ENIGMA AUTOMOTIVE FORENSIC SERVICES C.C.
(CK 97/44485/23)

Facilitation of Forensic Investigations
Vehicular Fire Investigations
Failure Analysis, Mechanical Damage
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P.O. Box 13429
Elspark
1418
Germiston
☎ (011)894 1257
🖷 (011)219 7109
E-mail: info@autoforensics.co.za
www.autoforensics.co.za

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5th June 2014

Go Power & Developments
19 Eleven Street
Springs
1560

Attention : Mr. Bradley Leach

Order Reference No.: Verbal - COD

TECHNICAL INVESTIGATION REPORT: LJ07-0614

Customer	: Not Recorded	
Vehicle	: Mitsubishi Pajero 3.2DiD	*Reg. No*: Not Recorded
VIN Number	: Not Recorded	*Engine No.*: Not Recorded
Item/s examined	: One damaged diesel piston.	
Subject	: Condition Assessment and Piston Damage Analysis	
Date of investigation	: 4th June 2014	

1. Introduction:

We were commissioned by Go Power & Developments (hereinafter also referred to as the Client) to examine one damaged piston from a Mitsubishi 3.2DiD engine (hereinafter also referred to as the piston) and to identify the nature and proximate cause of the damage exhibited by the piston.

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1.1 Information Provided:

1.1.1. The subject piston was extracted from an engine that has already operated for approximately 300000Kms.
1.1.2. The vehicle was in the workshop at Go-Power Developments for work to be done on the engine.
1.1.3. The vehicle subsequently drove for approximately 3000Kms until the vehicle broke down due to the subject piston suffering damage in the form a hole being burnt through the crown.
1.1.4. No additional information was made available.

2. Investigation:

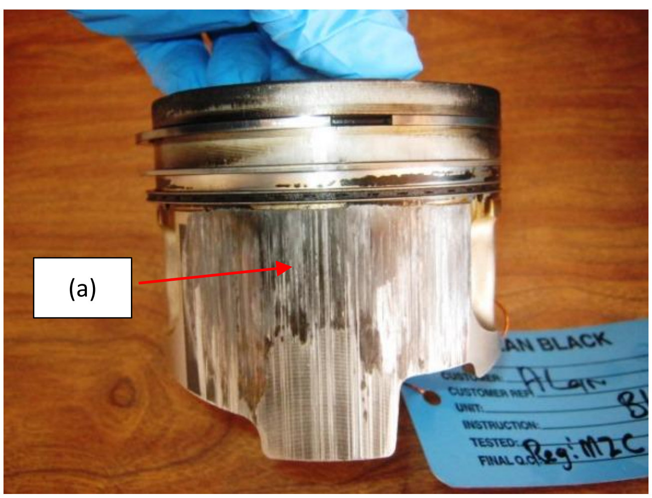
I examined the subject piston and made the following observations:

2.1. Constraints:

2.1.1. Only the one damaged piston was made available for examination. The condition of the rest of the engine and its associated and ancillary components is not known.

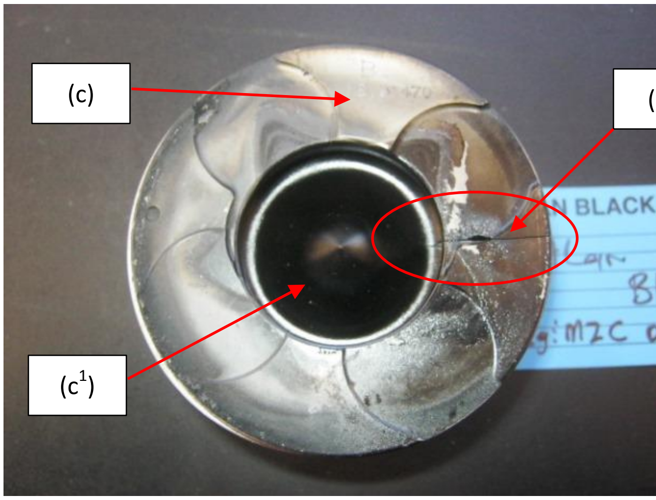
2.2. Component Examination:

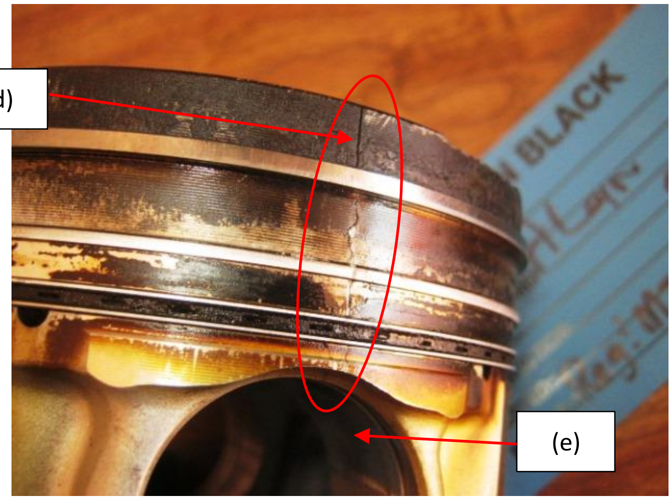
Examination of the subject piston revealed vertical piston to cylinder bore seizure damage (a) on one side of the piston's skirt on the thrust/ anti-thrust axis from below the oil ring groove downwards. The opposite side of the piston skirt depicted in the right frame below is free of any scuffing or seizure damage



