THE ANALYSIS OF CAUSES OF LORRY PISTON COMBUSTION ENGINE DAMAGE

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Resume

The article deals with analysis of causes of lorry piston combustion engine damage. For docummentation and analysis of causes was used macroscopical, microscopical and scanning electron microscopy. The analysis showed that the reason of fatal damage resides in production process of lorry combustion pistons which proved in implication of fatigue damage and subsequent burnout in two piston place.

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1. Introduction

The pistons for combustion engines are produced of aluminium alloys with various silicon contents and additional elements in different constructional version. The composition of aluminium alloy and application of production technology differs in dependence of specific utilize [1,2].

Engine pistons are one of the most complex components among all automotive or other industry field components [3,4]. The pistons are directly exhibited to fuel explosions and product of fuel combustion. Such obtained energy with help of piston is transformed into kinetic energy which is used for wheel drives. Big part in material draft plays used type of fuel itself. Petrol engines work more efficiently during higher turns as well as speeds from which follow that fatigue strength is achieved earlier and it also comes to higher friction than oil engines. Compression ignition engines work during distinctively higher pressures and higher temperatures. The decisive influence on the activity and also engine lifetime has chemical composition of fuel [5], therefore combustion products itself certain fuel compounds aggressively influence used materials in active part of engine. Damage mechanisms have different origins and are mainly wear, temperature, and fatigue related. Among the fatigue damages, thermal fatigue and mechanical fatigue, either at room or at high temperature, play a prominent role [6,7]. Also, analysis of the piston thermal behaviour is extremely crucial in designing more efficient engine [8,9].The aim of the article is to determine the cause of lorry piston combustion engine damage.

2. Damaged piston characterization and used experimental procedures

Two damaged pistons of lorry combustion engine were used for analysis. The damaged pistons in engine were changed before automobile had done 10000 km. Both damaged pistons were burnt out same in active and the most exposed parts of piston (Fig. 1) and in sideway of piston (Fig. 2). Crack occurred closely (red arrows) to burnout parts which spread out from piston pivot up to the central part of active piston area. The burnout places and also shape of the crack were identical in both cases of damaged pistons. The origin of damage was determined using macroscopic and microscopic analysis (optical and scanning electron microscopy) of damaged pistons.

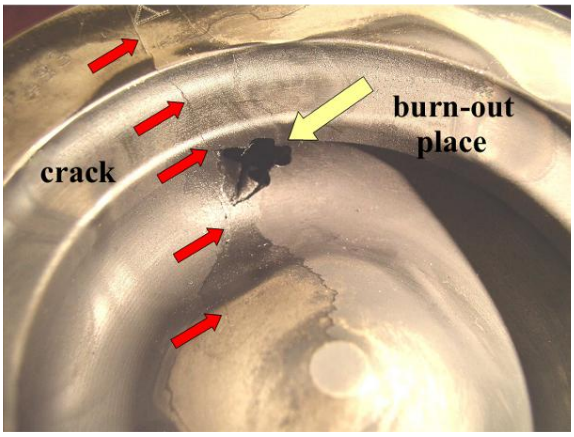

Fig. 1 Burnout place and crack in active part of piston
(full colour version available online)

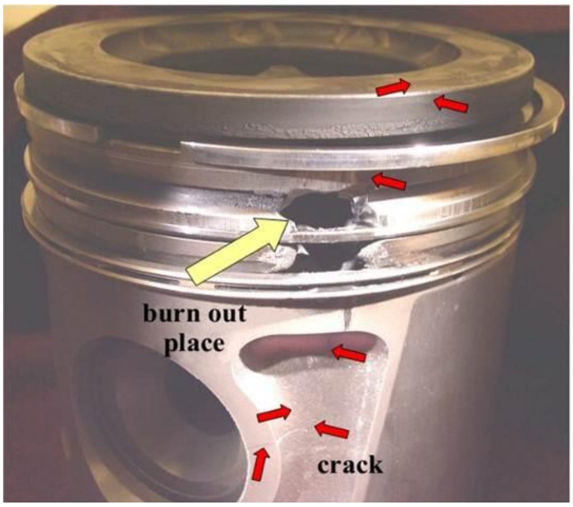

Fig. 2 Place of burnout sideway of piston and crack propagation
(full colour version available online)

For microscopical analysis piston was cut into more parts which were subject to analysis. Parts for microscopical analysis were prepared standard metallographical procedure without etching. For scanning electron microscopy fracture surfaces and parts of piston joined with degradation damage were cleaned in acetone using ultrasound. The analysis was carried out by means of TESLA BS 300 scanning electron microscope.

3. Macroscopic analysis

Two base features of piston degradation (except abrasion) were identified by visual investigation of damage piston combustion engine. At first the crack was created which rose up to the hole into piston pivot (Fig. 2) and stopped almost at the middle active piston part. The second feature was relatively big burnout holes in active and also sideway part of the gear piston. The seal ring was joined with piston in burnout place, distinctively abrasively worn and damaged. Due to the burnout localization close to the crack it can not be stated that burnout was initiator of piston damage but burnout was result of crack formation and its propagation in exhibition process of piston. In that case attention was focused on crack which had the same shape in both damaged combustion engine pistons.

