PETER LACZKO PTY LTD

Metallurgical Services

Title

EXAMINATION OF FAILED CUMMINS QSK45 ENGINE

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Client

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Title : Examination of Failed Cummins QSK45 Engine at Newcastle

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1.0 Introduction

The relevant components of a Cummins QSK45 engine, that had failed in service in an excavator were examined. The engine had been stripped and assessed by OEM. The engine had done approximately 4400 hrs service.

All major components relevant to the failure of the engine were available and had been stored under cover to maintain the original condition with the exception of the lube oil filter bypass plunger, which had been scrapped.

The condition of the engine components was consistent with that shown in the OEM report, and the conclusion of this report that the failure was related to poor filtration of the lube oil due to bypassing of the filter is sustained. However, this example serves to highlight the extreme sensitivity of the engine to rapid wear of the bearing metal layer on the main and big end bearings, leaving the engine running on the copper lead underlay.

The failure was caused by excessive heat generated by running on the copper lead instead of the bearing metal under sustained high duty cycle operation in an excavator. Over a period of time the lead is leached out of the copper lead underlay surface, leaving a copper bearing surface. Running on a lead free copper surface causes high friction and overheating of the bearing and is not acceptable for heavy duty diesel engines. Operation in hydraulic excavators is very demanding on bearings, particularly main bearings, and any factors that lead to increased wear rate of the bearing metal cause premature bearing failure.

In this engine the centre main bearing failed and metal debris was introduced to the adjacent big end bearings that also failed. Failure of the centre main was due to loss of the bearing metal by wear and loss of the copper lead by thermal fatigue and galling, eventually allowing the crank to run on the steel backing of the bearing shell. High oil temperature contributed to the failure by reducing the film strength of the oil and increasing the incidence of oil film breakdown and metal to metal contact in the bearings.

The reason for filter bypass is not known and requires further investigation. Steps to reduce oil temperature and to reduce the rate of engine loading when the hydraulics are loaded should be investigated. The accepted high bearing wear rate in Cummins engines used in excavators is not considered acceptable by the Author, and the above factors may be a means to prolong engine life.

2.0 Results of Metallurgical Examination

2.1 Visual Examination

The condition of the engine components were found to be consistent with the OEM report and only those relevant to gaining further understanding of the failure will be discussed here.

The pistons, liners and all other components inspected other than the crankshaft and bearings were in good condition, the oil filter bypass housing showed wear and scoring of the plunger bore indicating continuous movement of the plunger. It was clear that the filters were bypassing and only a portion of the oil going to the engine was being filtered at any one time.

The condition of the bearings was most interesting, all main and big end bearings showed severe wear, with loss of the bearing metal layer allowing the copper lead underlayer to show over a large portion of the bearing surface, indicating that the copper lead underlayer had been exposed for some time prior to failure.

The centre main bearing had been running on the copper lead at the time of failure, the appearance of the bearing and adjacent main bearings was typical of thermal fatigue failure where the copper lead material peeled off the steel backing in relatively large pieces. Several main bearing lower shells had pulled in across the open end due to overheating. This is reported in the Cummins report.

One of the big end bearings that did not show significant damage from failure metal debris was selected for laboratory examination. The #6L Upper shell was considered to be in the condition it was just prior to the failure, and was subjected to metallographic examination and Scanning Electron Microscopy.

This bearing had worn to show three visible zones. Bearing metal was present at both ends of the bearing near the split line, a region of grey coloured surface that did not appear to be bearing metal and a region of exposed copper lead underlay were present in the centre portion of the shell. See fig 1, 2, 3 and 4.

Samples were cut from each of there zones for metallographic and SEM analysis to determine the construction and condition of the bearing, and to determine the mode of metal loss.

2.2 Metallographic Examination

A circumferential section cut from the exposed copper lead underlay zone and from the transition from bearing metal to grey surface were prepared for optical metallography. It was found that the bearing metal layer was 25 to 27 μm thick in the unworn part of the bearing, and the copper lead underlay was 250 μm thick in the unworn part of the bearing. The copper lead underlay had a microstructure of interdendritic lead globules in a cast copper alloy matrix.

