FAILURE OF STATIONARY PUMP ENGINE PISTON

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ABSTRACT

Piston failures are not a common occurrence, but they do occur and failure is usually associated with fatigue crack growth. Most failures initiate at the gudgeon pin hole or in the skirt of the piston. Occasionally they fail elsewhere. In the example covered in this paper failure has initiated in the crown and progressed down to the gudgeon pin, before final failure occurred. This paper outlines the cause and mode of failure and shows that small metallurgical discontinuities can contribute to these failures given the right circumstances.

INTRODUCTION

We were supplied with a piston from a diesel tractor that had failed during service with the request that we determine the cause of failure. Apparently the engine had been running roughly and the claimant indicated that the fuel had been contaminated.

This paper presents the results of our observations, discusses and lists the conclusions that may be drawn from them.

VISUAL INSPECTION

The failed piston is shown in Figure 1 where a crack may be seen running down from the crown to the top of the gudgeon pin hole.

Figure 1. The failed piston with the crack running from the crown down to the gudgeon pin hole.

A view from the top of the piston, Figure 2, shows the crack inside the combustion chamber bowl and a hole created by the flow of hot gasses that have melted the piston.

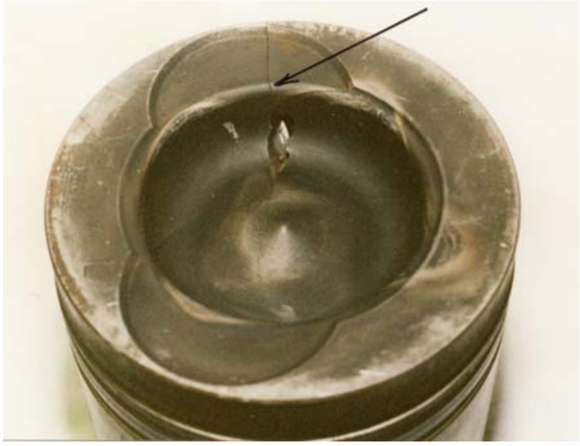

Figure 2. Looking down the hole formed from the combustion chamber to the lower ring. The crack initiated at the edge, arrowed.

From the bottom of the piston, Figure 3, the crack in the gudgeon pin hole and gas exhaust damage may be seen. The uncracked section of metal was cut to allow the fracture surface to be examined and a view of the fracture surface is shown in Figure 4.

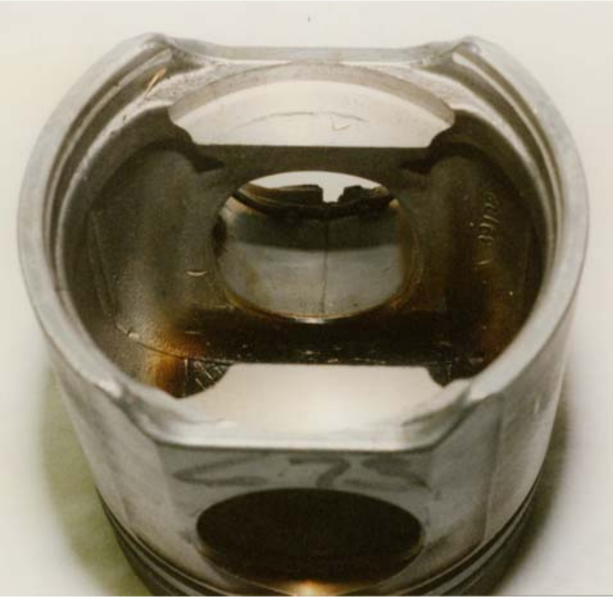

Figure 3. Looking at the top of the gudgeon pin hole with evidence of damage at the third ring.

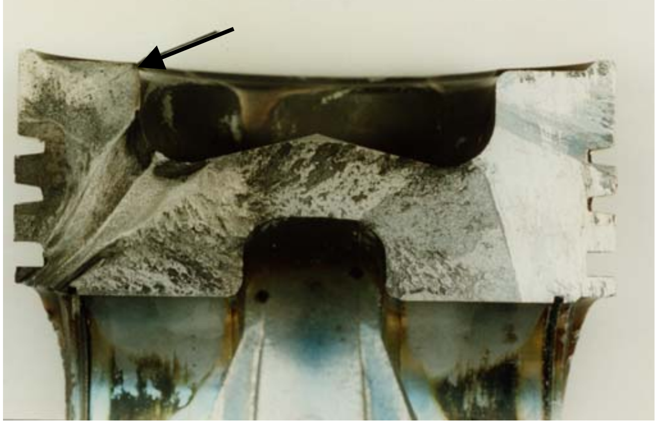

Figure 4. The fracture surface showing the point of fatigue crack initiation, arrowed.

