Understanding Concentration and Pressure Changes during Ultrasonication-enhanced Blending of Petrol-Ethanol Blended Fuel

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Motivation

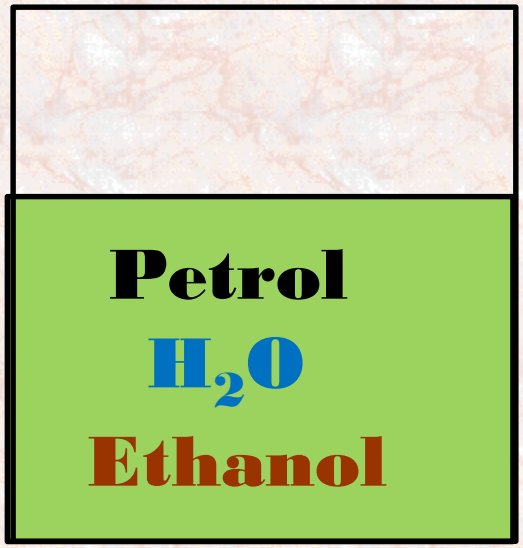
Source: DOESA, 2009

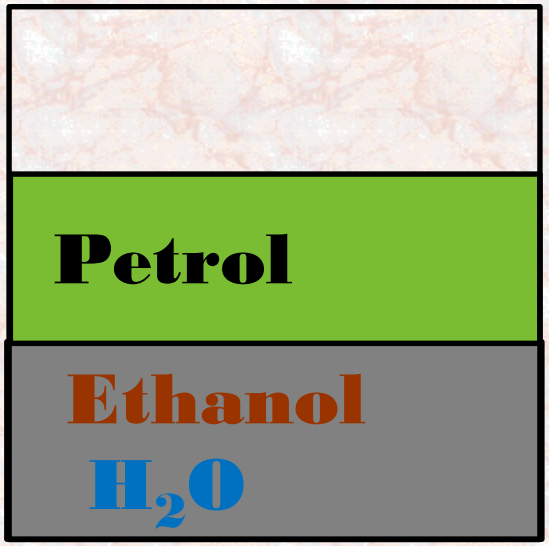
- Increasing demands in alternative clean fuels due to environmental pollution calls for fuels modifications
- Blending of petrol with alcohols, such as ethanol is a promising alternative due to its ability in the reduction of carbon monoxide emissions and thus resulting in less greenhouse effects
- Significantly higher research octane number of ethanol-blended fuel compared to unblended petrol
- Therefore, understanding production of petrol-ethanol blended fuel is very essential

Research Problem

Sources: Shad, 2011; Hughes, 2009

- Hygroscopic nature of ethanol causes phase separation in the ethanol-petrol blends





- Production of homogeneous mixture at low energy and control of phase separation is a challenge

Objectives

- Investigate effect of the position of ultrasonicator's horn on the concentration and pressure changes during ultrasonication-enhanced blending of petrol-ethanol fuels
- Understand the concentration and pressure changes during the blending of ethanol-petrol fuels

  - to achieve a perfectly homogenized petrol-ethanol blend

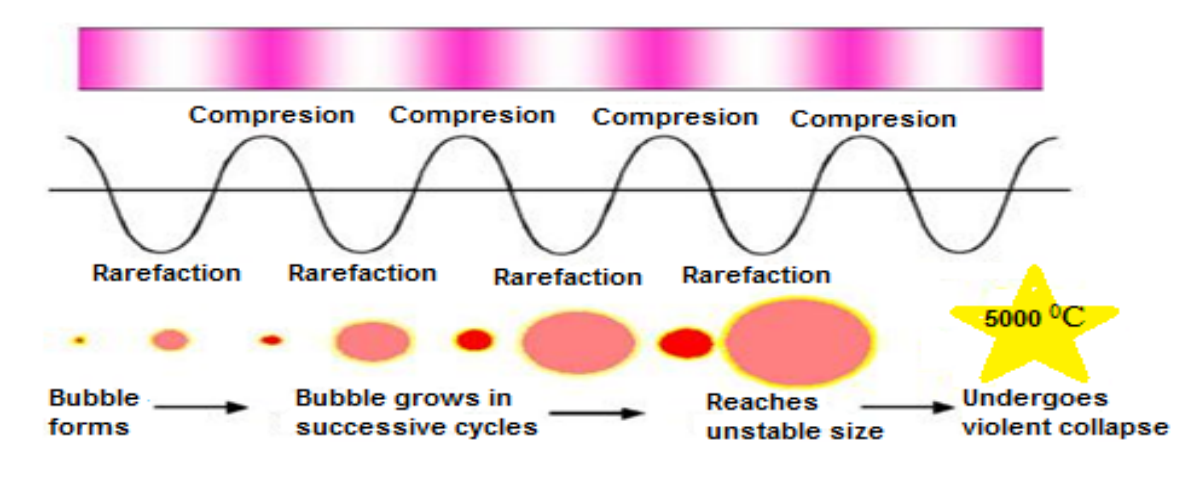
  - for design of blender for the purpose