The sample from the area of exposed copper lead did not have a bearing metal layer present, the copper lead was 219 µm thick, indication wear of 30 µm of the copper lead, and total wear of 55 µm (0.002") of the bearing surface. There had been some leaching of lead from the copper lead surface. The surface layer causing the grey appearance could not be identified optically and was identified using SEM. See fig 5 and 6.

2.3 Scanning Electron Microscopy

SEM analysis showed that the bearing metal was lead with no tin content. Indium was present as a layer on the copper lead/lead interface

The grey colour of the surface where the bearing metal had been worn off but the copper lead was not exposed was found to be due to the presence of a one micron layer of Indium.

Examination of the worn surface showed that the bearing had not galled and had worn to a fine smooth surface finish. This was consistent with normal operation or wear due to very fine particles in the oil.

Examination of a polished cross section showed that the lead globules in the copper lead underlay had been leached out to a depth of about one third of the layer thickness. See fig 7 to 10.

3.0 Discussion

This examination of the failed engine shows that the engine has been operating in a marginal lubrication regime for its entire life. The lubricating oil film has been repeatedly and frequently broken allowing metal to metal contact of the bearing surface with the crank journals.

This appears to be an endemic condition for engines operating in hydraulic excavators. Other bearings viewed showed that loss of the bearing metal occurred in excavator engines at less than one third life, and QSK45 engines from excavators with considerably less service time than similar engines from haul trucks showed significantly more bearing wear and overheating.

The engines operate in a very difficult mode where the load is increased from zero to full power instantaneously every time the hydraulics are loaded and unloaded. This is very stressful for the main bearings and to a lesser extent for the big end bearings. Lubrication film failure and metal to metal contact, wiping, of the bearings occurs. The bearing metal can tolerate this without overheating, but the copper lead underlay cannot and tends to glaze and fail by thermal fatigue.

Running on the copper lead underlay can only be sustained for a period of time until the lead is leached out of the bearing surface and the bearing presents a lead free copper surface. The lead is leached out by the hot oil and the process is accelerated as the bearing surface temperature rises due to friction. The copper surface is not a suitable bearing material and overheating due to friction soon causes thermal fatigue failure.

Any factors that accelerate bearing wear and loss of the bearing metal will increase the risk of failure of the engine. When the copper lead has been exposed the bearings can be considered to have used up their safe useful life. Thus the bypassing of the filters caused more rapid loss of the bearing metal layer and the high load operation of this engine could not be sustained by the copper lead bearing surfaces as th elead was leached from the surface.

The cause of bypassing should be investigated, and a means to reduce oil temperature should be sought. In this engine the oil is cooled by the cooling water and cannot be cooled to the temperature required for heavy duty operation in an excavator. Ideally, the oil temperature should be maintained at less than 85°C.

4.0 Conclusion

The engine components examined indicated that the engine failed due to seizure of the centre main bearing. Seizure was caused by overheating due to running on the copper lead underlay after the bearing metal had been worn off.

Bypassing of the filter caused an increased wear rate of the bearings, allowing the bearing metal to be lost more rapidly than usual, thus the engine was running on the copper lead underlay very early in its life.

Leaching of the lead from the copper lead underlay by the hot oil increased friction and running temperature resulting in thermal fatigue of the bearing.

Frequent oil film failure due to the mode of operation in excavators caused overheating of the main bearings, the centre main failed first as this is the more highly loaded bearing in this type of engine.

Steps should be taken to determine the cause of filter bypass, and to reduce the oil temperature. High oil temperature reduces the oil film strength, promotes oil film failure and increases the rate of leaching of lead from the copper lead underlay.