The fracture surface was heat affected and had to be stripped using cellulose acetate softened in acetone to remove the contamination. After cleaning it was evident that the crack had not initiated at the gudgeon pin hole but had started at the top edge of the combustion chamber bowl. The crack had grown by a fatigue mechanism and examination in a scanning electron microscope showed typical fatigue striations emanating from the inside corner, although there was evidence of surface metal melting in this area, Figure 5.

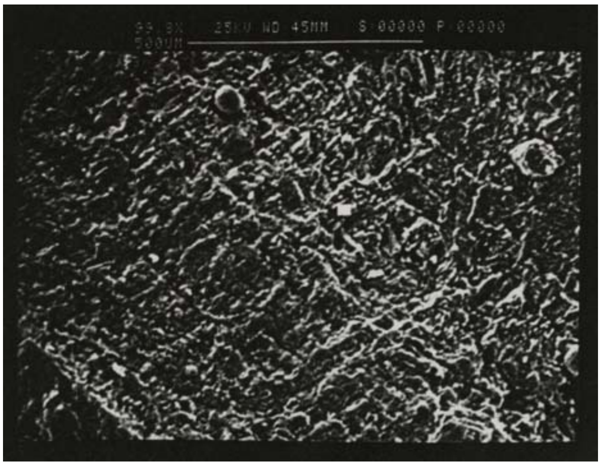

Figure 5. A view of the fracture surface from the SEM showing fatigue markings that have been affected by the hot gasses.

METALLOGRAPHY

A section through the crack origin was taken, mounted, polished and etched in 0. 5 0% hydrofluoric acid in water. Microscopic examination showed a microstructure of alpha solid solution with inter-metallics such as Mg_2Si and appeared typical of a; 336.0 or 242 sand cast aluminium alloy. As may be seen in Figure 6 there was considerable porosity concentrated at the combustion bowl edge where the crack initiated. There was little porosity elsewhere in the section taken.

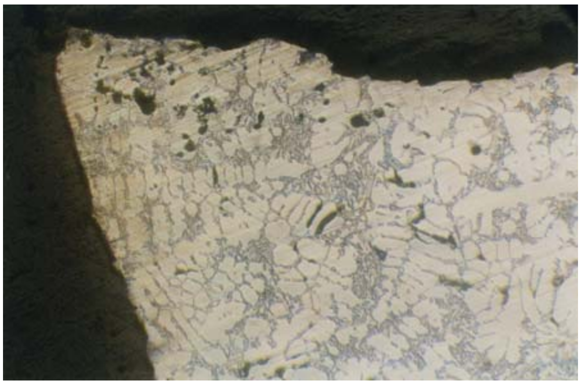

Figure 6. The microstructure at the point of crack initiation showing considerable porosity not evident elsewhere on the section taken.

DISCUSSION

Failure of the piston has been by a fatigue crack growth mechanism, initiating at the top edge of the combustion chamber bowl in an area of high porosity. This is an unusual area for crack initiation, normally it occurs at the gudgeon pin hole and works up to the crown of the piston. Stresses in this area must have been very much higher than normally expected and the only way this could be achieved is by premature detonation or combustion of the fuel. Premature combustion results in much higher stress in the combustion chamber and these would have been tensile around the bowl edge. Combined with the porosity, a manufacturing defect, this has resulted in initiation and growth of a fatigue crack followed by melting and blow through of the piston metal when the crack reached the bottom ring.

Incorrect timing can result in premature combustion and so can fuel contamination with petrol or kerosene. When combined with diesel fuel both petrol and kerosene act to reduce the Cetane number (a measure of fuel ignition timing and burn rate) causing premature combustion.

Thus it is possible that failure of the piston was contributed to by the use of contaminated fuel, however, a manufacturing defect, the porosity, has probably acted as the initiation site. Without this defect the crack would not have started, as in the case of the other pistons. Thus it appears as though failure was a combination of poor combustion timing and a manufacturing defect.

Hardness tests indicated the piston crown had softened due to exposure to the combustion gasses. But there was no evidence of damage due to excessive heat build up.

CONCLUSIONS

Failure of the piston was by a fatigue crack growth mechanism that probably initiated at porosity, a manufacturing defect.

The stresses necessary to initiate crack growth probably arose from early ignition of the fuel in the chamber.

Early ignition may have been due to faulty timing or possibly fuel contamination.