Ultrasonic & Ethanol-Petrol Blends

Source: Suslick et al, 2004

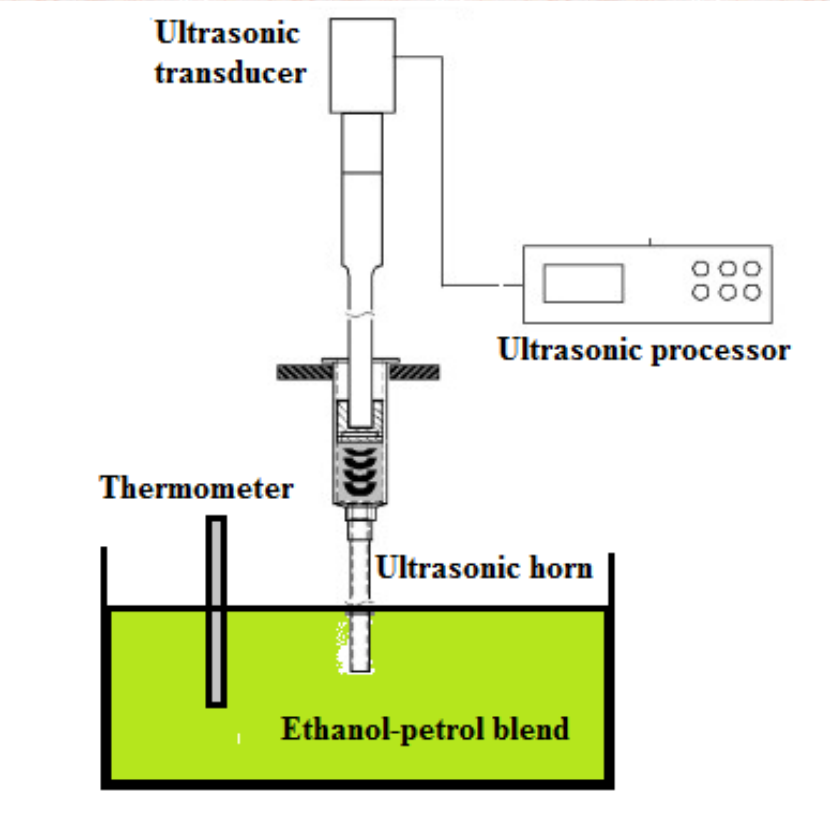
- Generation of intense, ultrasonic waves
- formation, oscillation,

  implosion bubbles in liquids
- induce high temperatures and pressures within imploding bubble
- allows for extraordinary physical + chemical conditions



Experimental Procedure

Ultrasonication-enhanced blending of ethanol hydrate - gasoline mixture

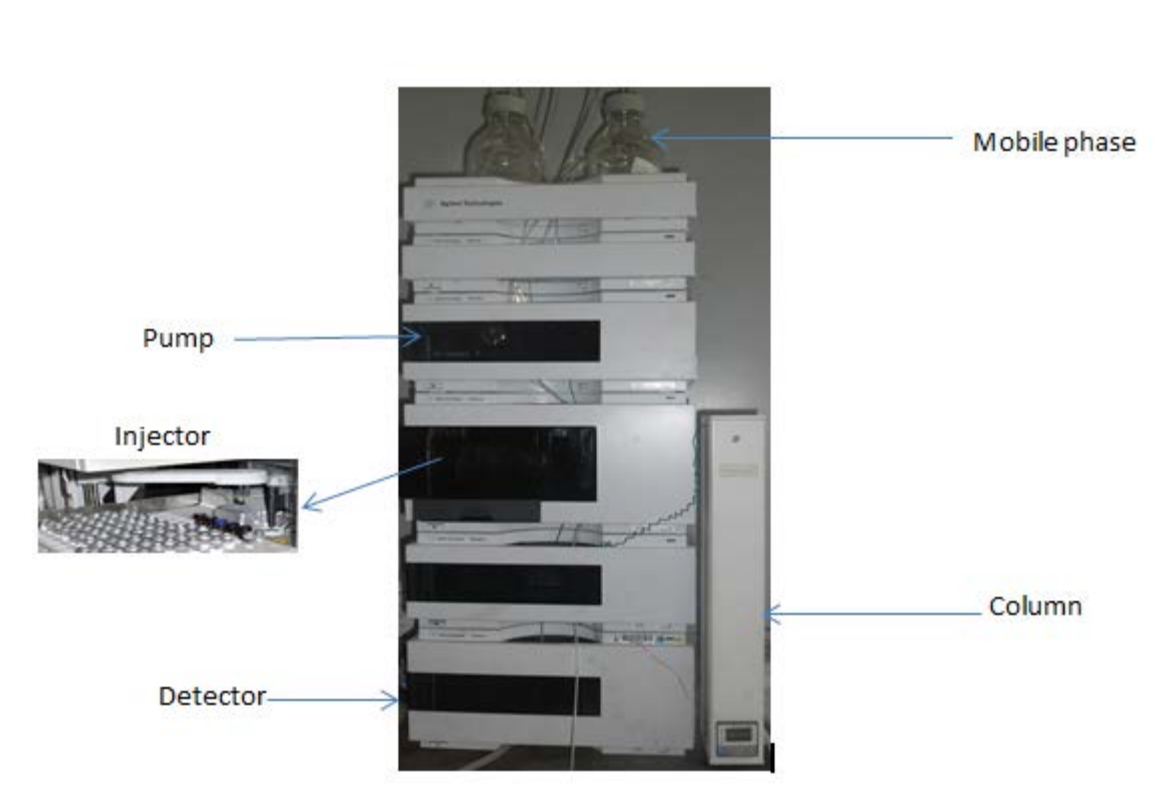


Frequency of horn	24 KHz
Cycle	1
Amplitude	30
Diameter horn	0.7 cm

Experimental set up for ultrasonication-enhanced blending of ethanol hydrate-gasoline mixture

