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EFFECT OF INTERCOOLER ON TURBOCHARGED DIESEL ENGINE PERFORMANCE

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ABSTRACT
Efficient way which currently uses to reduce the fuel consumption is based in reduction cylinder volume of internal combustion engine and power to be same or higher. Key component is turbocharged diesel internal combustion engine.
Increased air pressure outlet compressor can result in an excessively hot intake charge, significantly reducing the performance gains of turbo charging due to decreased density. Passing charge through an intercooler reduces its temperature, allowing a greater volume of air to be admitted to an engine, intercoolers have a key role in controlling the cylinder combustion temperature in a turbocharged engine.
In this paper through own worked out programmed code in MATLAB will presenting effect of intercooler (as a heat exchange device air-to-liquid with three different size and over – all heat transfer coefficient and one base) at e multi-cylinder engine performance for operation at a constant speed of 1600 RPM. Will presenting simulation predictions of temperature and pressure in cylinder for three tip of intercooler. Also we present the pressure and temperature in intake, exhaust manifold and other performance.
Keywords: internal combustion diesel engine, turbo charging, compressor, turbine, intercooler, simulation, modeling, intake and exhaust manifold, etc.

1. INTRODUCTION
Improving the fuel economy of diesel engines for automotive applications has a higher priority this decade. The driver of this strong focus is concern over Global Warming and the connection between fuel consumption and emissions of the greenhouse gas, carbon dioxide.
From European Automotive Manufactures requires average emissions for new cars are reduced to 140 g/km by 2008. This implies a reduction in fuel consumption of more than 25% from a 1995 baseline. An even more stringent CO_2 target of 120 g/km is under consideration for 2012.
One of the most effective strategies is *engine downsizing*. Downsizing, the use of a smaller capacity engine which operating at high specific engine loads, can be achieved by running with high levels of pressure boosting at full load using a supercharger or turbocharger although technical and market acceptance issues are not fully resolved. Compressors do not always operate at the same levels pressure boosting. Level of pressure boosting that compressor produces depends on the volumetric flow into it and the rpm that is turning. The performance of the compressor can be shown on a graph by a series of curves (compressor map). High levels of pressure boosting compressing air increase its temperature, which can cause a number of problems. The intercooler, situated between the compressor discharge and the intake manifold, serves to lowering charge air temperature by increase the its density. Intercooler is a type of heat exchanger which gives up heat energy in the charge to the ambient air.

2. INTERCOOLER MODEL

The intercooler is modeled as a heat exchanger (figure 1) with fixed area, heat transfer coefficient and cooling volumetric flow. Decrease of charge air temperature is determined from heat exchanger effectiveness (ε_i):

$$\varepsilon_i = \frac{rtemp(2) - hi(3)}{rtemp(2) - hi(2)} \qquad \ldots(1)$$

where is:

rtemp(2), K – compressor discharge temperature,
hi(3), K – intercooler discharge temperature and
hi(2), K – Coolant inlet temperature (is assumed to be fixed).

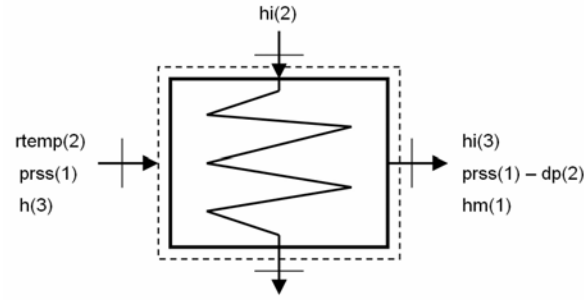

Figure 1. Schematic of Intercooler

The heat exchanger effectiveness can be derived from graphic correlations for the various types heat exchanger (6). Effectiveness can be determined with capacity ratio and the number of heat transfer unit, the expression for effectiveness is a simple form;

$$\varepsilon = 1 - e^{(-N_S)} \qquad \ldots(2)$$

Number of heat transfer unit (N_s) is determined from:

$$N_s = \frac{S \cdot U}{cmap(1) \cdot c_p} \qquad \ldots(3)$$

where is:

S, m^2 – Surface area heat Exchange (is fixed),
U, J/m^2K – heat transfer coefficient based on surface area S and
$cmap(1)$, kg/s – flow rates charge air and
c_p, J/kgK – specific heats at constant pressure.

In this paper is obtaining four types of intercooler:

1. Intercooler $S{\cdot}U$= 1000,
2. Intercooler $S{\cdot}U$= 1200 (base),
3. Intercooler $S{\cdot}U$= 1400 and
4. Intercooler $S{\cdot}U$= 1600. .

3. COMPARISON OF MODEL PERFORMANCE RESULTS AND MANUFACTURERS DATA

In this paper through own worked out programmed code in MATLAB [3] for model (figure 2) will presenting effect of intercooler (as a heat exchange device air-to-liquid with three different size and over – all heat transfer coefficient and one base) at e multi-cylinder engine performance for operation at a constant speed of 1600 RPM.

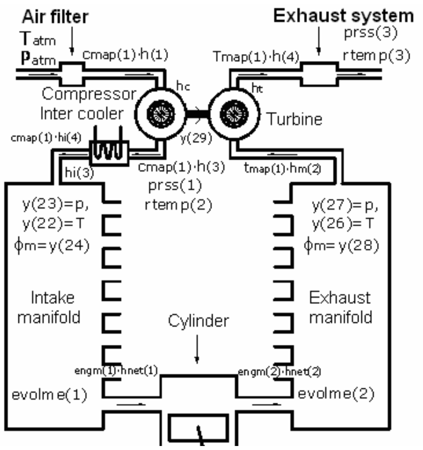

Figure 2. Model view

Effective Performance data (Table 1 – black for S·U= 1200 base) of the engine **Cummins** type **N14-M** are taken for the comparison with predicted by simulation same type of intercooler S·U=1200. Difference between data and prediction of simulation is 0.46 %.