Peter Laczko

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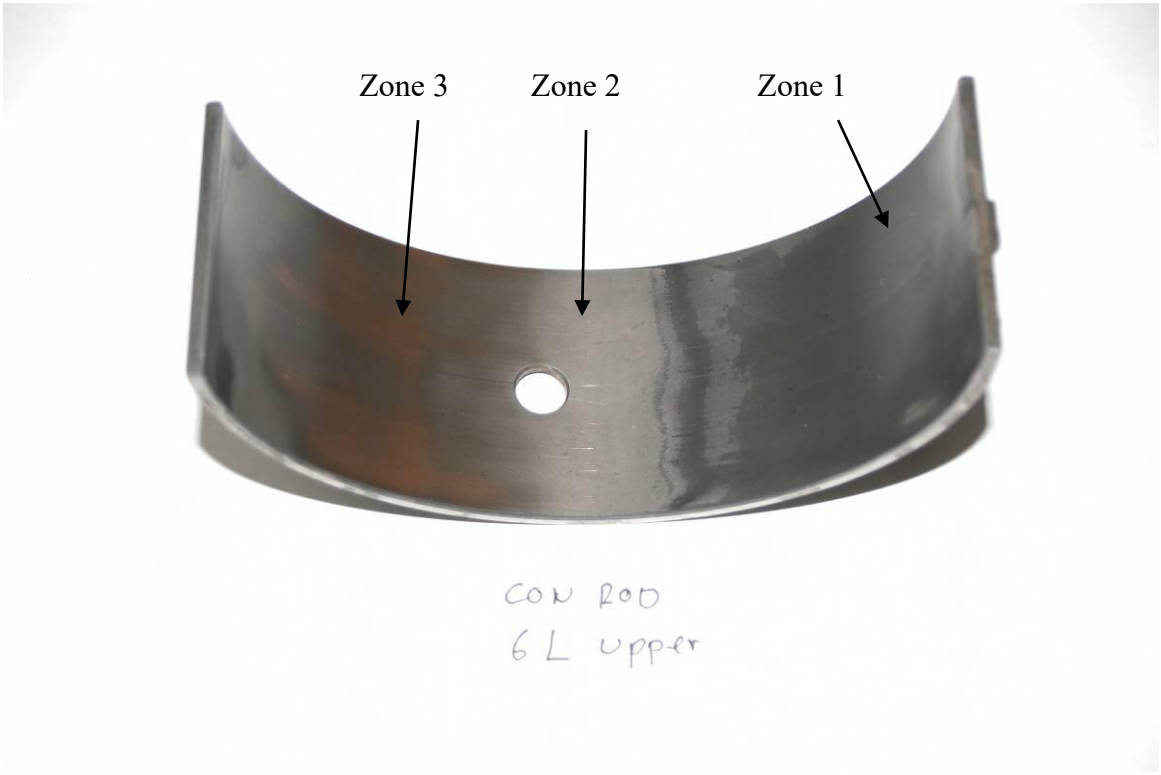

Fig 1 Big end bearing selected for metallurgical laboratory examination. (X 2/3)



Fig 2 Zone 1 Bearing metal still present. (X 1 ½)



Fig 3 Zone 2 Bearing metal lost, grey surface. (X 1 ½)



Fig 4 Zone 3 Copper lead underlayer exposed. (X 1 ½)



Fig 5 Photomicrograph of cross section from zone 3, exposed copper lead. (X 200)

