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Modelling of Manhattan K-Nearest Neighbor for Exhaust Emission Analysis of CNG-Diesel Engine

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ABSTRACT

Hybrid fuel for the operation of diesel engine is the motivated research in this study. The diesel engine is modified to operate with the hybrid diesel and compressed natural gas (CNG). In this work a four stroke, single cylinder diesel engine is considered to operate at variable load and speed. At is operation condition the emission characteristics are measured to model the proposed Manhattan K-nearest neighbor (MKNN) technique. The MKNN is modelled to effectively analysis and predict the torque, brake power, exhaust emissions and break specific fuel consumption (BSFC). The MKNN is modelled with the constant K=3 and applied Manhattan distance formula for neighbor determination. From the result analysis it is evident that the proposed MKNN technique can effectively predict the engine performance and exhaust emission while the usage of hybrid fuel.

Keywords: Hybrid fuel system; Compressed natural gas; Manhattan K-Nearest Neighbor; Manhattan distance; Diesel engine emission.

1. INTRODUCTION

Now a day's eco-friendly engines are suggested to use in automobiles and industries for prevent environmental hazards. In this sense usage of natural fuel become one of the suitable options for the eco-friendly engine design. Compressed natural gas CNG is the most used alternative fuel for Internal Combustion engines, and it is proved that the IC engine with CNG can effectively reduce the environmental population (Ghobadian *et al*. 2009; Yusaf *et al*. 1996; D'Amberosio *et al*. 2005). The usage of CNG in IC engines can also minimize the noise and vibration and enhance the brake thermal efficiency (Murata H 2000). While replacing the conventional fuel with the natural gas in commercial vehicles like, bus, passenger cars and heavy trucks provides numerous benefits some of them are (Cascetta *et al*. 2008; Fritz & Egbuonu, 1992; Gandhidasan *et al*. 1991);

- ✓ Particulate matter emissions can be significantly reduced.
- ✓ Maintenance and wear costs can be reduced.
- ✓ Also effectively reduces NOx emission

In the proposed paper, the single cylinder diesel engine is modified, so that it can operate on the both diesel as well as natural gas. The modified engine acts as dual fuel engine system can provide better performance. The following alteration is made to change the fuel compatibility of the engine; the compression ratio of the engine is reduced to prevent knock phenomena. A CNG injection is installed and modified the diesel injection system; and some minor modifications (Jonsson, 2000). A finite volume commercial CFD package is utilized to design Venturi mixer. (Sivakumar *et al*. 2017, Sathish 2017; Sathish and Jayaprakash, J. 2017; Sathish and Muthulakshmanan 2018; Sathish and Jayaprakash, 2015)

Testing modified engines under all possible operating conditions and fuel cases was considered to be both time consuming and expensive. Thus artificial intelligence technique is adapted to test all the engines under all the possible operating conditions. In this paper a Manhattan K nearest neighbor is proposed for the effective prediction of modified diesel engine to operate with hybrid diesel and CNG fuel.

2. RELATED WORK

Some of the recent work related to the usage of compressed natural gas fuel for the diesel engine is briefed below;

Salahi *et al.* (2017), have presented the effect of using a pre-chamber to extend some operating ranges in a Reactivity Controlled Compression Ignition engine. They also investigated the engine using coupled multidimensional computational fluid dynamics (CFD) with detailed chemical kinetic mechanisms. Heping Song *et al.* (2017), have presented a comparison of using diesel and polyoxymethylene dimethyl ethers (PODEn) as pilot fuels for natural gas DF combustion. Abhishek Paul *et al.* (2017), have investigated the effect of diesel, ethanol, and diethyl ether (DEE) blends on performance, combustion, and emission of single-cylinder compression ignition engine. Srinivasan (2017) studied and analysed about the missile with grid fins and the effect on flow drag using ANSYS. Godwin (2017) and Lakshmanan (2017) investigated about the optimum parameters for obtaining the best performance using alternate fuels of IC engines working under the current cooling system using Nanofluids.

3. EXPERIMENTAL INVESTIGATION

A single cylinder four stroke high speed diesel engine is modified to operate with hybrid diesel-CNG fuel is designed in the proposed work. The proposed modification on diesel engine is encouraged to reduce the environmental hazard. The main specification of the modified engine is given in table 1. The main idea for the major and minor modification of the diesel engine is referred from ref. (Yusaf 2009; Talal *et al.* 2010).

