6.1 CONCLUSION:

This present research work was taken up with the objective of conducting extensive investigations on performance parameters and emission characteristics of SI engine using ethanol-gasoline blends in varying volumetric ratios in a single cylinder 4-stroke gasoline engine. Experiments were carried out to collect data on performance parameters and emission characteristics of spark ignition engine for a range of parameters decided on the basis of practical considerations of the system and operating conditions. Results have been compared with those of previous work carried out by various researchers under similar conditions to determine the enhancement in performance parameters and reduction in the regulated emissions. The data has been presented in the form of variation of load with ethanol-gasoline blends in different proportions at a constant engine speed to bring out clearly the effect of these parameters on the enhancement in performance parameters and subsequent reduction in the regulated emissions. The experimental data have also been used to develop correlations between all the performance parameters and emission components using Artificial Neural Network (ANN) thus analyzing and validating the experimental results with the ANN predicted results. By using these results, one can easily figure out the best possible blend that may yield the best performance and lowest regulated emissions from the spark ignition engine.

The following conclusions have been drawn from the present work:

Decrease in calorific value fallout in higher consumption of fuel for ethanol-gasoline blends when weighed against to petrol. The, torque, brake thermal efficiency, power increase with increase in percentage of additive. E40 provided the best result for all measured parameters at all engine loads. Thus ethanol can be utilized as an additive for gasoline in future.

Brake Thermal Efficiency, volumetric efficiency increased as the ethanol is varied in volume percentage in the mixture. E40 has good thermal efficiency at higher loads. Specific fuel consumption increased, as we increase the blend of ethanol in gasoline.

Increasing ethanol ratio showed a clear improvement in the engine performance including decreasing in the main regulated emissions, improvement in combustion efficiency and increase in maximum BMEP. This improvement was obvious even at low ethanol ratio.

Increasing ethanol content improves thermal efficiency, mainly due to the increase in combustion efficiency and also, due to the decrease in exhaust and coolant losses.
Increasing ethanol ratios increases exhaust heat capacity as a result of changes in exhaust composition, in particular, higher water content. This is responsible for reduction in exhaust temperature.

Owing to the heating value which is lower for ethanol, increase of specific fuel consumption can be justified as compared with gasoline. Increasing the ethanol content in gasoline-ethanol mixture it results in density increase of the mixture which in turn increases the power. As a result of improved combustion, reduction in CO, NOx and Hydrocarbon emission and Exhaust temperature while increase in CO2 emission. CO and emissions related to Hydrocarbons are reduced for all the blends because of better combustion CO gets converted in to CO2 and hence CO2 emission increases.

This research study, gave us an important deduction that using ethanol–gasoline blend, CO emission may be reduced by 10–20%, while CO2 emission increases by 10–15% solely dependent on engine conditions.

The ANN results are very good, R values in this model are very close to one, while root mean square errors (RMSE) were very low. Analysis of the experimental data by the ANN revealed the ANN-predicted results and the data deduced experimentally bears a good correlation. ANN thus showed the potential to be the prominent tool for correlation and simulation of engine parameters. ANN provided an accurate and simple approach in the investigation of this complex, multivariate problem, the examination of the SI engine performance and emissions. It is by and large depicted that Artificial Neural Network provided the best solution to the engine performance and emission parameters and it can be predict the said parameters in the nonlinear and sophisticated conditions.

The outcome of this research clearly showed that a three layer feed-forward neural network achieved an enviable mapping between the inputs and outputs of the problem. High values of regression coefficients yielded when setting a regression line for predicted and measured datasets. The performance of proposed network is evaluated by several criteria so it can be applied in the industrial fields as well.

**Comparison of earlier reported data or past work with current work:**

i) Yucessu et.al (2006) during his experimental investigation using E0, E40,E60 in a single cylinder,SI engine with a variable compression ratio of 5:1- 13:1 at varying speed range observed that BSFC increased by 10% and 15% respectively for E0 and E40.An increment of 8% and 14% were noted in Engine Torque for E0 and E40 respectively. Hasan(2003) also noted a increase of 2.4% in the BSFC and an increment of 9% in Engine torque using E0-E25 with an increment of 2.5% in ethanol at constant speed in a 4-cylinder ,SI engine at 9:1 compression ratio.
Current work also demonstrated that 16.1% and 34.6% average increments in BSFC with E40 and E60, respectively at compression ratio of 4.5:1, when compared with E0 were noted. The average increment in engine torque compared with E0 was about 2% and 2.3% with E40 and E60 at compression ratio of 4.5:1.

