Bearing analysis
- Engine bearings application -

Aknowledgements:

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Summary :

Context:

The engine bearings permit the rotational guidance of the main engine shaft called crankshaft, and of its equipment (conrods, camshafts, etc) (**fig.1**). Made of smooth materials, in opposition to ball bearings, these parts are presented as half-shells both set-up the in front each other in order to englobe the journal considering the given space. Their hydrodynamic architecture needs a continuous lubricated oil environment. The running conditions of these bearings (polluted atmosphere, loads of several tons) leaded to the use of extremely exigent parts, as much in the materials used as in the precision of its manufacturing process. These bearings present several layers of materials stacked by a cold welding process (**fig. 2&3**), each one having a very precise function which we will develop later.

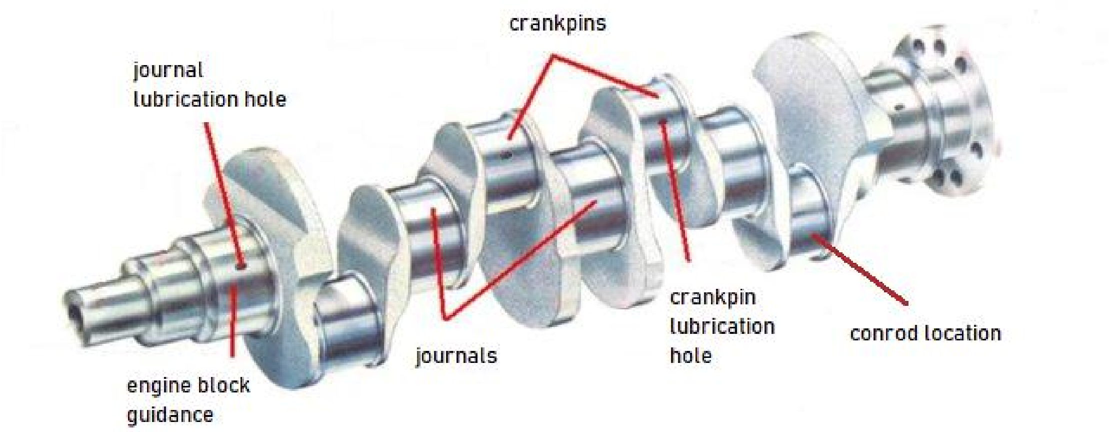
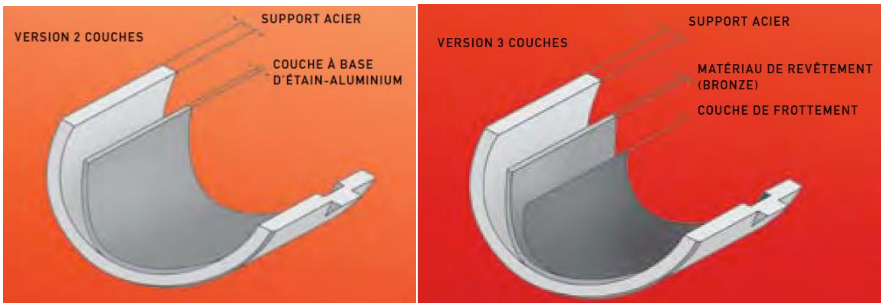


Figure 1 : Representation of a 5-guidance-bearing crankshaft for a 4 in-line cylinder engine.



Figures 2&3 : Visualisation of the several layers mainly used in the automotive engine bearings.

Introduction:

The engine shafts as the crankshaft or the camshaft are the most expensive components in a thermal machine constitution of alternative functionalism. If their rebuilding is given possible, it is extremely expensive regarding to the value of an engine, and it is rarely worthy. Some complex studies are made in order to anticipate the behaviour in order to prevent any risk of failure. In the case of classic cars, several parts are not provided anymore by the car manufacturer and neither the suppliers. The question of the utilisation of some re-manufactured parts is asked by many owners. Nevertheless it is not really worthy to use approximately quality components, for such critical parts as these ones.

In order to solve the problem, it seems quite audacious to dispose of several machines to evaluate the validation of this kind of component as the life of the entire engine depends of this part. Moreover this very long homologation would need the perfect control of several running parameters as the failure risks can be very numerous. The microscopic studies achievements are a current way of failure bearing analysis or during a quality process in a part supplier.