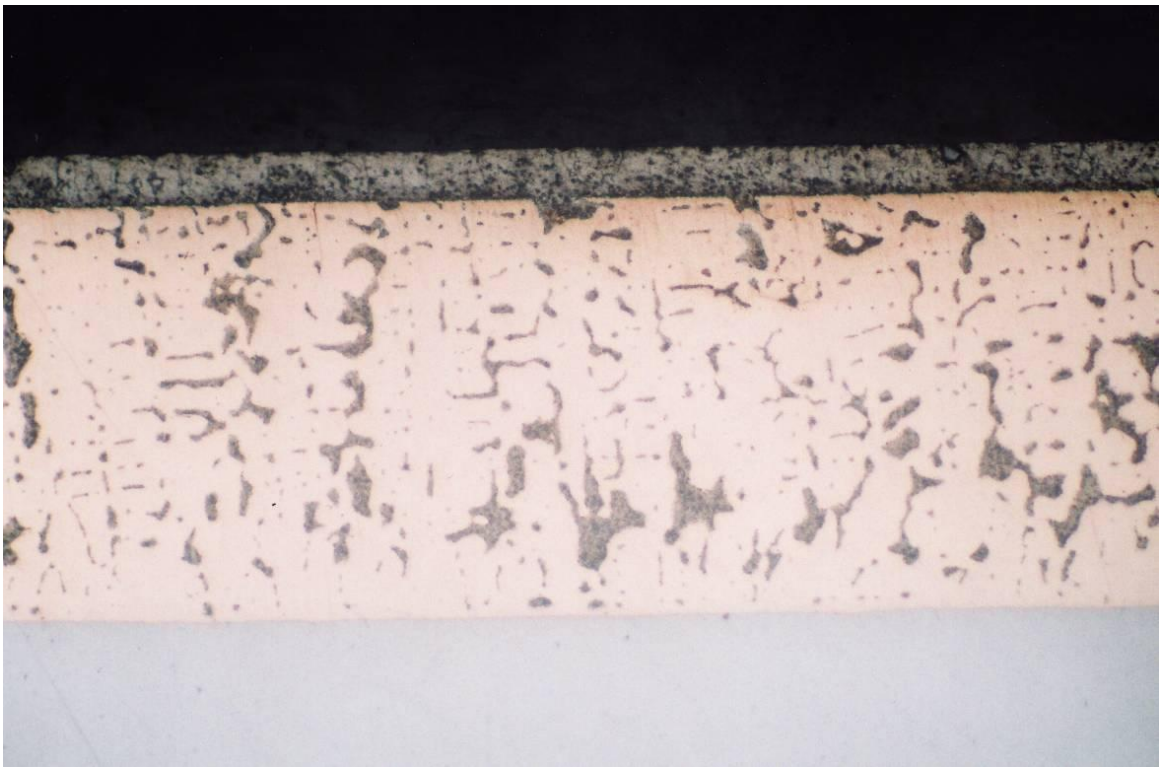

Fig 6 Photomicrograph of cross section from zone 1, bearing metal present. (X 200)

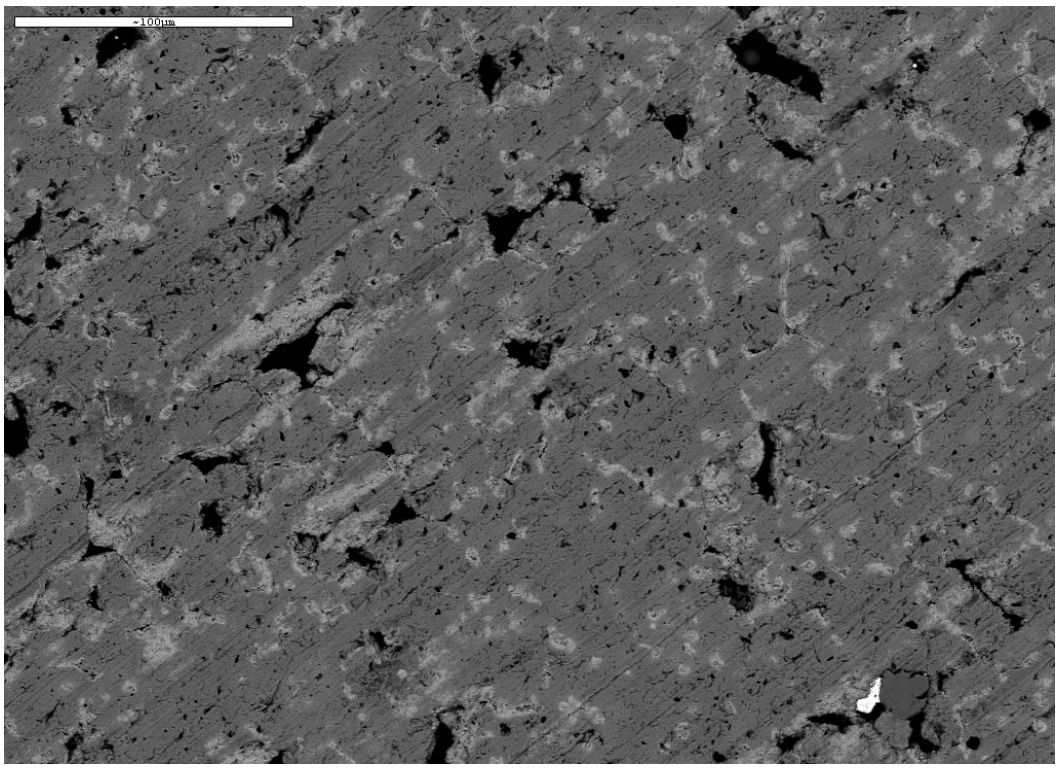

Fig 7 Surface appearance of Zone 3, SEM micrograph. Dark area is copper, lighter areas are remnants of the Indium layer. Black patches are voids. (X500)