Experimental Procedure

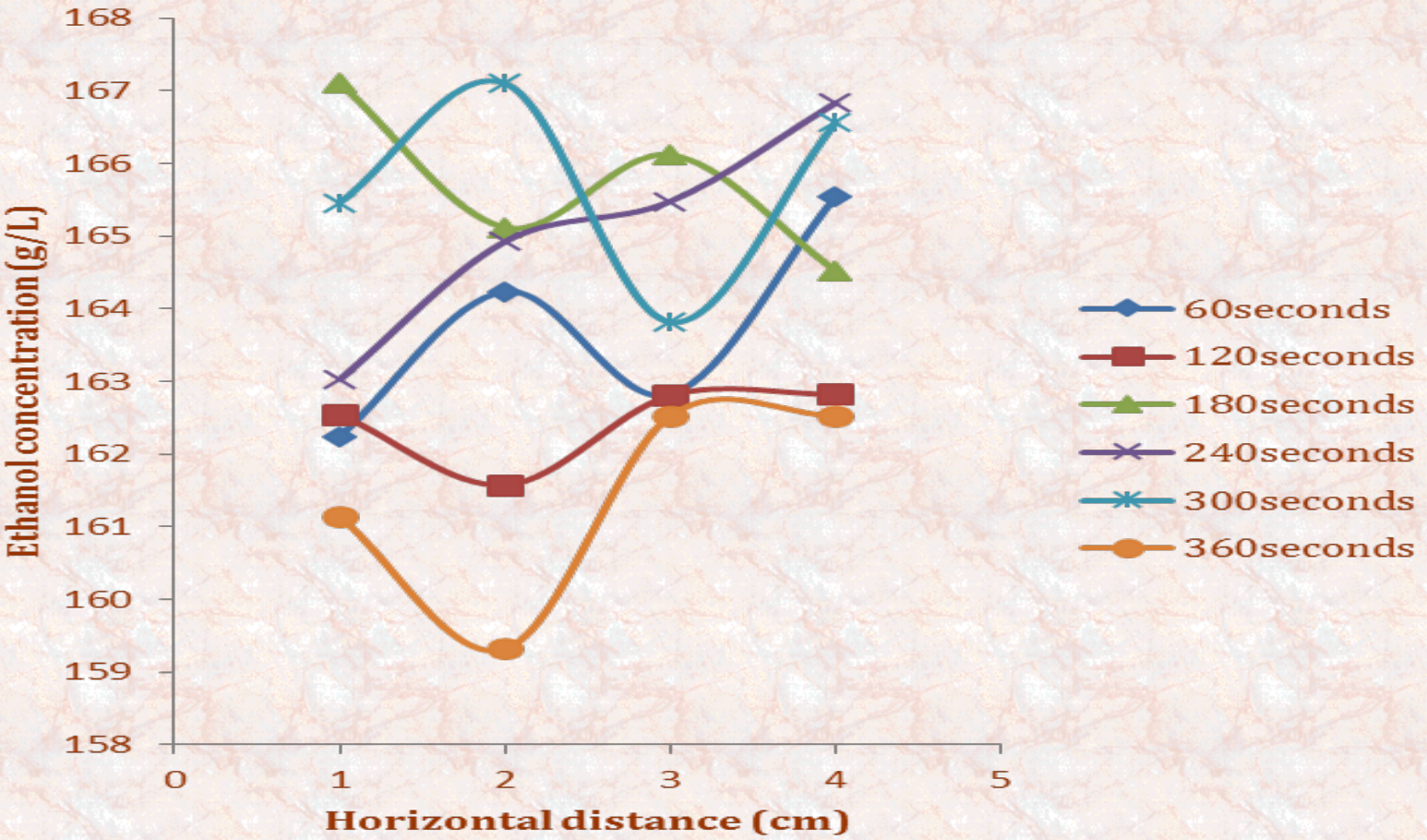
Analysis of the blended ethanol-petrol mixture



Agilent High-Pressure Liquid Chromatography
(Agilent 1200 Series HPLC System)