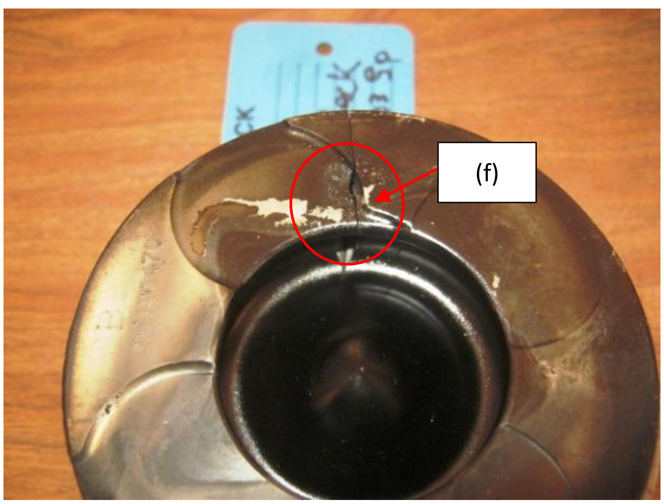
The piston rings (b) when inspected exhibited no evidence of any damage to the side or peripheral contact faces of the rings and a full circumferential contact pattern was noted on the peripheral sealing surfaces indicating the piston rings had been sealing and seating correctly on the cylinder bore surface. The piston rings are free in their respective grooves and no restrictions or resistance to their movement within the grooves was noted.

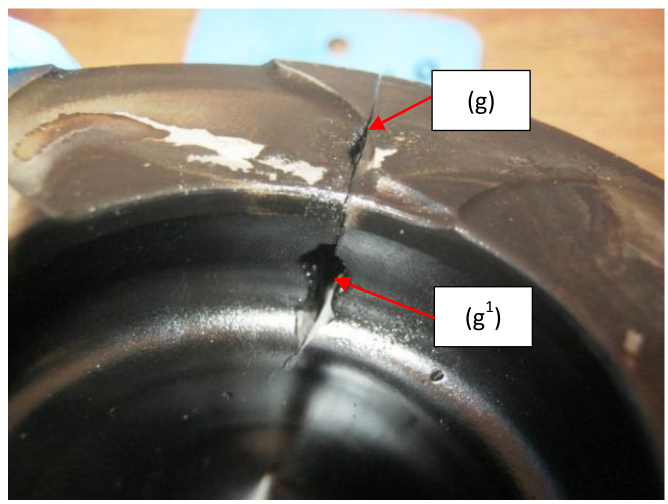
Close examination of the piston crown (c) and combustion bowl cavity (c^1) revealed a structural crack concentrated along the gudgeon pin axis of the piston and the crack has propagated from the rim of the combustion bowl cavity, across the crown and down through the piston ring zone into the gudgeon pin bore (e) on one side of the piston's minor or gudgeon pin axis.





The crack across the rim of the combustion bowl is located directly adjacent to the valve pocket in the crown surface. The area where the valve pocket recess interfaces with the combustion bowl (f) presents as a typical "stress raiser" location due to the acute angle prevailing in this area. Localised erosion of the piston's aluminium alloy material has occurred around the crack in the combustion bowl cavity resulting in the formation of a crater in the crown material (g) and a hole through the side of the combustion bowl (g^{1}).





3. Technical & General Discussion:

The damage exhibited by the subject piston is consistent with severe localised thermal overload conditions having been concentrated on the crown surface of the piston.

Abnormally high combustion chamber temperature conditions prevailing in the past resulted in the crown surface overheating. The dramatically elevated temperatures concentrated in the reduced cross section of material at the edge of the combustion bowl cavity where the valve pocket interfaces with the combustion bowl cavity caused this area to begin yielding and cracking when atomised diesel fuel which has a "quenching" effect is injected into the bowl and minute structural crack/s form across the rim of the combustion bowl.

Continued operation of the engine leads to the minor crack/s developing into larger fissure/s that begin propagating through the piston crown material into the ring zone and through into the oil drain holes or scuppers in the oil ring groove, etc. If left unattended this condition could develop into a catastrophic engine failure event.

During normal operation of the engine, the superheated and softened aluminium alloy material at the edge of the crack is "flushed" away with each new diesel fuel injection cycle and this leads to erosion of the piston material and the formation of a hole in the piston material sometimes with multiple holes forming along the crack path.