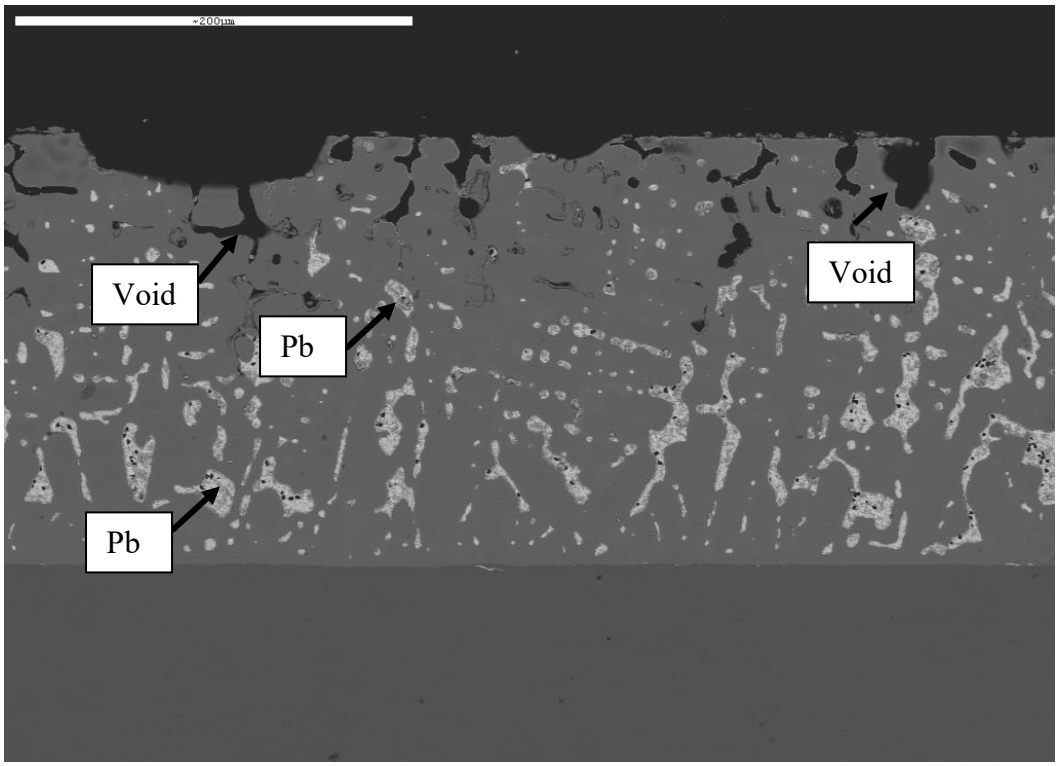

Fig 8 SEM image of cross section of copper lead layer in zone 3, no bearing metal present. The arrows show the voids left after the lead had been leached out. (X 325)

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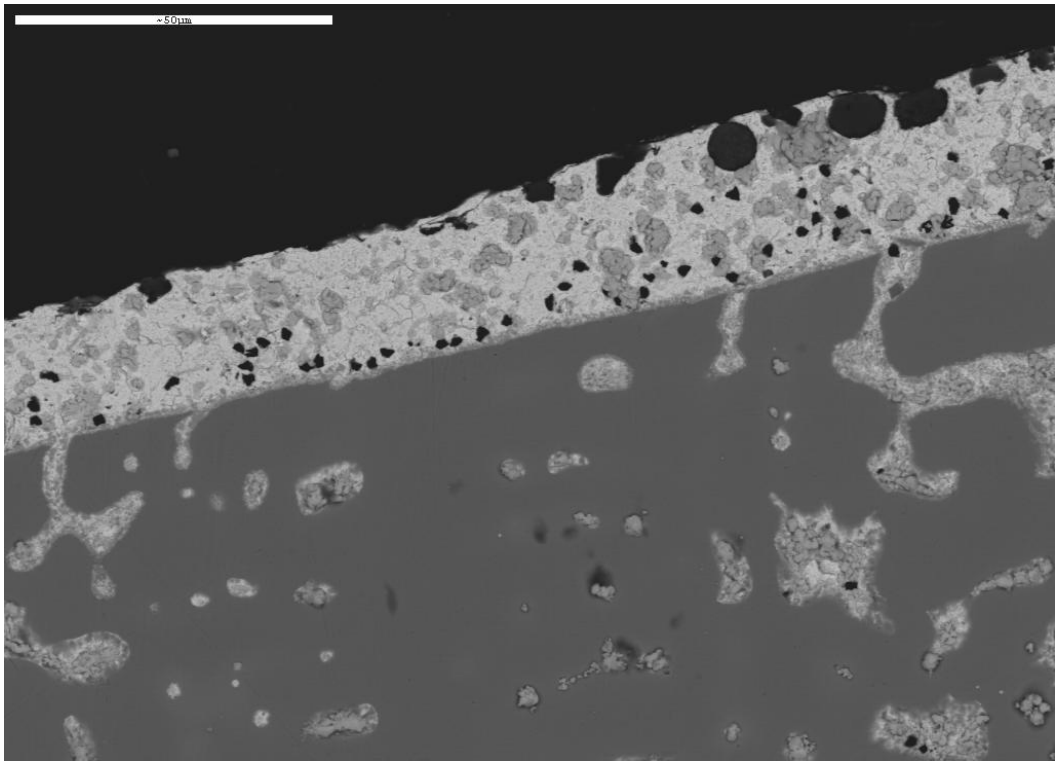