Results: Concentration Profile

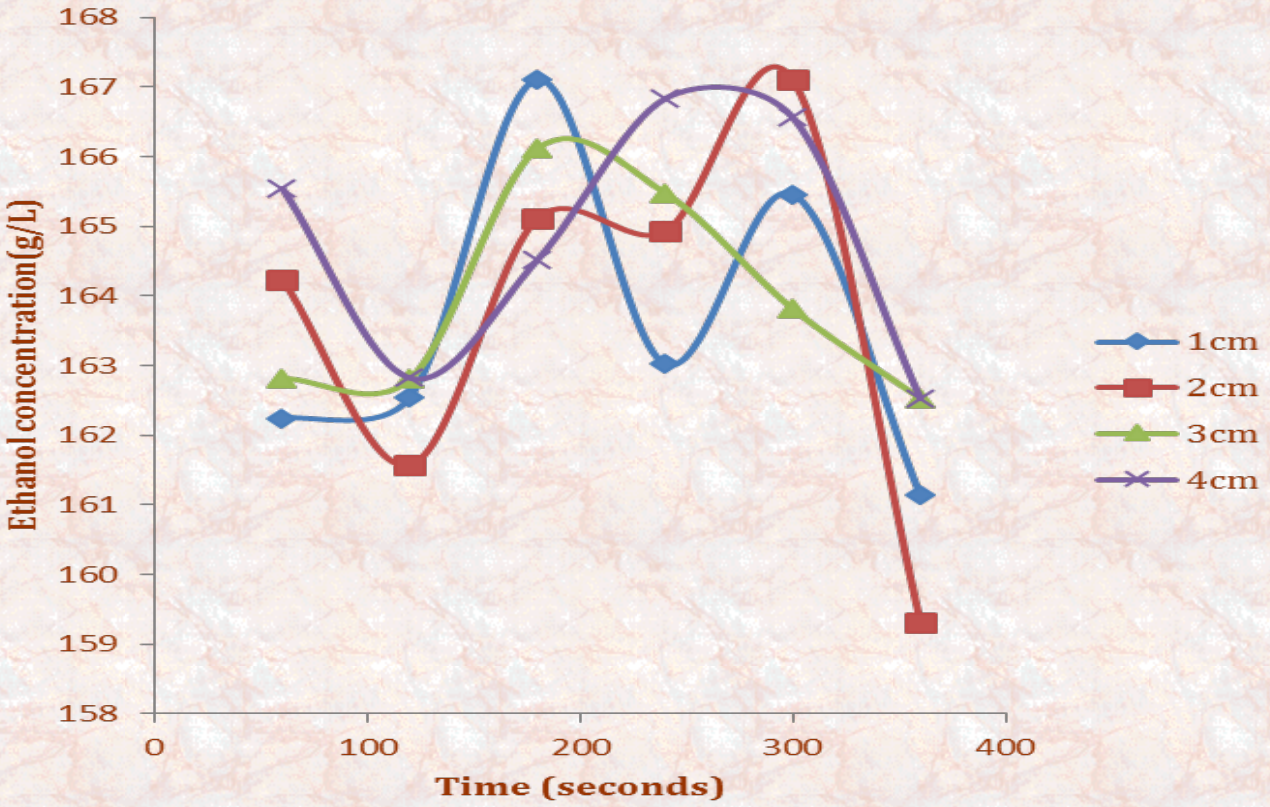
Variation of concentration with the horizontal distance and time



Variation of concentration with distance and time in the horizontal direction for a 30% ethanol mixture

Results: Concentration Profile

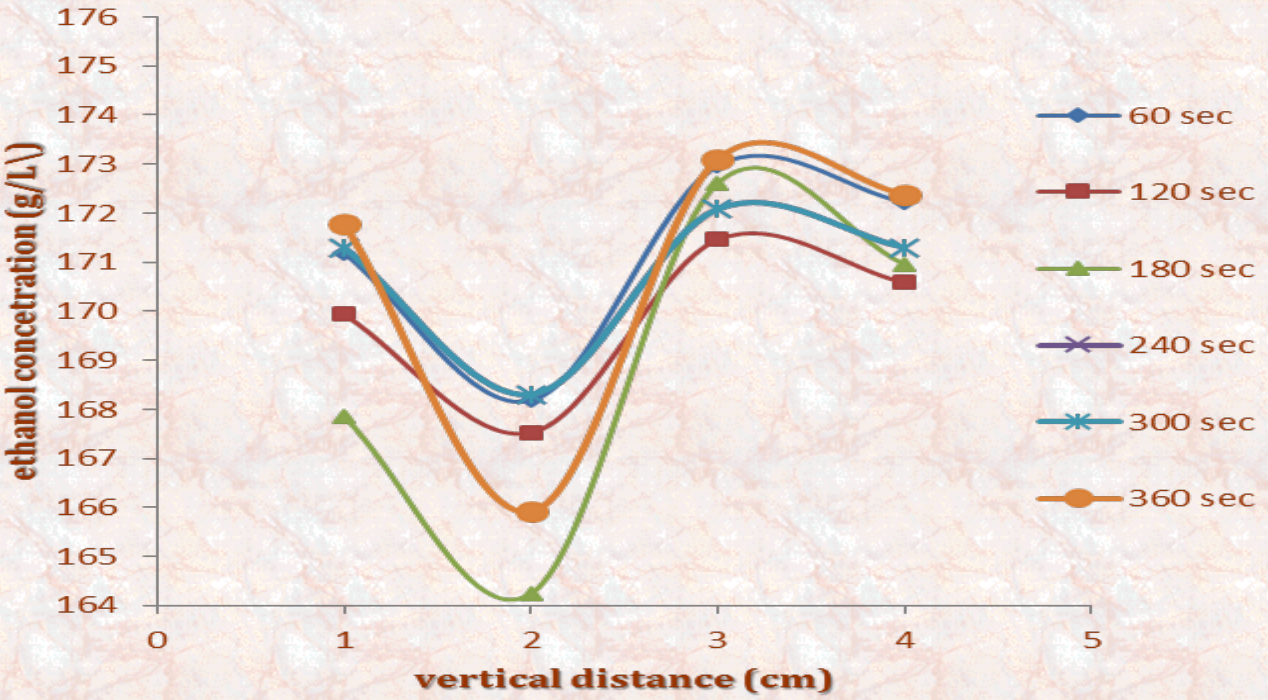
Variation of concentration with the horizontal distance and time