Celik (2008) noted an increase of 3%, 6% and 2% in Brake Power with E25, E50 and E75 respectively in a single cylinder SI engine at compression ratio of 6:1. Najafi et.al (2009) also saw marginal increment in the Brake power and Brake Thermal Efficiency using different ethanol-gasoline blends in a 4-cylinder, SI engine. Baghdadi (2008) also noted an increment of 4% and 3.5% at Compression ratio of 8:1 for E30 for a single cylinder, SI engine at 1500rpm respectively in Brake power and Brake Thermal Efficiency.

Current work also demonstrated that the Brake power increase by 4% at a compression ratio of 4.5:1. The Brake power increased as the volume percentage of ethanol fuel is increased in the fuel mixture to E80. The additive of ethanol showed higher Brake Thermal Efficiency as compared to E0. However E40 displayed the maximum BTE on increasing load from no load to full load.

Costa et.al (2011) noted that E100 produces higher Volumetric efficiency at low compression ratio at all speeds as compared to E22 in a 4-cylinder, SI engine. Datta et.al (2012) also found a substantial increase in volumetric efficiency using E0, E10, E20, E30, E40 fuel in a single cylinder, SI engine.

Current investigation also showed that the additive of Ethanol showed that the volumetric efficiency is higher than the gasoline. However E40 displayed highest volumetric efficiency at increasing loads.

Ceviz et.al (2005) noted that using ethanol–unleaded gasoline (E0, E5, E10, E15, and E20) blends on cyclic variability (slow burns and incomplete burns) and emissions in a SI engine, the HC and CO emissions decreased by 20.2% and 30.01% respectively and CO2 emissions increased. Celik (2008) carried out his investigation to study the effect of ethanol on engine out emissions. The test fuels used were E0, E25, E50, E75, E100. The values of CO emissions as observed were 3.76%, 2.65%, 2.06%, 1.24% and 0.73% for E0, E25, E50, E75 and E100 fuels, respectively. Increasing the ethanol content reduced the CO2 emissions to 13.25%, 12.14%, 11.62%, 10.25% and 9.51% with E0, E25, E50, E75 and E100 fuels, respectively.

Current Work also demonstrated that CO emission was lower than value of 1% by volume for all fuels (E0, E10, E20, E40, E60, E80 and E100) at compression ratio of 4.5:1. However the lowest emission was observed...
for E100 fuel. CO₂ emission is higher in alcohol–gasoline blends than in pure gasoline; on average, CO₂ emissions by E100,E80,E60,E40,E20,E10 are 12%, 10%, 8%, 5%,4%,3% significantly higher than E0.

v) Balki et.al (2014) studied the effect of alcohol (ethanol and methanol) use on emissions characteristics of a low power single-cylinder engine at full throttle and varying engine speeds. HC emissions decreased by 13.6% and 27.12% with ethanol and methanol usage as compared with gasoline. CO emissions also decreased by 29.07% and 31.34% with ethanol and methanol usage as compared with gasoline. Celik (2008) noted that he value of NOx declines to 1711ppm, 1434 ppm, 1150 ppm and 988 ppm with E25, E50, E75 and E100 fuels, respectively, from 2152 ppm with E0 fuel.

