The impact of the *Turbo Saviour* on turbocharger bearing temperatures

Introduction

Turbochargers use oil to lubricate their turbine shaft and bearings, and to carry heat away from the turbine assembly. If the flow of oil becomes restricted or stops whilst the turbine is still hot, the resulting high bearing and turbine shaft temperatures can lead to "coking" of the residual oil and, ultimately, bearing failure[1].

Premature turbocharger bearing failure can arise through restrictions in the oil supply lines or galleries, inadequate oil pressure, or poor shutdown procedures such as shutting the engine off without first allowing the turbine and its housing to cool. The latter is a significant problem, since heat transfer occurs from the spinning, hot turbine into the bearings, which are no longer being lubricated by flowing oil; this heat transfer is also known as "heat soak".

To avoid heat soak, a common practice with turbocharged engines is to idle for a few minutes prior to shutting down. Alternatively, a post-lubrication system can be installed in order to maintain the flow of lubricating oil for an appropriate time after shutdown. One such system is the *Turbo Saviour*[2].

To demonstrate the effect a post lubrication system such as the *Turbo Saviour* can have on heat transfer in a diesel engine turbo-charged motor, we undertook some tests using a utility (Toyota, Hilux) equipped with an oil-cooled, aftermarket turbo system (Denco, Schwitzer).

Method

The tests were focussed on the temperature of the bearings that support the turbine/compressor shaft. We attached thermocouples (K-type, mineral insulated, stainless steel sheathed, D&N Engineering Supplies) to the turbine and bearing housings (top side), as well as the oil inlet and outlet connections; note that the latter were not in direct contact with the oil. Another thermocouple was used to monitor the exhaust gas temperature. To install the thermocouples in the turbine and bearing housings, small hollows were drilled into their cast iron surface to a depth of 1 mm. This allowed us to place the thermocouple sheath into the hollow, and keep it in contact with the metal surface at all times during the test. The thermocouple sheaths had a diameter of less than 1 mm, ensuring they responded quickly to temperature changes.

The *Turbo Saviour* was configured so that it could be switched in and out of the turbocharger lubrication circuit using a 3-way valve, which allowed for quick changeover during the tests.

The test protocol consisted of driving the vehicle under loads that caused the exhaust gas to reach temperatures of over 500 °C, until the turbine housing surface reached temperatures that ranged from 250 to 400 °C. Once the required turbine housing temperature was achieved, the vehicle was stopped and the engine shut off either immediately, or after 1 or 3 minute idle periods, and the temperatures at each thermocouple recorded at 2 second intervals.

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[1] Polichronis, D, et al., *Turbocharger Lubrication - Lubricant Behavior and Factors That Cause Turbocharger Failure,* International Journal of Automotive Engineering and Technologies, 2013, Vol. 2, Issue 1, pp. 40 – 54.

[2] http://www.turbosaviour.com.au/ (Accessed 9/11/2016)

Results

Turbine Housing Temperature

The turbine and its housing are heated by the exhaust gas, whose temperature increases with engine load. While the exhaust gas temperature responds very quickly to the engine power, the thermal mass of the turbine means it takes time to both heat up and cool down. Figure 1 shows a cooling curve for the turbine housing recorded after running the engine under load and then shutting it off immediately.

The cooling curve can be decomposed into two components: a slower decay most likely due to cooling by convection (heat transfer to the air), and a faster process due to conduction through to the remainder of the turbocharger assembly, namely the bearing (centre) housing and the compressor.

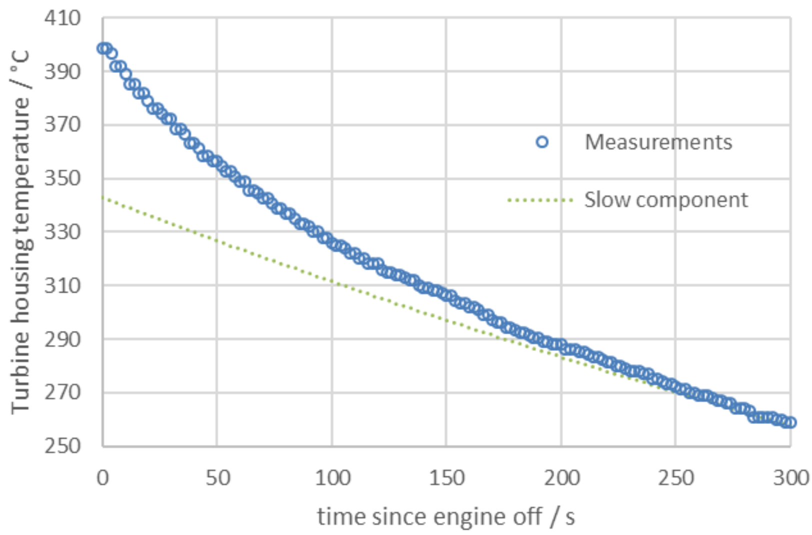

Figure 1: Cooling curve for the turbine housing

Shutting down

The heat transfer processes from the turbine housing are also occurring whilst the engine is running, but in this case, the heat that is transferred to the turbine shaft bearings is removed by the lubricating oil. When the engine stops, so does the oil flow, but because the heat transfer continues (Figure 1), we expect an increase in the bearing temperature. Note that although the engine has stopped, the turbine will continue to spin, causing additional frictional heating of the bearings in the absence of lubrication.

Figure 2 provides an example of what happens to the bearing housing temperature when the engine is switched off after running under load. Heat is conducted from the turbine housing and turbine into the bearings and bearing housing. With no oil flowing, the bearing housing temperature climbs to 25 °C higher than its initial temperature, and only starts cool back down after 4 minutes. The continued oil flow provided by *Turbo Saviour* maintains the housing at close to its initial temperature for at least 5 minutes after the engine has been switched off.