Objectives:

In the present case, we have a part reference of which the brand and the composition is completely unknown. The aim is first to observe the part at a microscopic scale in order to evaluate its shape. We will also determine its precise chemical composition as these parts should be made of an extremely strict materials distribution. We will study our main bearings (crankshaft ones), made for the Porsche 924 in 2,0L engine, all versions concerned (1978-1985) (**fig.4&5**). Viewed with a scanning electron miscroscope (SEM) with energy dispersive spectroscopy (EDS) we will determine the different layers of materials. Observations will be compared with international literature data, so as with the manufacturer archives.

Figures 4&5 : Zoom on the studied parts, when receiving the package.

Preparation:

The analysis will take place on the slice of the part which will allow to visualize the different elements on a single capture. In order to held the metallographic study, it is necessary to obtain a very smooth surface roughness to reveal the different crystals in place. The part will be polished with 1000 and 2000 wet sandpaper. After a finish polish trough a bright mirror roughness, the part is thus ready **(fig.6).**

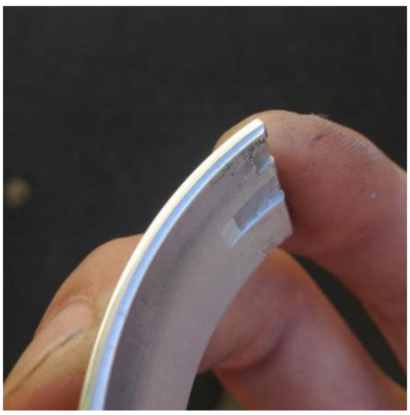


Figure 6 : View of the surface roughness obtained on the slide before the analysis.

Results:

The microscopic study reveals 3 layers of distincts materials. The captures are shown below:

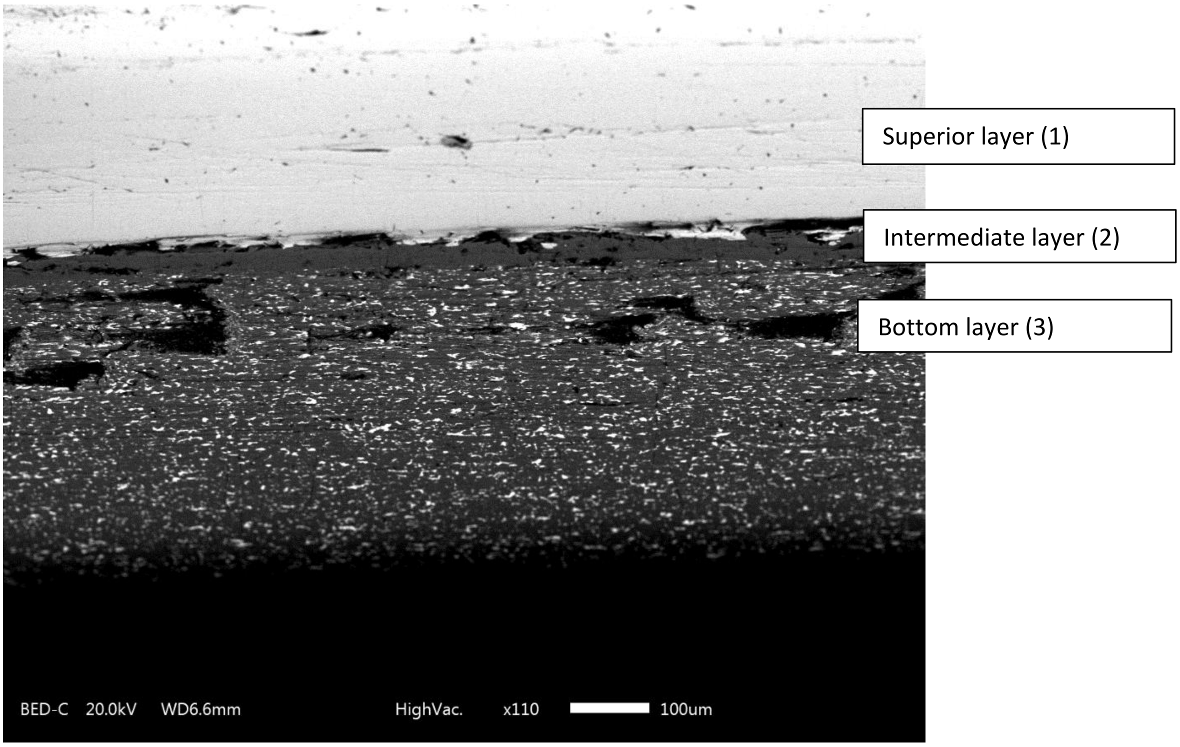


Figure 7: View of the microscopic analysis on a first MEB

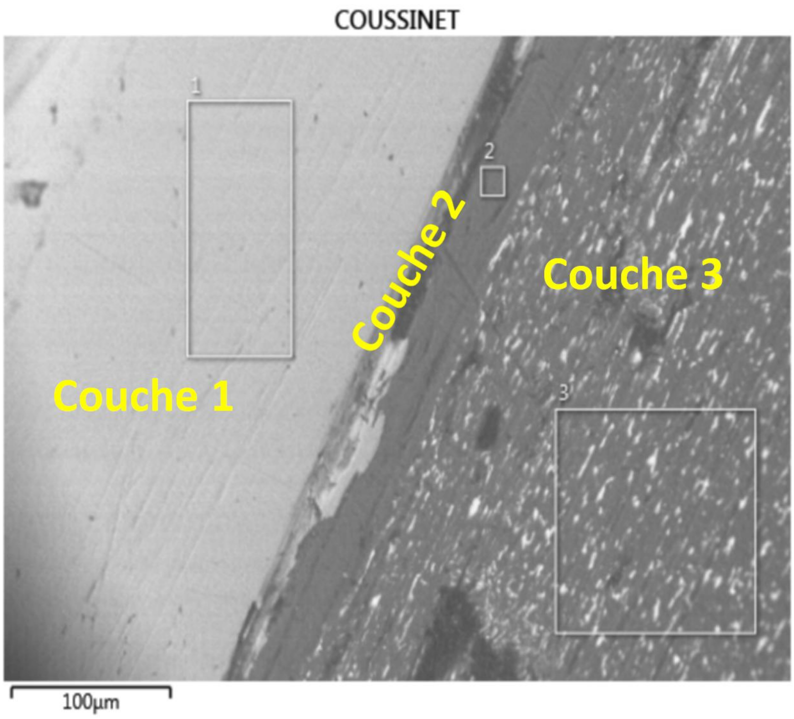
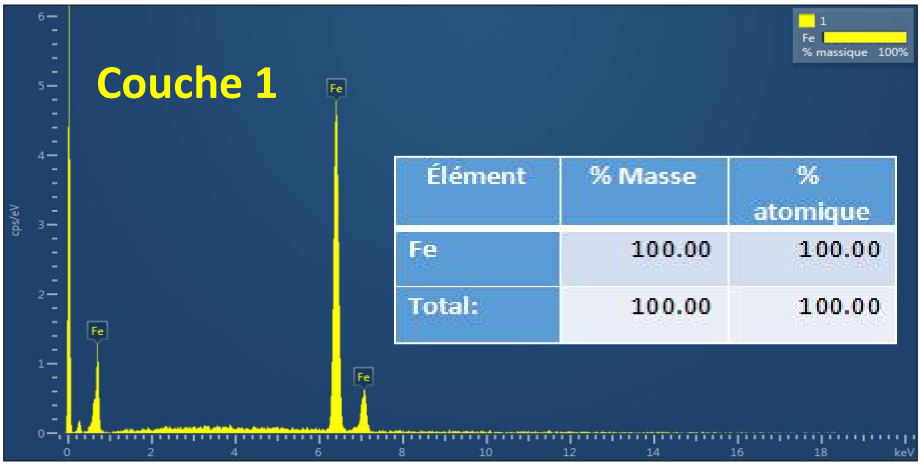
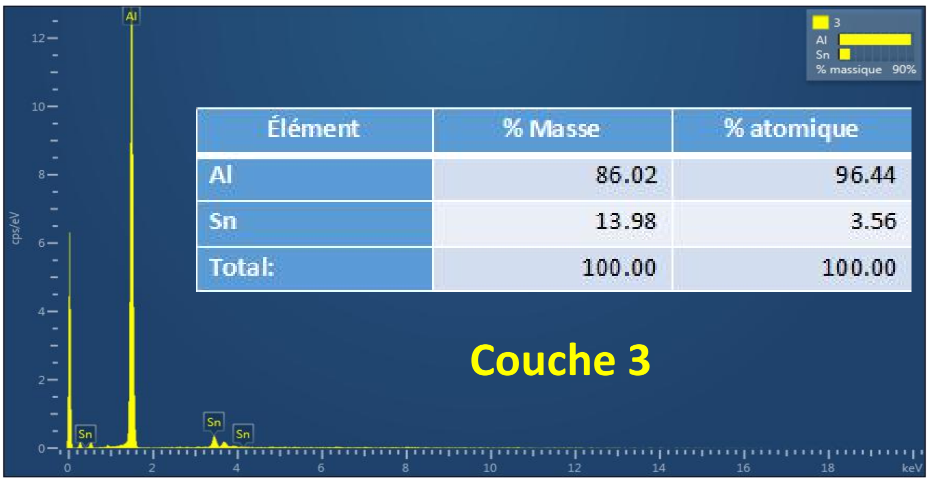


