ENGINE BUILDER

ENGINE BEARING SUMMIT

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Transcript of Question 1

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Engine Builder Engine Bearing Summit Participants

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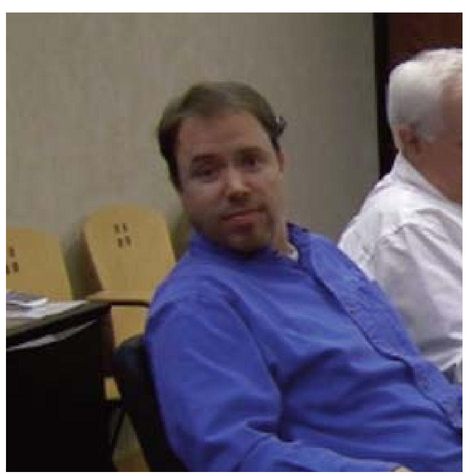

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Over the years, few engine components have caused more concern, consternation and confusion with *Engine Builder* readers, editors and advertisers than engine bearings. Though they have no moving parts, weigh virtually nothing and rarely, if every, are seen by the motoring public, the engine bearing may be one of the most important yet least understood part under the hood.

To answer questions and allow an open discussion without falling into a "pizza wars" debate we convened the inaugural *Engine Builder* Engine Bearing Summit on March 31 at the Babcox Media corporate headquarters. We invited participants from the leading bearing manufacturers to participate in a roundtable discussion on pre-determined topics.

To say the day exceeded expectations would be an understatement. Participants were prepared, cooperative and frank about engine bearing technology and applications.

The following industry experts participated in the Summit. From Federal-Mogul Corporation: **Bob Sturk**, Chief Applications Engineer, Bearings: North America; and **Raymond King**, Director of Global Engine Parts. From King Engine Bearings: **Dr. Dmitri Kopeliovich**, R&D Manager at King's manufacturing facility in Israel; and **Michael James**, with King's export and high performance programs. From MAHLE Clevite Inc.: **John Havel**, former Director of Aftermarket Engineering (Retired); and **Bill McKnight**, Team Leader – Training.

Brendan Baker, senior editor and **Larry Carley**, technical editor of Engine Builder joined editor **Doug Kaufman** in moderating the discussion.

Question 1: What are the primary differences in hardness, strength and embedability between today's aluminum and tri-metal bearings?

HAVEL (MAHLE Clevite): Hardness really is not a characteristic we measure as a production quality check when we make bearings. It's a relative term. You have to look at it in terms of the bearing metals that are most commonly used in crankshaft bearings, which are, in alphabetical order, aluminum, copper, lead and tin. Obviously there are others, but these are the primary elements that are used. And they are all, on a comparative basis, much softer than the iron and steel crankshafts that we run them against.

Aluminum and copper are the harder of the two, and they are the basis for the commonly used bearing alloys. And lead and tin are softer, weaker and are used more for their surface characteristics, their ability to embed and provide surface action and so on.

Tri-metal bearings employ an overlay that's made up of both an alloy of both lead and tin while the popular bi-metal bearings are made up of aluminum plus a relatively small amount of tin added as an alloying element. Consequently tri-metal bearings provide the greatest level of embedability and surface action compared to aluminum bearings. You have more soft phase at the surface and this provides for better embedability and also their ability to provide what we call surface action. And we'll talk more about that as we go on.

Tri-metal bearings may be constructed with either a copper/lead or aluminum intermediate layer. I think copper/lead today is by far the more popular. There are still some tri-metal aluminum bearings out there, but I think especially in the aftermarket tri-metal copper/lead are by far more popular. And among the copper/lead tri-metals available, those having a cast structure, that is the copper/lead alloy is applied to the steel backing by a casting process as opposed to the somewhat less expensive sintering process, these cast alloys exhibit the greatest resistance to fatigue from cyclic engine loads. And over the years testing in literally thousands of tests, the cast copper/lead has consistently shown itself to be at least 20 percent stronger than the comparable alloys produced by the sintering process.

Although Clevite brand is best known for its tri-metal bearings, a substantial number of bi-metal aluminum bearings using a material that we identify as our MAS-19, just our materials specification, have been introduced as an alternative to tri-metals to meet the demand from rebuilders for this type of bearing. This material has fatigue resistance that is similar to sintered copper/lead tri-metals. It uses tin to enhance surface properties and it has a small percentage of silicon to provide wear resistance from the abrasion resulting when run on cast iron crankshafts.