Variation of concentration with distance and time in the horizontal direction for a 30% ethanol mixture

Results: Concentration Profile

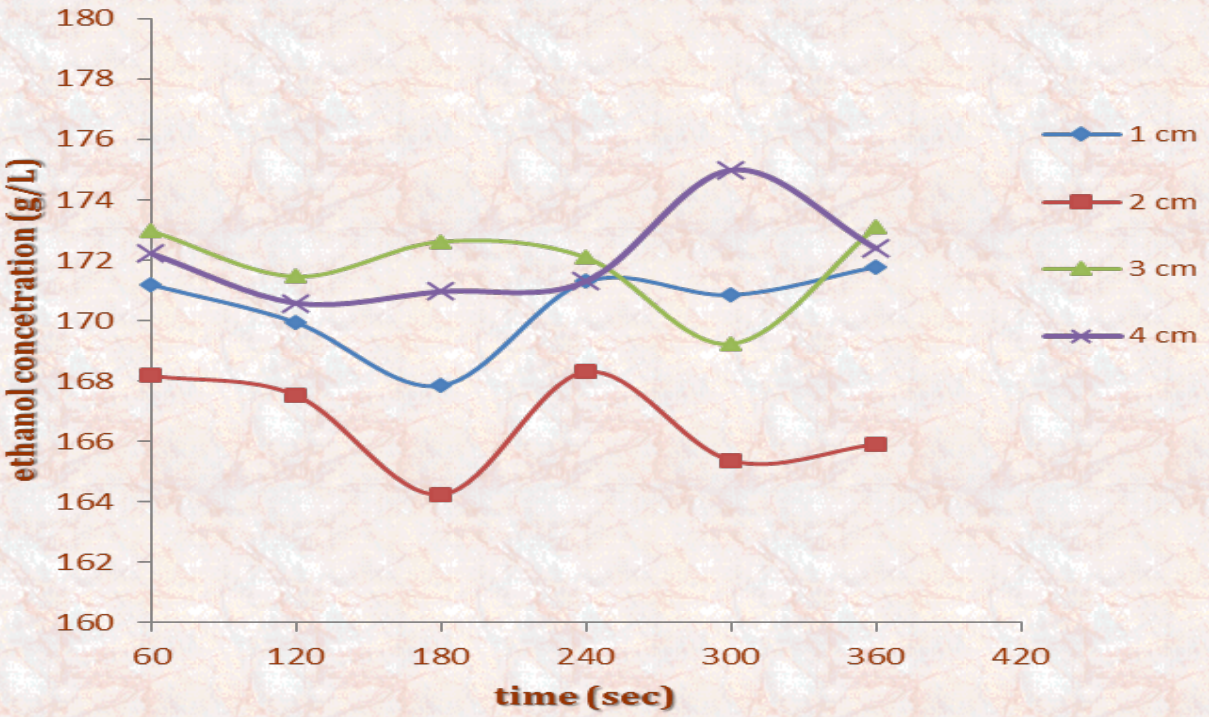
Variation of concentration with the vertical distance and time



Variation of concentration with distance and time in the vertical direction for a 30% ethanol mixture

Results: Concentration Profile

Variation of concentration with the vertical distance and time



Variation of concentration with distance and time in the vertical direction for a 30% ethanol mixture