Current work also resulted in a significant reduction in HC emission between no load and 25% as a result of the leaning effect and oxygen enrichment caused by the ethanol addition. The lowest HC emission was obtained with E100 fuel operation while the maximum HC emission with E0. Experimental results gave the lowest possible NOx emissions at the chosen compression ratio of 4.5:1 and was found to reduce down to 100ppm from a marginal value of 180 ppm when the engine was allowed to run on full load condition. E100 generated the lowest possible value of NOx emission.

vi) Najafi et.al (2015) carried out his research using E0, E5, E10, E15 and E20 experimentally with the assistance of artificial neural network. The ANN results were found to be excellent; R values in this model were very close to 1, while a low value of root mean square errors (RMSE) was observed. Yucesu et al (2006) used a single cylinder, 4-stroke SI engine to carry out his research using ethanol-gasoline blends in the proportion of 10%, 20%, 40% and 60%. The results of experimental values were used for mathematical modelling analysis as training and test data. After training, it was found that the value of R2 (absolute fraction of variance) were recorded as 0.999996 and 0.999991 subsequently for the engine torque and specific fuel consumption. Similarly, these values for testing data were 0.999977 and 0.999915 respectively. Ghobadian et.al(2009) in his study framed an ANN model which generated good results with correlation coefficient (R) values of 0.9487,0.999,0.929 and 0.999 for engine torque, SFC, CO and HC emissions respectively when experiments were performed on diesel engine using waste cooking biodiesel fuel.

Current Work also revealed that the ANN model so developed generated the best correlation coefficient(R) ranging from 0.999923-0.999977 for all performance parameters and the exhaust emissions. Mean relative errors (MRE) values were in the domain of 0.12-5.56%, while root mean square errors (RMSE) were very low. ANN provided the
best accuracy in modelling the emission indices with correlation coefficient of 0.99, 0.99, 0.84 and 0.99 for CO, CO₂, HC and NOx, respectively.

**Limitations of Present Experimental work:-**

In this research study, the experiments were performed on a 3 HP HONDA, single cylinder, four-stroke and spark-ignition (SI) gasoline engine. The engine was allowed to run on a constant speed of 2500 rpm only. The performance and emanation of harmful effluvium from the engine running on ethanol commingled with gasoline (E0, E10, E20, E40, E60, E80 and E100) only were evaluated and compared with gasoline fuel. Only regulated emissions were the findings of the research study. Non regulated emissions were not a part of the research findings. Prediction carried out by artificial neural network (ANN) used Levenberg-Marquardt (trainlm) as the training algorithm to train the network. Network with one hidden layer and 20 neurons was selected as the optimum ANN in this research study; however multiple hidden layers with different neurons could be used also to carry out the experimental work.

**Concluding comments:**

In summary, the use of ethanol in SI engines has the advantage of reducing most regulated emissions, as well as improving combustion and thermal efficiency. This effect is noticeable even at low ethanol contents. However, contrary to assumptions, there is no linear trend between increasing ethanol content and any change in combustion and performance characteristics. The effect of ethanol on these characteristics manifests itself only at medium to high ethanol levels. E40 has the most pronounced effect on performance parameters and emissions at all loads. This is particularly important for future modelling of engine running on different gasoline-ethanol blends.

Apart from Sweden, the use of ethanol in the engine is still limited to low proportion ethanol-gasoline blends (ranging from 5% to 10%). According to the finding of this thesis, the current level of ethanol showed substantial improvement in performance parameters and low level of regulated emissions. However, plans towards reducing dependence on fossil fuels push towards the use of alternative fuels such as ethanol. The changes in engine combustion and performance characteristics, when running on high percentage ethanol blends, should be taken into account in future flexi-fuel engine design.

**6.2 FUTURE SCOPE:**

1) Engine modifications should be done in order to use E40 blend without any engine running problems.

2) Ethanol can be blended with other fuels and may get optimum results.

3) Experiments could be carried on MPFI engines also.
4) Some other derivatives of alcohol can be blended with gasoline to obtain the optimum results.
5) Optimum value of ethanol can be varied to check for better performance analysis.
6) Experiments can be performed on CI engines also, to compare the performance analysis and comparison can be made for SI and CI engines using fuel blended with ethanol.
7) The effect of gasoline-ethanol mixtures on the combustion behaviour and heat transfer characteristics.
8) Further work investigating the heat transfer characteristics and combustion behaviour for different fuel blends should be carried out for other engine designs.
9) ANN (Artificial Neural Networks) Approach can be used for the Prediction of Thermal Balance of SI Engine Using Ethanol-Gasoline Blends.
10) Various Non-regulated emissions can also be analysed in near future and the same can also be predicted by ANN.