Figure 8 : View of the microscopic analysis on a second MEB.

The second step consists in bombarding with X rays a local zone which reveals the chemical composition. We can obtained that by reading the emitted photon energy due to the floor electronic electrons jumps (visible on abscissa).





Figures 9,10&11: View of the results on the 3 different X rays dispersion depending on the layer part studied.

Analysis:

First of all, in order to sweep the microscopic captions, we can notice that the presented configuration **(fig. 7&8)** looks like to the bi-metal aluminium-tin productions **(fig.12)** which are mainly present in the automotive industry. Regarding to the sliding layer (third one), an aluminium matrix in grey (light material) hosts tin crystals of whose density is three times higher. A grey colored bonding layer (second layer) has same color as the sliding layer matrix. This makes the link between the back (first layer) and the aluminium-tin layer. Finally a quite heavy element constitutes the back of the element (first layer) as its color is relatively bright. We are expecting to discover a ferrous material.

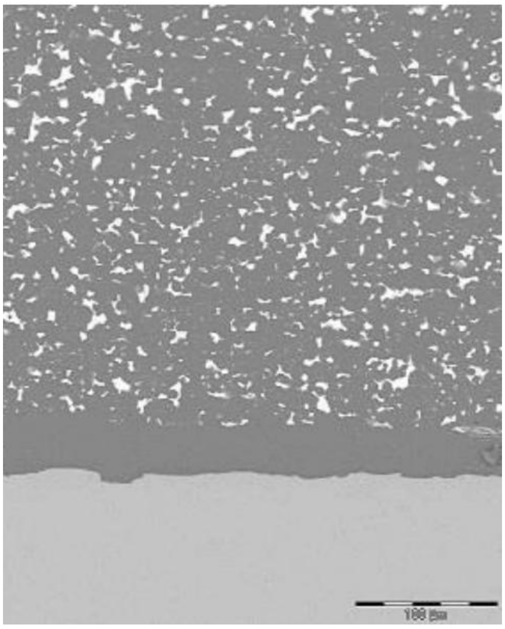


Figure 12: View of a bi-metal aluminium-tin component microstructure.

In a second statement, we observe the presence of consequent porosities on both captions **(fig. 7&8)**. Those cavities are located on the superior superior layer, as so on the back of the bonding layer. If on the second capture **(fig.8)** they could eventually be caused by the lack of the sample preparation, the observation of the first caption **(fig.7)** is much more sharp. These defaults viewed at the bonding interface reveal a concern on the casting process of the aluminium-tin composite. The welding made during the rolling process seems as much imperfect, because the bonding between the back and the layer is not continuous. Those cavities represent propice places of cracks birth due to the stress concentration they imply.

Then, the relieved thickness of the sliding layer reaches 0,40mm. This value is globally high as it is more common to meet substrate near 0,30mm. If it's probably easier to roll, it appears that a higher thickness leads to higher share stress in the superior bearing layer, which is harmful to the fatigue lifetime effect.