External cylindrical surface was worked on the base of morphology by roughly lathe-turning. Probably, cutting tool caused tearing out of material by wrong machining parameters in hole place for piston (Fig. 3) from hole edge for piston pivot (green arrows) in consequence relatively sharp and large notches were created at that place.

That way damaged hole edge had effect as the initiation place for formation of fatigue crack which after achieving hole for leading away excess oil from wipeable ring and subsequently propagated in its direction. That documents Fig. 4 where sudden change is seen in the orientation during crack propagation. Material is in the closeness of that hole weakened what enables its next propagation up to the active piston part. In this place high temperatures and pressure effect for material of piston. Fuel mixture was getting into material volume by the crack what caused also local melting down of fracture surface and by medium pressure caused its removal through crack and the weakest section out of piston material.

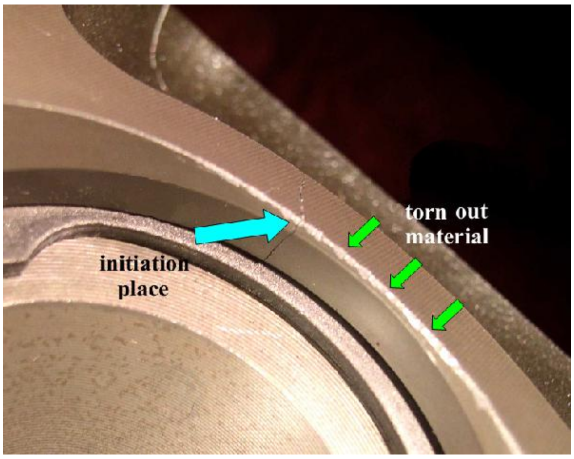

Fig. 3 Split off piston edge of pivot after machining
(full colour version available online)

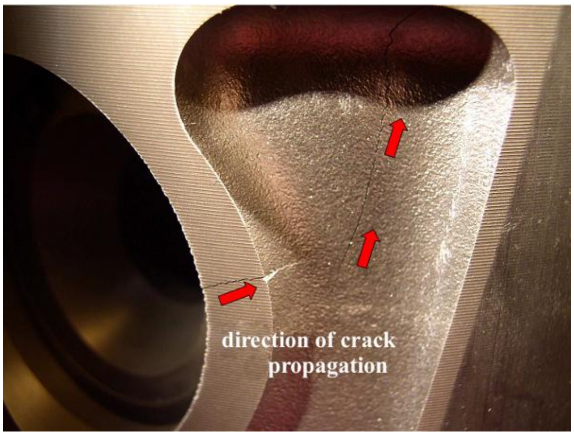

Fig. 4 Direction of fatigue crack propagation
(full colour version available online)

4. Microscopic analysis

Microstructure of piston cast was analysed in bottom, middle and active part of piston. In all three areas microstructure was formed by base matrix on the basis of aluminium solid solution, sharp-edge Si particles and interdendritic spaces were filled by eutectics. On the base of microstructure it can states that it is alloyed hypereutectic Al-Si alloy [10]. Microstructure of active piston part is documented in Fig. 5, its middle part is given in Fig. 6 and bottom part of piston is shown in Fig. 7. Microstructural heterogeneity in individual piston parts is observed in photographs.

In Fig. 8 fracture surface in place of the fatigue crack initiation can be seen. Typical fatigue (relaxation) lines were observed in fracture surface which proceeded from place of initiation fracture in this case from place where parts of material were torn out from surface during machining. Groove for safety ring of piston pivot was situated in left upper part of image.