4. PROPOSED MANHATTAN K NEAREST NEIGHBOR

The K- Nearest neighbor is the straight forward classifier with greater accuracy. The classification in this algorithm depends upon the Manhattan similarity measure. The continuity of attributes is very much important in this process. The progression stages in the nearest neighbor algorithm are shown in figure 1.

Table 1 Specifications of the test engine

Engine type	Y170f vertical 4 stroke diesel engine
Bore	70 mm
Stroke	55 mm
Displacement	211 mm
Engine speed	3600 rpm (max)
Max. power	3.5 (kW)
Continuous power	3.13 (kW)
Compression ratio	16:1
Cooling system	Air cooled
Combustion system	Direct injection

$$RMSE = \left(\frac{\sum_j^n \left(t_j - o_j \right)}{n} \right) \tag{1}$$

$$MRE = \frac{1}{n} \sum_1^n \left| 100 * \frac{\left(t_j - p_j \right)}{t_j} \right| \tag{2}$$

The present work uses MKNN modelling to predict the relationship of brake power, brake specific fuel consumption, torque, emission components and brake thermal efficiency with the engine speed and percentage CNG as inputs. The MKNN is modelled with two inputs and nine outputs, which were obtained from the experimental analysis.

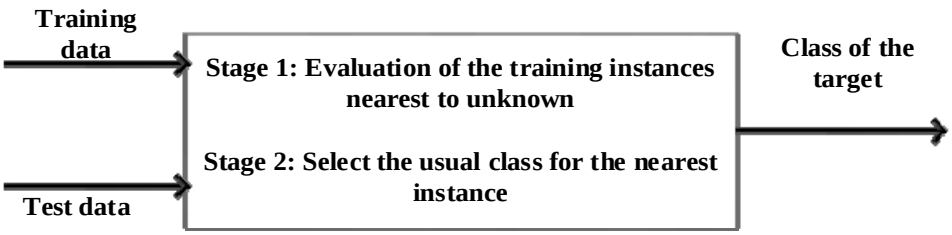

Fig. 1. MKNN classification with training and test data input for progression

Table 2 Performance value by proposed technique

Operating Condition	Torque	BTE μ_{th}	BSFC	Exhaust Temperature	CO	CO_2	NOx	O_2
1	11	28	222	203	21	2	22	12
2	18	31	236	240	43	3	36	14
3	24	35	254	290	85	6	54	15
4	29	36	278	320	92	7	87	18
5	34	39	298	395	118	8	99	21

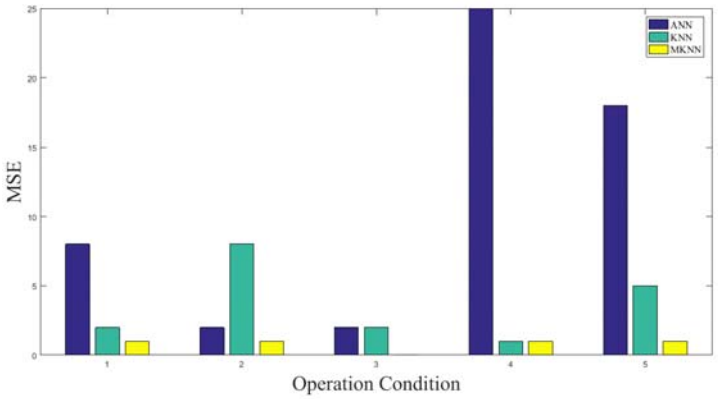

Fig. 2. Mean Square Error Comparison

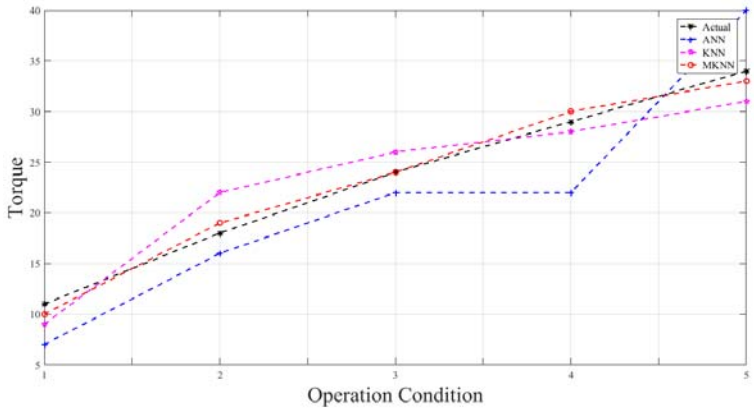

Fig. 3. Comparison of Torque (Nm)

