Heat Dissipation Analysis of UTHM Chassis Dynamometer

W. S. Jiung, M. F. M. Ali, M. A. H. Mohamad and A. Mohammed

Abstract—Chassis dynamometer, as available in UTHM's automotive laboratory, are suitable for measuring torque and power produce by a vehicle; the reading produced are indicative of the vehicle's performance on the road, considering the losses due to friction in the mechanical components. A major problem that could affect the dynamometer readings accuracy is the high temperature reached by the system after prolong usage. This is due to excessive heat produced at high operational loads. Thus a study was done to determine whether enough heat dissipation can be achieved at maximum operation load. This project seeks to improve the cooling efficiency of the dynamometer cooling system though several means. Firstly, the piping system was reconfigured to increase the surface contact with the cooling fluid, thus improving the heat transfer. Secondly, a cooling fluid that has a higher specific heat capacity was added to the existing water circulation so that more heat can be rejected at the same flow conditions. The results were compared with the existing data to determine the level of improvement achieved at the end of the project.

Keywords: chassis dynamometer, heat exchanger, cooling efficiency

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I. INTRODUCTION

A **dynamometer** or **"dyno"** for short is a machine used to measure torque and rotational speed (rpm) from which power produced by an engine, motor or other rotating prime mover can be calculated. A dynamometer can also be used to determine the torque and power required to operate a driven machine such as a pump. In that case, *motoring* or *driving* dynamometer is used. A dynamometer that is designed to be driven is called an *absorption* or *passive* dynamometer. A dynamometer that can either drive or absorb is called a *universal* or *active* dynamometer [1].

In addition to being used to determine the torque or power characteristics of a machine under test (MUT), Dynamometers are employed in a number of other roles. In standard emissions testing cycles such as those defined by the US Environmental Protection Agency (US EPA), dynamometers are used to provide simulated road loading of either the engine (using an engine dynamometer) or full power train (using a chassis dynamometer). In fact, beyond simple power and torque measurements, dynamometers can be used as part of a test bed for a variety of engine development activities such as the calibration of engine management controllers, detailed investigations into combustion behavior and tribology. A chassis dynamometer measures power delivered to the surface of the "drive roller" by the drive wheels. The vehicle is often parked on the roller or rollers, which the car then turns and the output is measured. Modern roller type chassis dyne systems use the Salvisberg roller, which improved traction and repeatability over smooth or knurled drive rollers. Other types of chassis dynamometers are available that eliminate the potential wheel slippage on old style drive rollers and attach directly to the vehicle's hubs for direct torque measurement from the axle. Hub mounted dynos include units made by Dynapack and Rototest. The chassis dynos can be fixed or portable. Modern chassis dynamometers can do much more than display RPM, Horsepower, and Torque. With modern electronics and quick reacting, low inertia dyne systems, it's now possible to tune to best power and the smoothest runs, in real-time [1].
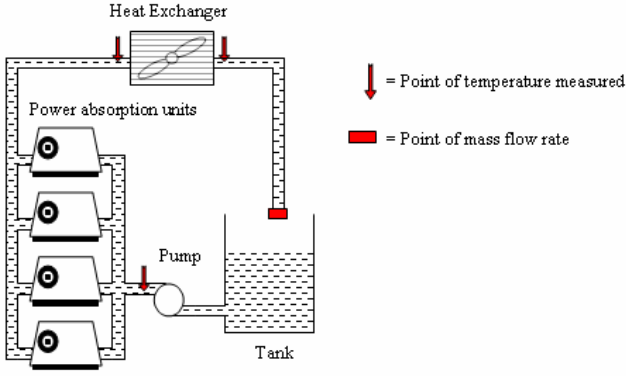
II. DYNO PIPING DIAGRAM

Figure 1: Dyno piping diagram

III. BASIC EQUATION FOR CALCULATION
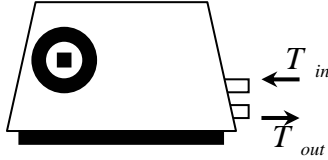
Heat generates by the power absorption units.

