xy(1,2),'x','LineWidth',2,'Color','yellow');
   plot(xy(2,1),xy(2,2),'x','LineWidth',2,'Color','red');

   % Determine the length of the line segment
   len = norm(lines(k).point1 - lines(k).point2);

   % Update the length of the longest line segment
   if ( len > max_len)
      max_len = len;
      xy_long = xy;
   end
end

% Highlight the longest line segment
plot(xy_long(:,1),xy_long(:,2),'LineWidth',2,'Color','red');
```

Results:

1.400 bar:





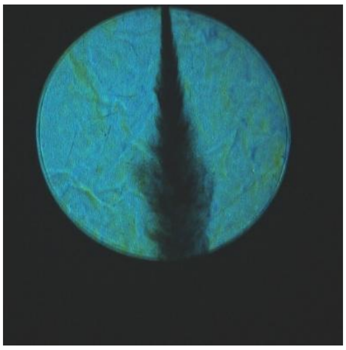


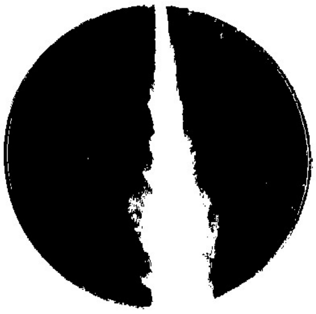
Equation of Lines:

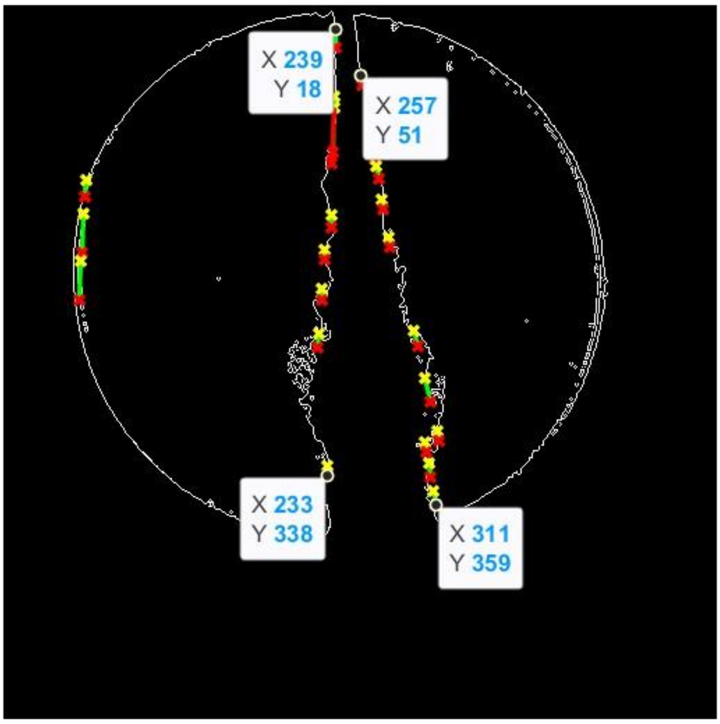
269x + 9y - 63,933 = 0 and 265x - 42y - 66,596 = 0

Angle = 10.92°

2.600 bar:





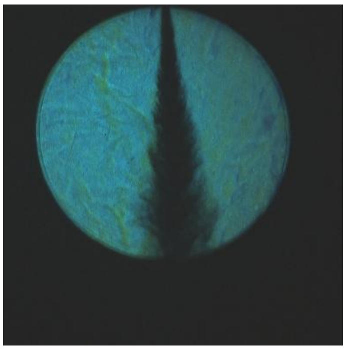


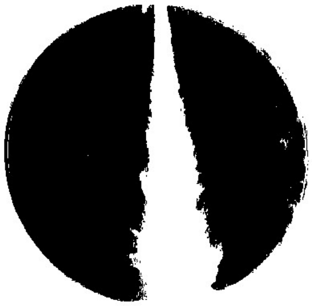
Equation of Lines:

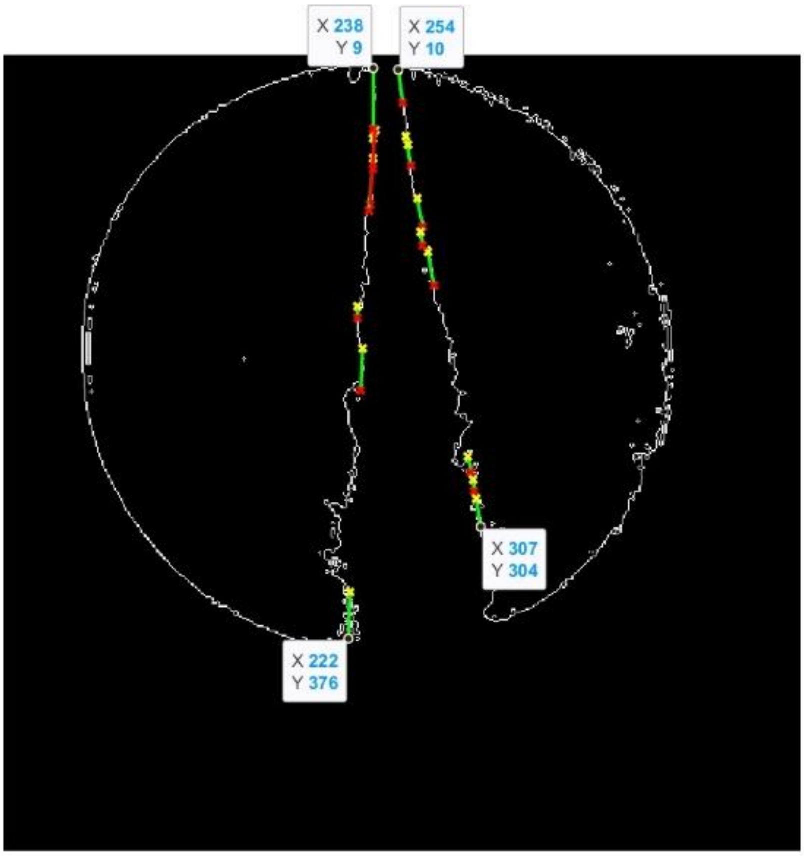
320x + 6y - 76,588 = 0 and 308x - 54y - 76,402 = 0

Angle $= 11.01^{\circ}$

3.800 bar:







Equation of Lines:

367x + 16y - 87,490 = 0 and 294x - 53y - 74,146 = 0

Angle = 12.72°

Conclusion:

This experiment examined the effect of fuel injection pressure on spray cone angle using the Schlieren technique. The measured spray cone angles were **10.92° at 400 bar**, **11.01° at 600 bar**, and **12.72° at 800 bar**, showing a general increasing trend. The results suggest that higher injection pressures improve fuel atomization and dispersion. However, slight variations in the trend may be influenced by **nozzle geometry, air-fuel interactions, and turbulence effects**. Additionally, **spray collapse at intermediate pressures** and **image processing limitations** could have affected the measurements. These findings highlight the importance of optimizing injection parameters to enhance combustion efficiency. Further investigations, including multiple trials and refined image processing techniques, can provide more precise insights into spray behaviour.