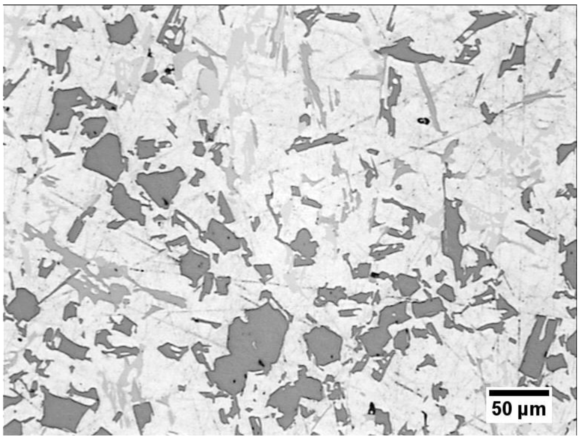

Fig. 5 Microstructure from active part of piston

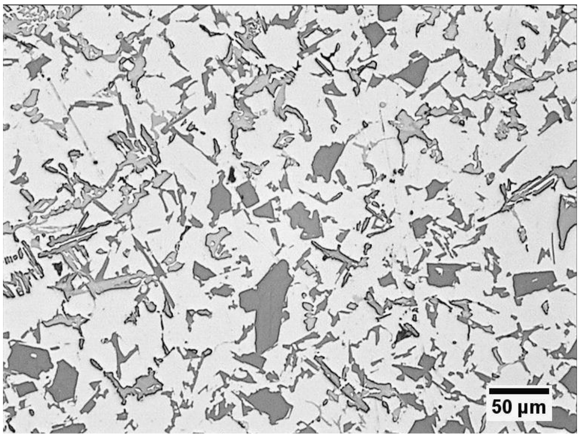

Fig. 6 Microstructure from middle part of piston

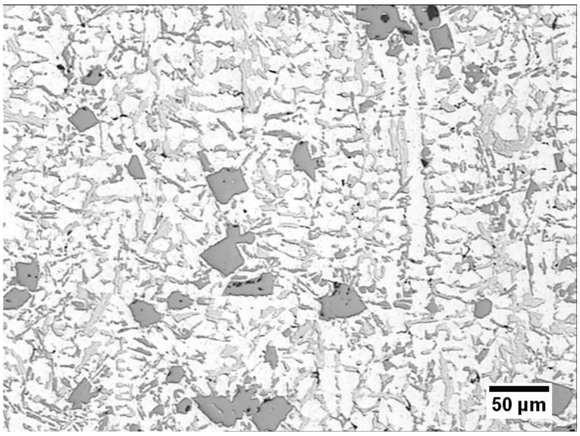

Fig. 7 Microstructure from bottom part of piston

Fig 9 documents micrograph of external machined surface which contains tracks caused by cutting tool. Places were observed in edge (left) where material was torn out during machining of surface. Same damage (tearing out) was observed in opposite side of hole for piston pivot.

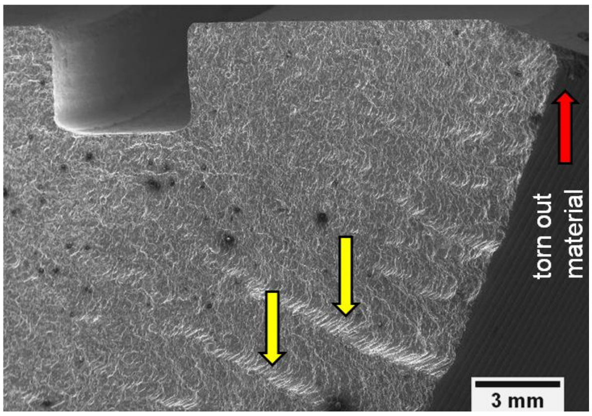

Fig. 8 Surface fracture in place of crack origin, fatigue lines, split off material

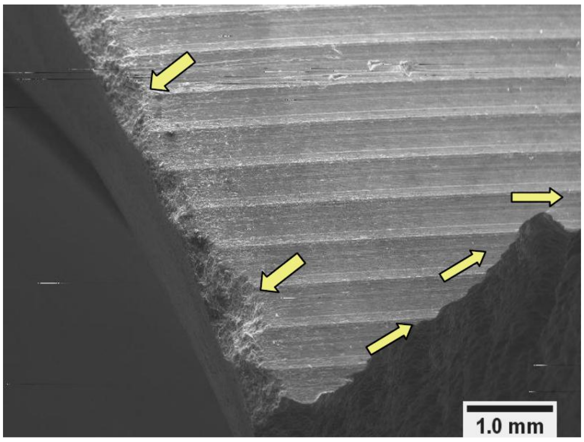

Fig. 9 Machined piston surface, split off material and fracture surface

5. Discussion and conclusion

On the base of carried out analyses it can be stated that the most probable cause of piston damage during exhibition process is caused by wrong machining parameters of external cylindrical piston surface. Parts of material were torn out in hole place for piston pivot during machining. This place is cyclically also dynamically strained during the activity of engine while role itself plays also temperature change of material of piston.

As microscopic analysis showed in the microstructure of combustion engine piston relatively big particles of primary and eutectic origin occurred which support the material to tear out after impact of tool. The tearing out of small material particle in edge hole led in consequence of cyclical loading to initiation and subsequent fast fatigue crack propagation which continued in direction of the least material resistance of piston, i.e. in direction of channel which serves for conducting away excess oil deflated by wipeable ring from combustion engine cylinder.

The next consequence of created crack was formation of the burnout. The fuel which was supplied into combustion space over piston penetrated by effect of pressure by crack into material piston volume and during its igniting it probably causes local overheating and later melting down of surface fracture. In the process of time burning out of piston happened by way of repeated pressure of burning fuel. Melted down material had effect as abrasive which wore piston rings in burnout place.

The conclusion states that during whole production process conditions of individual technological operations are needed to respect. Not respecting of define conditions can lead to damage of component and it means to distinctive decrease of lifetime and actually to complete destruction of constructional unit which part is component [11].

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