Thermal overload on the crown of an engine's pistons can occur due to a host of abnormal conditions including but not limited to one or a combination of the following:

a) Blocked or restricted exhaust passages or ports,
b) A cooling system related localised engine overheating condition,
c) Abnormal combustion activity caused through a diesel fuel injection system anomaly,
d) Low or poor compression pressure values in the cylinder/s,
e) Excessively high compression pressure values caused through excessive skimming of the cylinder head for example.
f) Sustained high load versus low rpm operation commonly referred to as labouring of the engine and/ or extended periods of idling,

At this stage the likelihood of a malfunctioning diesel fuel injector and/ or diesel fuel injection system can be excluded as there is absolutely no evidence of any typical fuel washing damage characteristics or indications of any fuel injection related anomalies resident on the piston skirt or the peripheral contact face of the piston rings.

The seizure on one side of the piston skirts is considered to be the result of the crack having propagated into the gudgeon pin bore thereby adversely affecting the gudgeon pin and the piston began "tightening up" on the pin and consequentially over-thrusting against the bore surface. Excessive piston thrust led to over-scraping of the piston's oil control ring on the bore surface and elimination of the surface lubrication on the cylinder bore surface and the piston begin running against a "dry" surface, hence the scuffing damage.

No damage characteristics were found during examination of the subject piston to suggest any defect with the piston in terms of its material, design or construction.

4. Conclusion:

In the light of the above observations and findings the following conclusions can be drawn:

- The damage exhibited by the subject piston is concentrated on the crown and in the combustion bowl cavity and on one side of the piston skirt on the thrust/ anti-thrust axis.
- The piston has cracked along the gudgeon pin axis as a result of severe thermal overloading of the piston crown material.

- Continued operation of the engine with the piston in a cracked state led to the aluminium alloy material along the edges of the crack melting and eroding with each new injection cycle.
- Piston crown cracking is a common phenomenon and occurs as a result of external influence acting on the component which in this instance is abnormally high surface temperature conditions concentrated in the piston crown material. Refer to the published literature relating to damage of this nature appended hereto in Appendix 1 below.
- There are several conditions that lead to crown cracking of this nature and given that only one piston has been affected at this stage, the condition/s that precipitated the crack formation are considered to have been concentrated in and around the affected cylinder.
- Based upon empirical damage of this nature, it is also considered highly probable that this condition was already in existence prior to the vehicle attending at Go-Power Developments for work to be done on the engine and the prevailing condition achieved a critical level in the approximately 3000Kms since leaving the workshop.
- This however at this stage cannot definitively be proved therefore further investigation is required using a process of elimination of the aforementioned factors and this will most likely serve to isolate and identify the offending condition.

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Yours sincerely,

L. Jenkinson
Automotive Specialist.

Appendix 1:

Piston damages

DESCRIPTION – ASSESSMENT – CAUSES

Damage assessment

As a result of the high thermal overload, the piston material is heated up significantly in localised areas where the prechamber jets reach the piston (prechamber engine) or on the edge of the bowl (direct-injection engines). In the heated up areas the material expands much more than elsewhere. As the overheated areas are not surrounded by any cold surrounding materials, the material at the hot, thermally overloaded area is permanently deformed beyond its limit of elasticity. Exactly the opposite happens when it then cools down again.

In the areas where before the material was buckled and forced away, there is now suddenly a shortage of material. This results in tensile stresses in this area which ultimately cause stress cracks (see Figs. 3 and 4). If in addition to the stresses resulting from the thermal overload there are also superimposed stresses caused by warping of the piston pin, then in some cases the stress cracks can turn into a much larger major crack which causes complete breakage and failure of the piston.

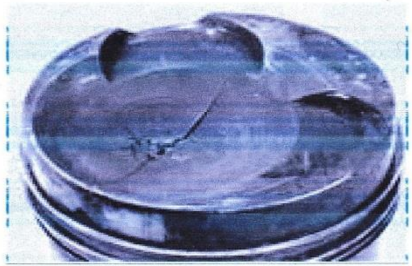

Fig. 3

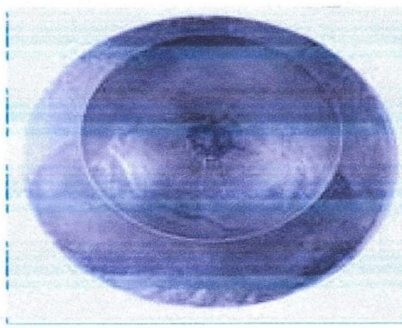

Fig. 4

Possible causes for the damage

- Faulty or incorrect injectors, faults in the fuel-injection pump, damage to the prechamber.
- High temperatures as a result of defects in the cooling system.
- Faults on the engine brake, or excessive use of the engine brake. This results in overheating.
- Insufficient piston cooling on pistons with a cooling oil gallery, caused for example by blocked or bent cooling oil nozzles.
- On engines which are subject to frequently changing loads, e.g. city buses, earth moving machinery etc., these factors can become particularly critical.
- Use of pistons with an incorrect specification, e.g. installation of pistons without a cooling oil gallery on an engine where the specifications require pistons with a cooling oil gallery, installation of pistons made by third-party manufacturers without fibre-reinforcement of the edge of the bowl.
- Installation of pistons with an incorrectly shaped piston bowl for the engine. See also point "3.4.7 Piston seizure due to the use of incorrect pistons".

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