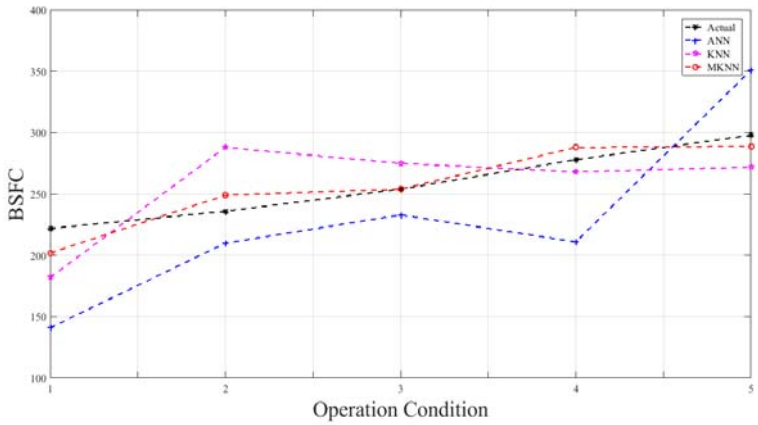

Fig. 4. Comparison of BSFC (g/kW.hr)

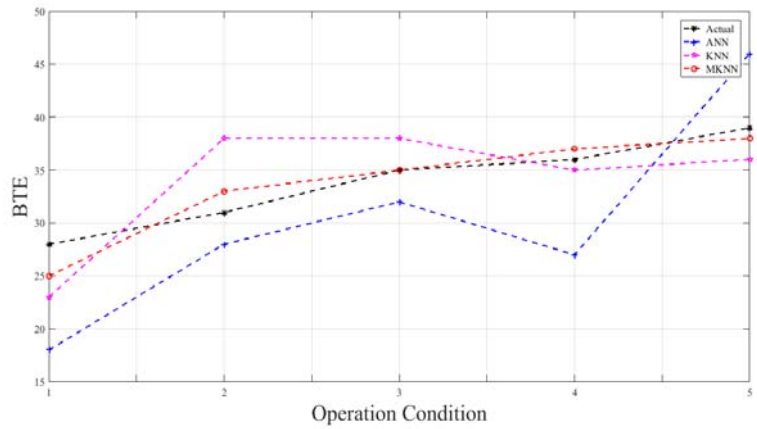

Fig. 5. Comparison of BTE μ^{th} (%)

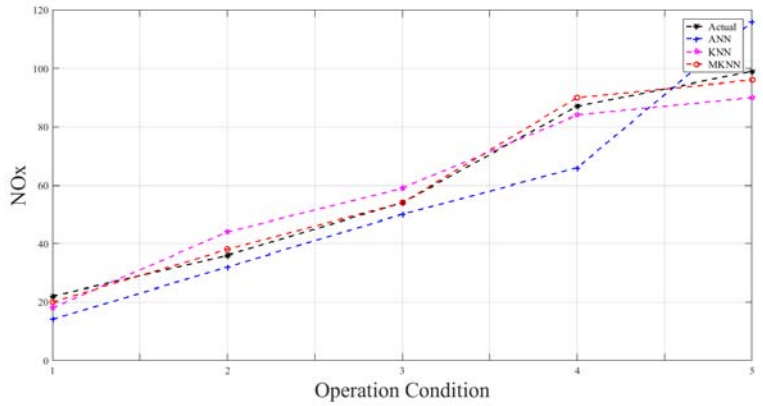

Fig. 6. Comparison of NO_x (PPM)

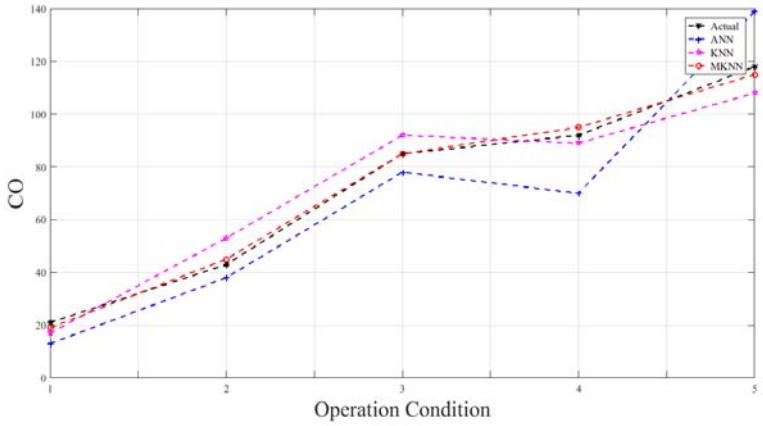

Fig. 7. Comparison of CO (%)