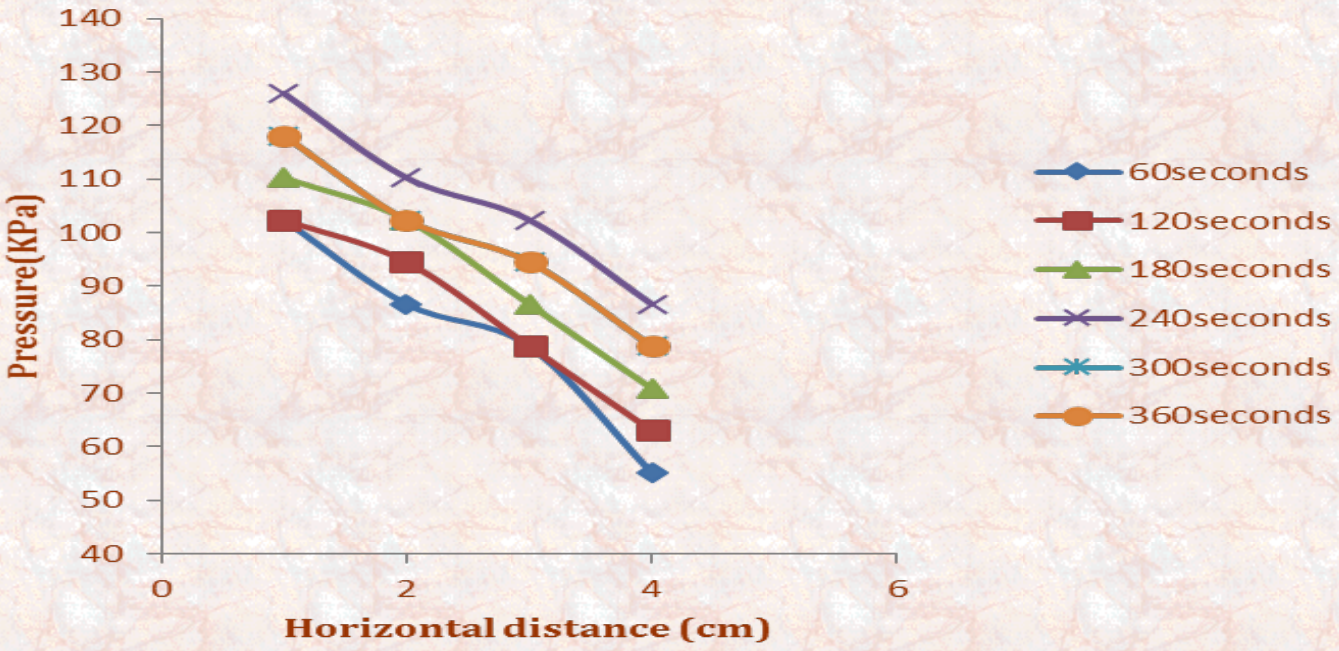
Results: Concentration Profile

Sources: Hielscher, 2005; Raman, 2006

- Wave behaviour: growth and collapse of bubbles due to the energy absorbed
- Non uniform amplitude pattern due to different size of bubbles and wave superposition (reflection off the reactor walls)
- Concentration gradient and diffusion rates were higher in the vertical direction, making the diffusion in the horizontal direction a rate-limiting step. The dimensions of the blender for an homogenized mixture should have larger height-to-diameter ratio.

Results: Pressure Profile

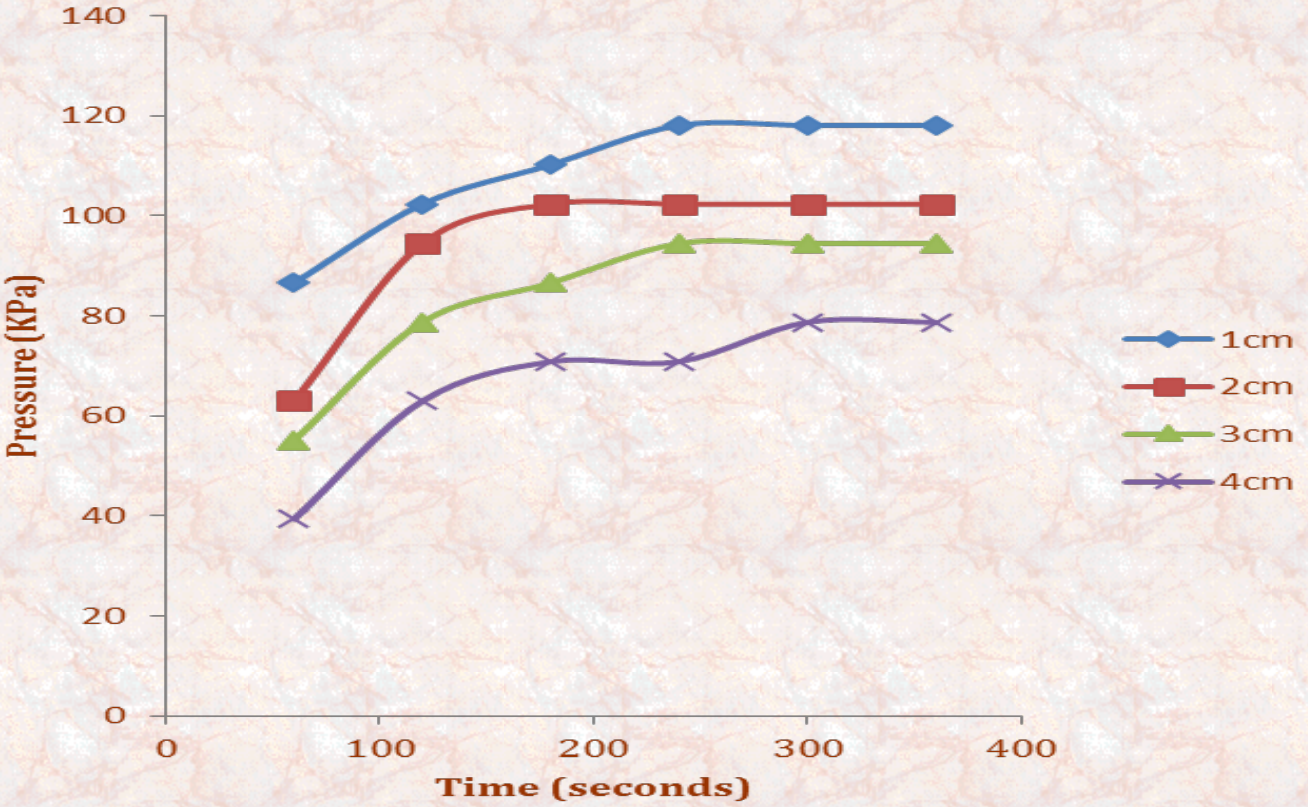
Variation of pressure with the horizontal distance and time