Table 1. Comparatives between data and prediction.

S·U	1200	**1200**
Value	Heavy duty	
rpm	1600	**1600**
kW	258.80	**260,00**
l/h	60.60	**60.60**

4. RESULT OF SIMULATIONS

From the program, besides effective parameters of the engine, there can be gained other data in the function of crank shaft angle: Pressure, Temperature and average equivalent ratio in the cylinder, intake manifold, exhaust manifold, etc.

Next are shown some examples of calculation of temperature in the engine cylinder (figure 3), temperature in intake manifold (figure 4) and intake manifold air mass (figure 5), for three different tips of intercooler and base as a function of crank angle, for engine speed 1600 RPM (min^{-1}) for heavy duty load operation.

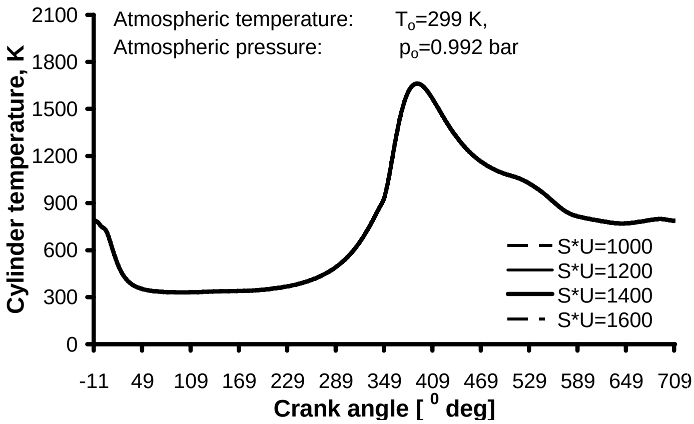

Figure 3. Cylinder pressure predicted by the simulation as a function of crank angle

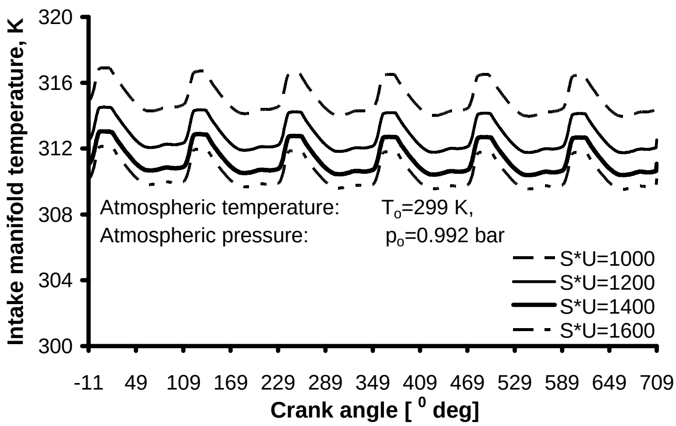

Figure 4. Intake manifold temperature predicted by the simulation as a function of crank angle

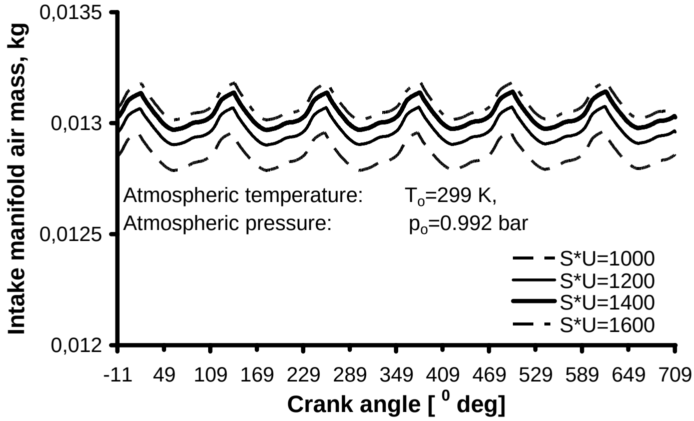

Figure 5. Intake manifold air mass predicted by the simulation as a function of crank angle

Also we present engine and intercooler performance at table 2.

Table 2. Engine and intercooler performance

*S*U*	1000	1200	1400	1600
Volumetric efficiency, %	80.23	80.72	81.01	81.20
Power, kW	258.11	258.81	259.20	259.47
rtemp(2), K	387.97	387.86	387..82	387.79
hi(3), K	311.50	309.02	307.60	306.54
ε, -	0.92	0.95	0.97	0.98
Maximal temperature in cylinder, K	1665.60	1666.50	1661.70	1659.19

5. CONCLUSIONS

Maximal temperature in engine cylinder is decreasing from 1665.6 K at SU =1000 to 1659.2 K at SU=1600, sometimes engine power and volumetric efficiency is increased. Also intercooler performance is increased with increased the design parameter.

The curves in the graphs for temperature and air mass in intake manifold have the same behavior, i.e., a series of six identical repeating pulses, each produced by filling process of the individual cylinders of six cylinder engines. The curve in the graphs for temperature of intake manifold has a same behavior, each produced by empting process of the individual cylinders of six cylinder engine. Intercooler efficient is 0.92 at SU =1000, respectively 0.98 % at SU=1600.

According the achieved results by simulation of processes turbocharger engine may notice that presented model for chosen intercooler is a good base for system in downsizing concept.

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