Figure 2: Power absorption units

For 4WD, there are four power absorption units. Assume that all four are generate equal amount of heat. This is because the pressure applies as load among of them are same. Hence, the total heat generate can be measured at the inlet of the heat exchanger. It can be used to measure the heat generate by two power absorption units or four. Most of the cars are two wheel drives. Hence, in this thesis only the two wheel drive vehicles are tested.

Heat generate can be calculate using the first law of thermodynamics. Assume that the liquid steady flow system [2];

$$\dot{Q} = \dot{m}c_p \Delta T \tag{1}$$

where

$\dot{Q}$ = the rate of net heat transfer into or

out of the control volume.

$\dot{m}$ = the mass flow rate

$$\Delta T = T_{out} - T_{in} \tag{2}$$

= The difference of the temperature

out and into the control volume

Heat Transfer rate of the water,

$$\dot{Q} = \left[\dot{m}c_p \left(T_{in} - T_{out}\right)\right]_{water} \tag{3}$$

$$\dot{Q} = UA_s F\Delta T_m \longrightarrow U = \frac{\dot{Q}}{A_s F\Delta T_m} \tag{4}$$

where

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} \tag{5}$$

$A_s = n\pi D_i L$ = total surface area of the tubes

D_i = internal diameter

L = length of the tube

n = number of tubes

$$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{\left(\dot{m}c_p\right)_{tubeside}}{\left(\dot{m}c_p\right)_{shellside}}$$

$$P = \frac{t_2 - t_1}{T_1 - t_1}$$

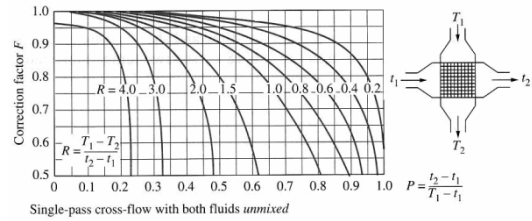$$\left.\begin{array}{c} \\ \\ \end{array}\right\} F \tag{6}$$

Figure 3: Correction factor F charts for common shell-and-tube and cross-flow heat exchangers (*From Bowman, Mueller, and Nagle*) [3]

After calculate the ratio of R and P using the graph in Figure 3, thus find the correction factor, F at y-axis.

Substituted all data get into Eq 5 and obtained the overall heat transfer coefficient, *U*. The heat transfer coefficient uses to calculate the heat dissipate by the heat exchanger.

IV. RESULTS AND DISCUSSION

The purpose of the test is to analyze whether the existing cooling system can dissipate the heat generated by power

absorption units that function on full load testing. The full load test can be conducted using constant speed test. The dyno computer system will measure and apply the load to constantly maintain the speed that has been set. The temperatures were measured at three points, which are pump discharge, heat exchanger inlet and outlet. It can be use to observe whether the power absorption units are overheated. Once the power absorption units are overheated, the test must be stop to prevent the heat damage the power absorption units. The temperature that activates the alarm of dyno is 55 ℃. The way to prevent it from overheating is by observe the temperature of heat exchanger inlet. If it reaches the temperature 55 ℃, the alarm will ring after 1.5 minute if the tests not stop. It will delay 1.5 minute because it take time for the hot water flow to collected and into the inlet if heat exchanger. This is very useful to care the dyno from damage due to high temperature.
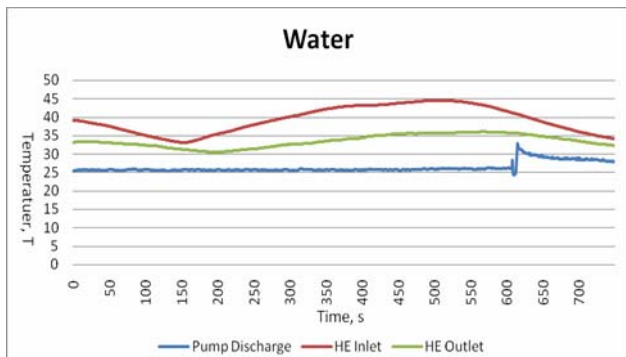