Fig 9 SEM image of bearing metal layer on copper lead underlay. Note that the lead bearing metal shows some porosity and corrosion pitting of the surface. (X 1000)

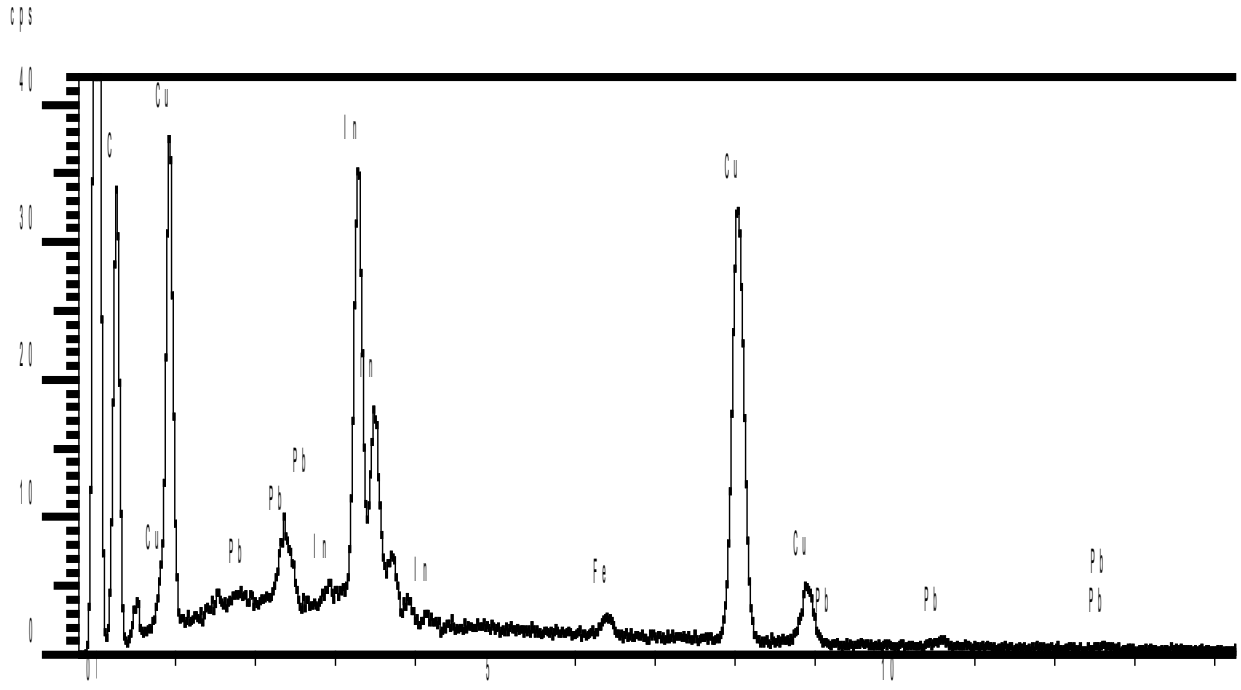

Fig 10 SEM spectrum showing that the grey surface material in Zone 2 is Indium.