Following to the sweep analysis **(fig. 9,10&11)**, the layer composition is compared to the SAE-783 norm **(fig. 13)**, international reference in terms of bi-metallic aluminium-tin automotive bearings. In addition to this, as several kind of materials distributions are worth considerable for this application, we'll add to the comparison a composition which meet our sample, proper to the MAHLE company:

	Element	SAE-783 norm	MAS 26 (MAHLE)	Sample studied
Sliding layer (3)	Aluminium	74,7 - 81,8 %	83 %	86,02 %
Bonding layer (2)	Aluminium	100 %	100 %	100 %
Back of the bearing (1)	Iron	99,3 - 99,2 %	x	100 %
Specific loading capacity (MPa)		40-42	85	x

Figure 13 : Comparison of the several identified elements of the part with literature data

Tin on the sliding layer has for main role to limit the risks of seizure by offering a wet weak lubrication. It works as a fuse component, and tin also helps to increase the conformability. This feature represents the capacity of adaptation to misalignment due to manufacturing process and running parts distortions (shafts, bores). One of the roles of aluminium is to slightly increase the fatigue load capacity of the composite. Unfortunately we constat the lack of copper component, known for giving a non negligibly impact on the specific fatigue capacity as among other proves the MAS-26 alloy. This one increases the manufacturing cost and need a more delicate operating process, beside the proportions it is used with.

An other surprising element is the use of pure iron instead of steel for the last layer in the manufacturing process. The hardness of the Iron element is coherent regarding to the requirements for the manufacturing of this kind of part. However pure Iron, differently from steel presents a very low tensile strength which implies a high risk of permanent deformation, even under a moderate load. It is particularly true for the grooved bores of the block where oil is supplying, as the bearing is not supported anymore and is subject to bending and share stress.

Even if we have motivated our study by comparing the studied part with other kinds of bearings in bi-metal alu-tin, it appears that the original manufacturer within the supplier Glyco prefered to use tri-metal SA-794 bearings. The tri-métal appellation leads to the use of three main chemical components which constitute the layers such as copper, lead and tin **(fig.14)**.

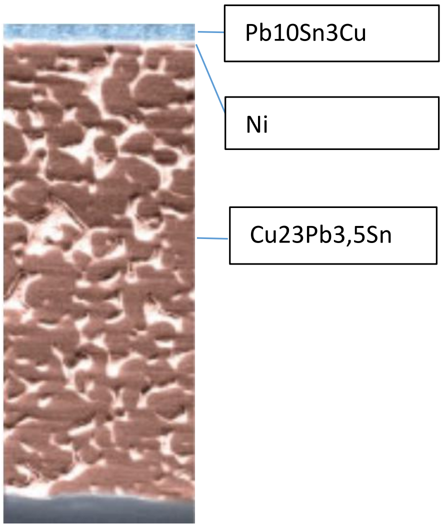


Figure 14: Microscopic cut of a tri-métal bearing SAE-794.

Lead operates as an excellent fuse in order to prevent from seizure risks in case of succinct lubricating failure. Copper gives a certain mechanical resistance whereas tin of the superficial layer mainly allows to protect the bottom layer from the corrosion due to the acid atmosphere. The use of two main layers allow to combine the mechanical features of each one. Hence, the specific loading capacity of this configuration reaches 75 MPa, which is more than the majority of aluminium-tin alloys. This specific loading capacity is an important data used to design the original materials components. A lower capacity fitment could lead to the risk of early failure. Nevertheless, if the thin sliding layer comes to be worn, the bearing loading capacity decreases. In addition, the operating of this part format is more complex and usually more expensive.

The hardness of the alu-tin substrate in comparison to the copper-lead-tin doesn't disqualify it for the use of a 2 layers material instead of a 3 layers one. Actually, in order to preserve the bearing journal in case of failure, it's necessary that the hardness of the shaft is 4 to 5 times higher than the bearing one. Shafts made to host copper-lead-tin bearings are sufficiently hard for this application. However the contrary is not worth considerable.

Conclusion:

The chemical composition study of a technical part has been realized thanks to the sweep selective energy dispersion technology. The studied part seems to suffer from noted quality concerns during the manufacturing process of casting and welding. The lack of the copper component questioned about the mechanical features of the sliding layer. Moreover the use of pure iron in the back composition does not seem to be an interesting choice. In addition, the use of a bi-metal part instead of a tri-metal one is not strongly recommended. The next step would consist in the realization of tests in running conditions, even if it would require huge resources in order to make rigorous comparisons.

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