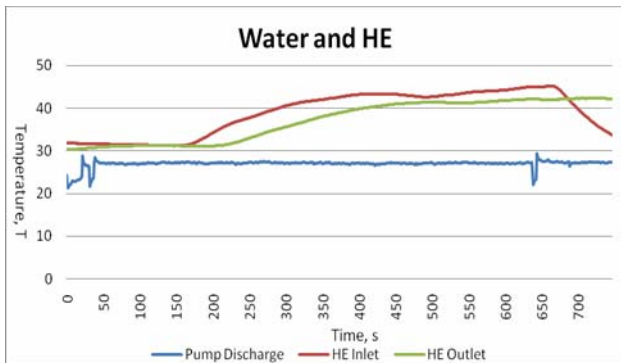Figure 4: Temperature of cooling only with water versus time

Figure 5: Temperature of cooling with water and heat exchanger versus time

Figure 4 and 5 shows the ability of the existed cooling system which is heat exchanger cooling effect. The speeds are varied between 2000 rpm to 4000 rpm. Each speed was tester with full load for 10 second and stop for 90 second. Notice that the test with heat exchanger will give faster cooling effect. The ratio of the time for cooling down the temperature to 34 ℃, with heat exchanger to without it is

1:2.83. Thus, we know that the heat exchanger can dissipate 50 % of the heat generate by the Dyno.
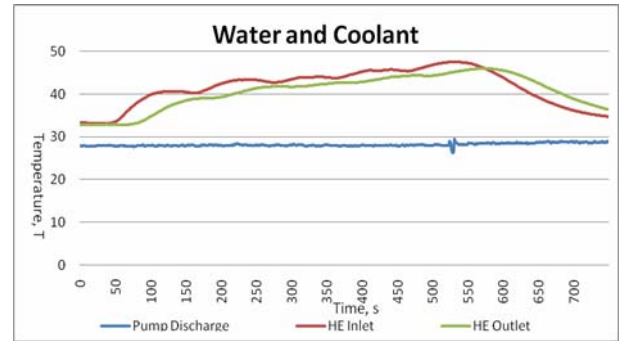

Figure 6: Temperature of cooling system with coolant versus time

Figure 6 shows data obtained from the test with only coolant and water. The purpose is to observe that how far the effect of the coolant to the system. It is clearly show that the coolant will reduce the cooling time and increase the capacity of water carry the heat generates by dyno. The dyno will give 90 second of rest before start the next test. The temperature is remaining constant once the dyno stop. This will prevent the increasing continuous of temperature and overheat. Compared to the Figure 3, the maximum temperature of test with coolant is higher 3.07 ℃ than without coolant. The coolant will only prevent the temperature increase after the dyno stopped, but the cooling effect is lower than the test only with water.
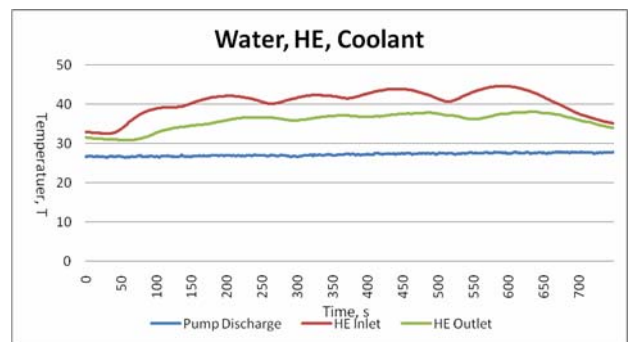

Figure 7: Energy of exhaust gas variation versus inlet air temperature

The coolant and heat exchanger can be a good combination. The maximum temperature is not reduce in all the figure but the time of cooling have achieve the great improve, which is reduce by 38 %.

V. CONCLUSIONS

From the project it can be concluded that the cooling system has successfully improved with the mix of coolant into the water. Cooling time has been reducing by 38 % but the heat exchanger is still need to reduce of heat transfer to tank.

REFERENCES

[1] Dynamometer - Wikipedia, the free encyclopedia (2008, November 15). Retrieved November 16, 2008. From en.wikipedia.org: http://en.wikipedia.org/wiki/Dynamometer.

[2] Yunus A. Cengel and Michael A. Boles, *Thermodynamics An Engineering Approach*. 5th ed. McGraw-Hill, 2006.

[3] Yunus A. Cengel, *Heat and Mass Transfer: A practical Approach*. 3rd. ed. McGraw-Hill, 2006.