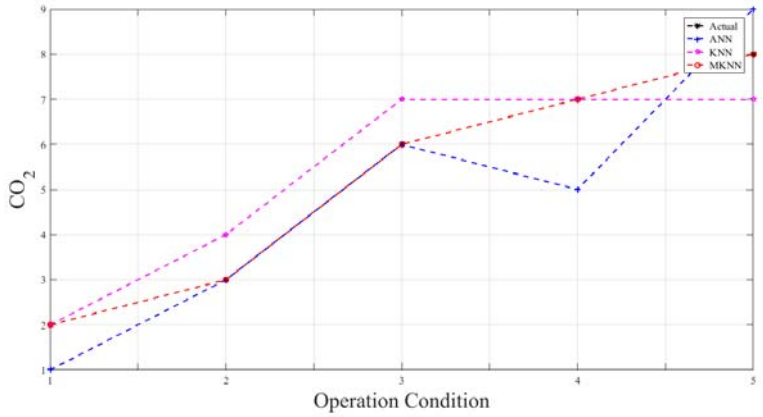

Fig. 8. Comparison of CO_2 (%)

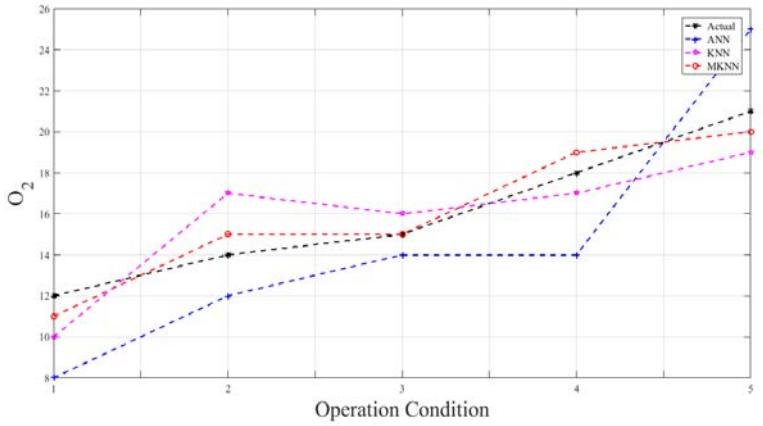

Fig. 9. Comparison of O_2 (%)

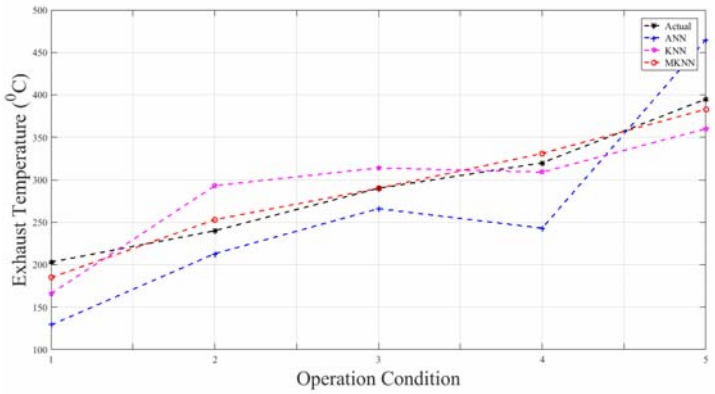

Fig. 10. Comparison of Exhaust Temperature (0^C)

5. RESULTS AND DISCUSSION

The proposed MKNN technique is modelled to analysis the testing performance of the modified diesel engine. The MKNN technique is modelled with two inputs and nine outputs and implemented in the matlab 2016a in windows platform. The prediction accuracy is evaluated by comparing the actual value with the predicted value. The obtained performance is given in table 2 and is plotted in the graphs given in fig 2 to fig 10.

So far performance analysis proved that the proposed MKNN technique provided better performance than the conventional prediction techniques such as ANN and KNN. Moreover the proposed technique predict the value which is closer to the actual value. Hence the proposed technique will become a better option for the analysis of modified diesel engine.

6. CONCLUSION

The hybrid fuel system for the modified diesel engine provided better eco-friendly performance and motivated to reduce the environmental hazard. The proposed hybrid fuel system combines both diesel and compressed natural gas. The diesel engine is suggested to modify its diesel injection system and install natural gas injection system. A novel Manhattan K nearest neighbor r technique is modelled to test the performance of the modified diesel engine. The performance evaluation proves that the proposed MKNN technique effectively analyzed the test performance and provided better prediction accuracy.

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