Variation of pressure with distance and time in the horizontal direction for a 30% ethanol mixture

Results: Pressure Profile

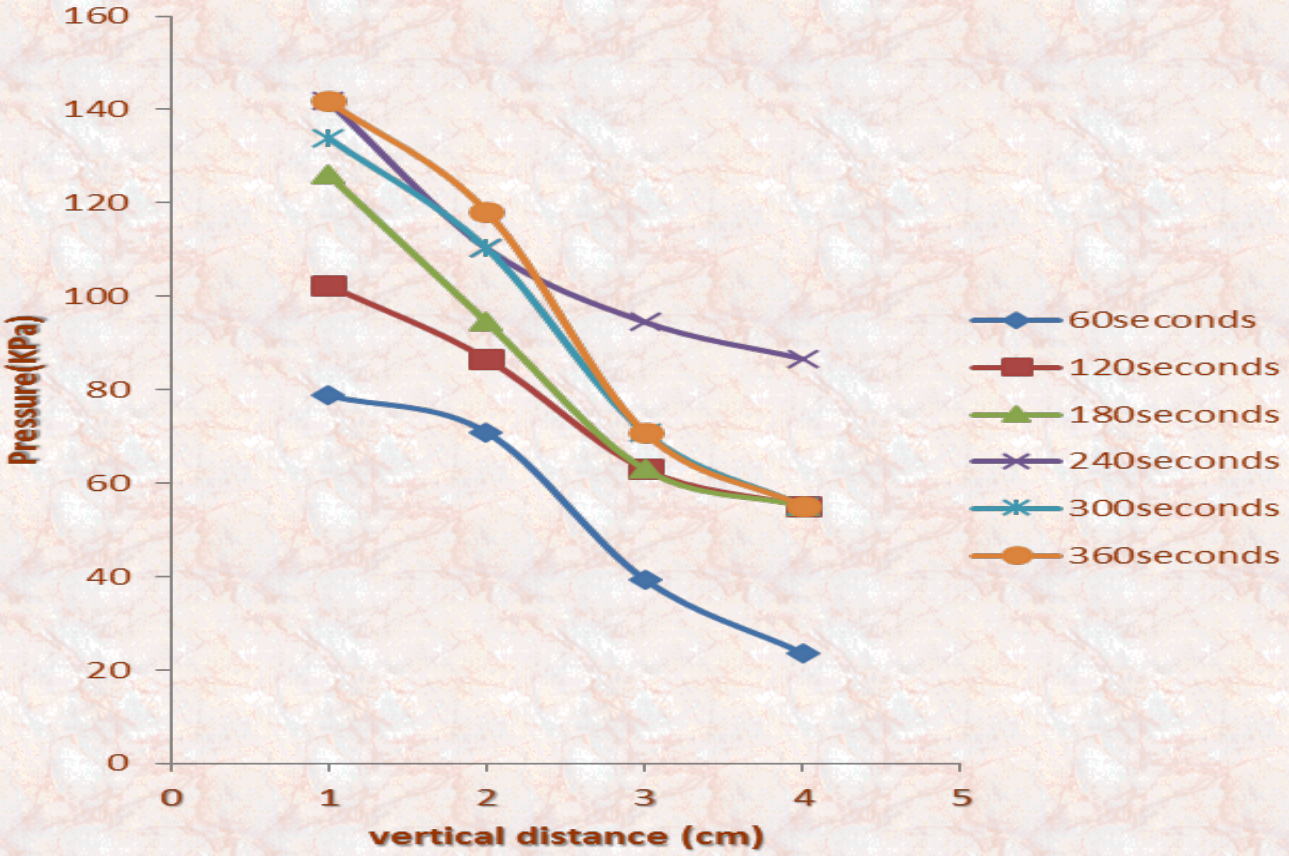
Variation of pressure with the horizontal distance and time



Variation of pressure with distance and time in the horizontal direction for a 30% ethanol mixture

