CONSTANTA MARITIME UNIVERSITY
FACULTY OF NAVAL ELECTROMECHANICS
DEPARTMENT OF MECHANICAL ENGINEERING

(abstract of PhD thesis)

Contributions in Studying NOx Emissions of Diesel Engines Used for Marine Applications

SCIENTIFIC COORDINATOR:
PhD. Engineer Paul BOCĂNETE

PhD candidate:
Mahran Dawwa

Constanta

2016

List of Contents

Thesis Summary

Chapter 1 explains the importance, the objectives, and the content of the thesis.

Chapter 2 is an introduction which explains the principles of diesel engines, the applications of diesel engines in marine sector, and diesel engines exhaust emissions and their impacts on the environment.

Chapter 3 a thermodynamic model based on two-zone model was performed to predict NOx emissions from diesel engine at different engine operating regimes. Al the phenomenon such as heat release, heat transfer, and ignition delay which take place into combustion chamber were explained and modeled. an improvement was introduced in order to enhance the accuracy of the model by modifying two vibe function by using a third function, which resulted in improving the flexibility of two vibe function in describing the heat release phenomenon in diesel engines at different engine operating regimes

Chapter 4 In this chapter, a CFD model was performed to predict NOx emissions from diesel engines. For this purpose a combustion chamber geometry was created by using SOLIDWORKS program, then the geometry was imported, decomposed, and meshed by using ANSYS ICE program. For the sake of predicting NOx emissions, different physical processes were simulated, such as the injection process, the flow inside the engine cylinder, and combustion process. The simulation process was carried out by the use of KH-RT model for simulating injection process, K-epsilon model for simulating the turbulence inside the combustion chamber, three different combustion models laminar finite-rate model, eddy-dissipation model, and finite-rate/ eddy-dissipation model. NOx emissions modeling was performed based on resolving the transport equation for nitrogen monoxide NO

Chapter 5 is the experimental section, engine test stand and all sensors which were used for measuring the different parameters were illustrated in this chapter.

Chapter 6 NOx emissions where predicted at different engine operating regimes by using a thermodynamic model based on two-zone thermodynamic model and other sub-models such as heat release model, and heat transfer model. The program that was created on MATLAB program shows that it is able to predicted NOx emissions at different engine regimes with a satisfied accuracy. The results were very satisfied in terms of accuracy when they were compared and validated with the experimental measurements. The results show that CRI-MECH 3.0 equation is more accurate in predicting NOx emissions than Heywood and Baulch et al. equations. Introducing a correlation coefficient is the second enhancement which improved the accuracy of thermodynamic model at low and high loads, and maintained a good accuracy at medium loads. Sensitivity analysis showed the influence of different parameters such as the temperature of residual gases, vibe function parameters, and the parameter of burned zone temperature on the model sensitivity.

The results of simulation study show that eddy-dissipation model is more accurate in predicting NOx emissions from diesel engines than laminar finite rate model. The results of simulation study by using eddy-dissipation model show that eddy-dissipation model is able to predict NOx emissions from diesel engines at different engine operating regimes with a good and satisfied accuracy. CFD model is able to predict thermal NO and prompt NO. The contribution of thermal NO and prompt NO in the total predicted NO was illustrated and explained, while thermodynamic model is just able to predict thermal NO, All simulated, modeled, and experimental results confirmed that the formed NOx are linked with engine operating regimes. Increasing the engine load at the same engine speed leads to increase the formed NOx, while increasing the engine speed at same engine loads leads to reduce the formed NOx emissions.

Chapter 7 After the validation of the results of CFD model at different engine operating regimes, the CFD model was used in simulation studies for simulating the effect of injection timing, cone angle, injection angle, and EGR on the formation of NOx emissions. Every simulation case was compared with the base case that validated with the experimental measurements. Simulation study was performed to show the effect of the combined use of EGR and retarded injection timing on the formation of NOx emissions, this study used two different EGR rates and two different injection timing. The results of simulation study confirmed that NOx emissions can be reduced by using EGR technology. The results of simulation study confirmed that NOx emissions can be reduced by retarding the injection timing. The simulation study showed that by the combined use of EGR and retarded injection timing, NOx emissions were reduced. Two different strategies of the combined use of EGR and retarded injection timing were discussed and illustrated. The results of simulation study show that injection angle and cone angle are an important factors that influence the formation of NOx emissions in diesel engines.

Personal contribution

The main personal contributions can be listed as follows:

- Building a specialized program on MATALB which is able to predict NOx emissions from diesel engines at different engine operating regimes.
- Introducing a correlation coefficient for improving the accuracy of the thermodynamic model in NOx prediction.
- Detailed description of the designing steps of combustion chamber geometry, and the steps of preparing the geometry to be used in simulation study.
- Simulating thermal NO and prompt NO by using three different combustion model and by the use of ANSYS program.
- Simulation study of the effect of EGR technology on the NOx formation in diesel engine
- Simulation study of the effect of injection parameters such as injection timing, cone angle and injection angle on the NOx formation in diesel engines.
- Simulation study of the effect of two different strategies that combine EGR and retarded injection timing on the NOx formation in diesel engines.

Publications

- Dawwa M., CFD Simulation of Injected Fuel Spray in Marine Diesel Engines, International Journal of Scientific Research,Vol.4, Issue 7, pp.124-127, 2015.
- Dawwa M., Simulation of Combustion Process in Diesel Engines Based on Eddy Dissipation Model, Proceedings of the International Conference of Mechanical Engineering ICOME2015, Craiova, Romania, October 8th -9th , 2015.
- Dawwa M., Baboiu I.L., Simulation and Modeling of Compression Stroke in Diesel Engines, Proceedings of the International Conference of Mechanical Engineering ICOME2015, Craiova, Romania, October 8th -9th , 2015.
- Dawwa M., Bocanete P., A CFD study on the effect of injection parameters on the formation of NOx emissions in diesel engines, Journal of Marine Technology &Environment, Vol.1, pp.29-32, 2016.
- Dawwa M., Bocanete P., The preduction of NOx emissions from diesel engines based on two-zone thermodynamic model, Journal of Marine Technology &Environment, Vol.1, pp.33-36, 2016.
- Dawwa M., Bocanete P, CFD study on the reduction of NOx emissions from marine diesel engines, Constanta Maritime University Annals, Vol.24, pp.63-66, 2015.
- Dawwa M., Bocanete P., Prediction of NOx emissions from marine diesel engines based on eddy dissipation model, Constanta Maritime University Annals, Vol.24, pp.67-70, 2015.
- Dawwa M., Zakria Y., Predicting the Fluid Flow Shape in the Combustion Chamber of an Internal Combustion Engine by Using CFD Simulation, Journal of Ecomomics and Technology Knowledge, Vol.1, No.3, pp.67-72, 2015.

Future studies

NOx emissions are considered one of the main challenged issues that face diesel engine companies and developers especially after implementing a new regulations of NOx emissions from marine diesel engines. Reducing the emitted NOx with maintaining fuel consumption without any increase will be the focus point on the future study. The main two directions that can be followed are:

- The combination of different reduction technologies such as the combination between EGR and pilot injection.
- Studying the possibilities of reduction the NOx emissions by modifying the combustion chamber shape.