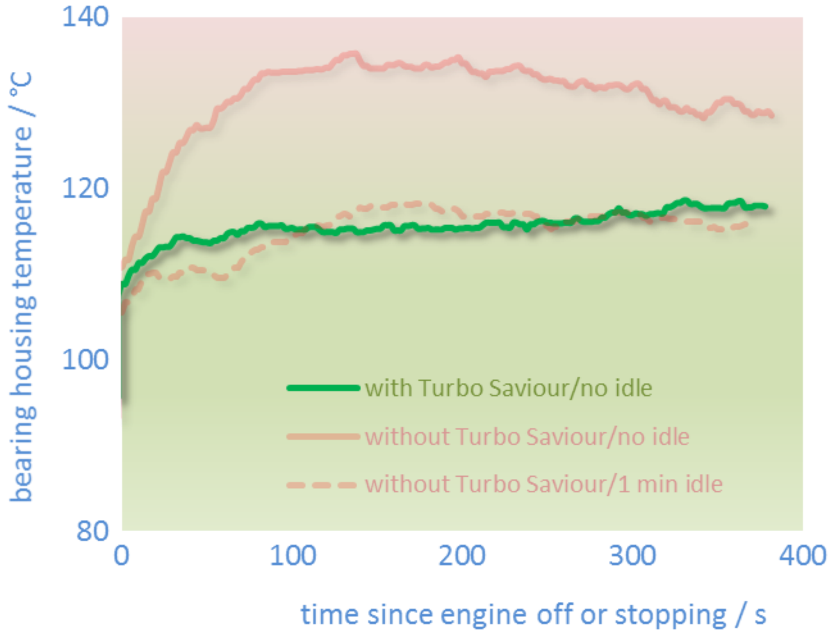

Figure 2: Bearing housing temperatures following engine shutdown.

Figure 2 also shows the effect of idling for 1 minute prior to shutting the engine off. As expected, after idling, without the *Turbo Saviour* the bearing housing surface temperature reaches a lower peak than occurred without idling, but still slightly higher than occurred when the *Turbo Saviour* was used (without idling).

Assuming heat is transferred via conduction, we expect that the maximum temperature attained by the bearing housing will be proportional to the temperature of the turbine housing when the engine is shut down. This is shown in Figure 3, which demonstrates that, for this type of turbocharger, maintaining low bearing temperatures is not possible if the engine is shut down immediately after use under high loads, unless a post-lubrication system such as the *Turbo Saviour* is fitted. At the highest load achieved the bearing housing reached temperatures of 175 °C in the absence of oil flow.

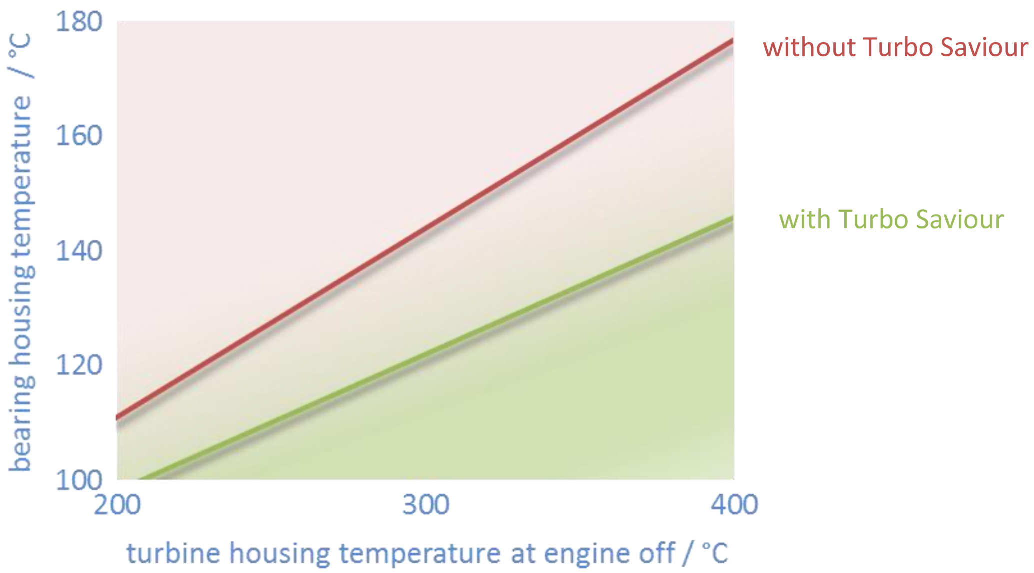

Figure 3: Bearing housing temperature peak achieved as a function of turbine housing temperature (engine load).

It is worth noting that in these tests it is the bearing housing surface temperature that is being measured; the internal bearing temperatures would be higher, particularly at the bearing close to the turbine. The onset of oil coking, particularly in used oil, can occur at temperatures as low as 150°C[1]. In such cases, even moderate loading of the engine followed by immediate shut down would be expected to cause oil coking in the absence of post-lubrication.

Conclusions

A post-lubrication system such as the *Turbo Saviour* clearly provides cooling oil flow through the turbocharger system after the engine has been shutdown. This results in a significant reduction in the temperature to which the turbo bearings are exposed, limiting the chance of oil degradation and the long-term degradation of both the bearings and the oil distribution galleries. This is especially important in situations where the engine is shut down immediately after being under high load, but also helps to cool the bearings further when using a shutdown procedure that involves idling.