Results: Pressure Profile

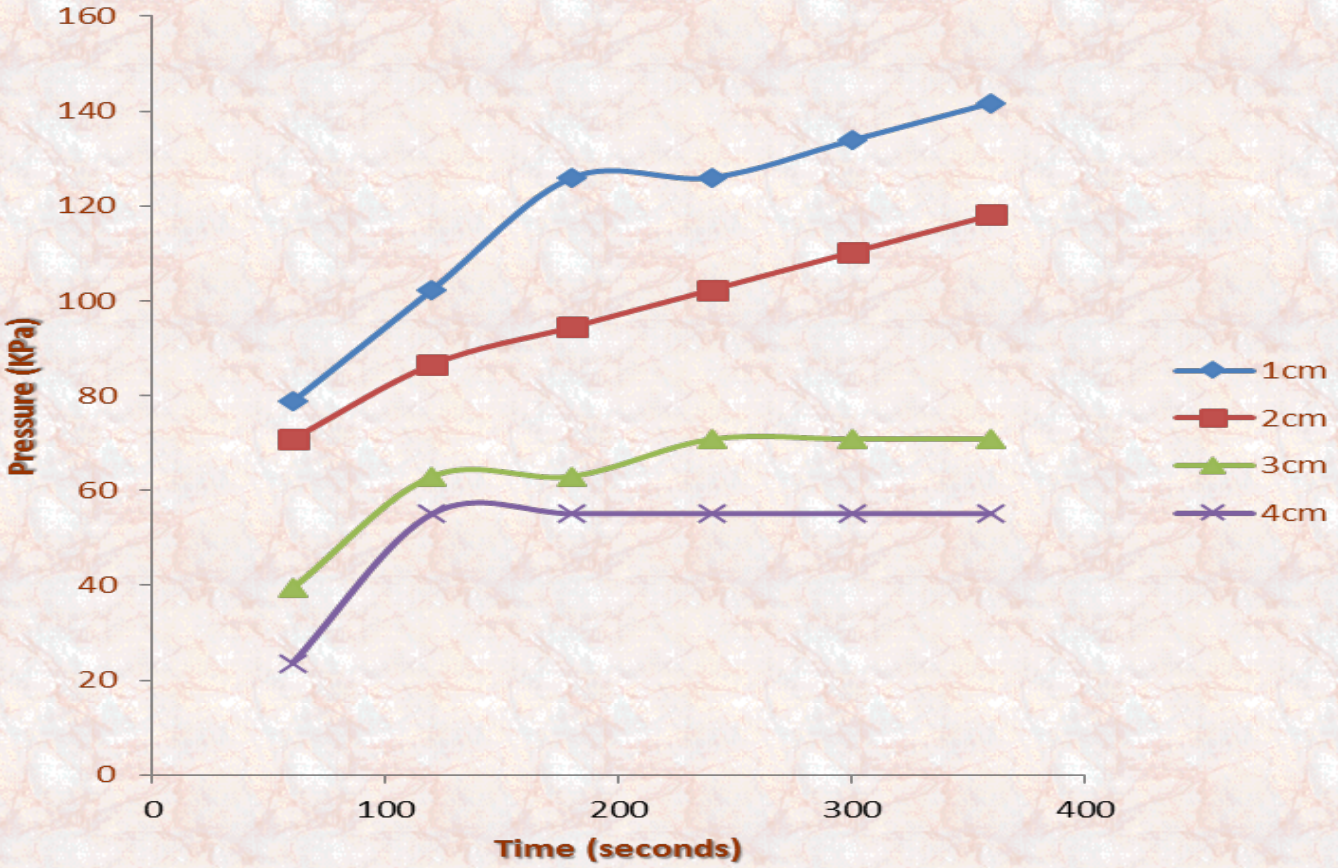
Variation of pressure with the vertical distance and time



Variation of pressure with distance and time in the vertical direction for a 30% ethanol mixture

Results: Pressure Profile

Variation of pressure with the vertical distance and time



Variation of pressure with distance and time in the vertical direction for a 30% ethanol mixture

Results: Pressure Profile

Sources: Goksen et al, 2004; Klima et al, 2006

- This behaviour shows that the intensity of energy is assumed to decrease accordingly with an increasing area into which it is spread ($I \sim 1/A$)
- Ultrasonic energy is consumed within a volume near the horn
- Between 120 and 360 seconds, the pressure gradient became zero (a plateau), indicating a constant distribution of ultrasound energy, hence perfectly homogenization of the fuel blend.

Conclusions & Recommendations

- The concentration profile is a wave function for both horizontal and vertical direction. Furthermore, highest concentration gradient was obtained in the vertical direction.
- Ultrasonication has an impact on both the horizontal and vertical diffusion since the concentration profiles are waves confirming the formation of cavitation in the mixture.
- Ultrasonication increases pressures which in turn enhances diffusion rate and thus mixing possibilities of ethanol and petrol.
- The experimental results on the concentration gradient conclude that if the blender geometry was to be proposed, it will have a greater height than the radius since the vertical diffusion seem to be favoured.

Conclusions & Recommendations

- Further investigation on the influence of ultrasonicator parameters and mixing mechanism should be done in order to understand the effect of ultrasound on the phase behaviour.
- Further study in the area of optimization might be required to obtain optimum operating variables, such as, the amplitude, the pulse rate, the temperature, the pressure, the blending time and the frequency, that could be related to the force required to break the molecular bonds of ethanol-water mixtures at various concentrations

Acknowledgments

Wits FEBE Top-slice Grant

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Thank You for Your Attention

BACK-UP SLIDES

Phase separation

- Ethanol + petrol blends sensitive to moisture