So although we consider tri-metal to be the superior type of construction, we do offer bi-metal aluminum to meet the demand of the marketplace.

STURK (Federal-Mogul Corp.): For heavy-duty applications, cast copper/lead, copper/lead, sintered copper/lead are the materials that have by far the strongest fatigue resistance. So for heavy racing I don't think I would recommend anything but a tri-metal style bearing.

For the bi-metals to work well, I think, in street performance, our A Series bearings from Federal-Mogul are of the aluminum-tin-silicon family where the silicon helps to provide a lot of conditioning of the nodular iron surface by removing those ferrite caps. It has the tin as the soft phase for embedability and surface characteristics, sliding properties, the surface action that you were talking about. But by far for heavy duty and racing applications where very high fatigue loads are expected, the tri-metal bearings are really the way to go.

KOPELIOVICH (King Engine Bearings): First of all, I would like to say that there are different aluminum-based bi-metal bearings and different tri-metal bearings. There are conventional aluminum bearings and high-strength aluminum bearings and there are some conventional metal tri-metal bearings and high-strength tri-metal bearings.

Regarding the hardness and strength – or, more correctly, fatigue strength – of aluminum bearings, these parameters depend on the aluminum composition and the manufacturing method. The hardness of aluminum/tin not containing silicon is about 30 hardness on the Vickers scale (HV). The lowest capacity or fatigue strength of such bearings is about 5,500-5,800 psi. The hardness of aluminum alloys containing silicon is 40 HV and load capacity is 7,200 to 8,000 psi.

Hardness and strength of aluminum alloys may be dramatically increased by small variations of chemical composition combined with some special technological treatment. We at King Engine Bearings have developed such a high strength aluminum bearing alloy. Its hardness may reach 90 HV and load capacity may reach about 14,500 psi, which is much higher than conventional aluminum bearings.

The hardness and strength of tri-metal bearings are determined primarily by the properties of the overlay, by which I mean composition and thickness. Conventional lead/tin/copper overlay has a hardness of about 15 HV, mainly depending on the copper content. The load capacity of conventional tri-metal bearings is 8,700 to 10,000 psi. The thinner the overlay, the higher the bearing load capacity.

However, there are tri-metal bearings materials having much harder and stronger overlays. One such example is the sputter bearing, which is not so popular in the United States, but it is quite popular in Europe. Sputter bearings are extremely expensive to produce. Its overlay is aluminum/tin alloy applied on the copper-based intermediate layer by the method of physical vapor deposition. The overlay hardness of this aluminum alloy is 90-100 HV and the load capacity of sputter bearings is about 20,000 psi.

We at King have developed another type of high-strength tri-metal bearing with strong lead-free overlay, which is applied by a non-sputter method. We call this material GP or Gold Performance. The overlay hardness approaches that of sputter, and the load capacity is about 18,000 psi.

Embedability is the ability of material to entrap and sink beneath the surface foreign particles circulated in the lubricating oil. Embedability is determined by two parameters: the hardness of the bearing material is the first, and the second, its thickness. Of course, the softer the bearing material, the better the embedability. The softest bearing material is lead/tin/copper used as an overlay in conventional tri-metal bearings. However, its embedability is limited by the overlay thickness particularly in the bearing areas where the overlay is partially or totally worn out. Conventional aluminum/tin and aluminum/tin/silicon bearings are less soft, but they have no overlay. Therefore, they may embed larger particles of greater sizes, greater than let's say four ten-thousandth inch, which cannot be retained by a thin babbitt overlay of tri-metal bearings and which are actually responsible for damaging journals and bearings. Of course, high-strength bi-metal and tri-metal materials possess the lowest embedability because of their hard structure.

KAUFMAN (*Engine Builder* magazine): And now we'll open up for discussion upon that question. Are there clarifications anyone would like to make or do you have further questions?

HAVEL: Yes. I have a question about the statement that Dimitri just made regarding the volume or size of particles the bi-metal aluminum bearing can embed compared to tri-metal. You said that bi-metal aluminums, even though they contain a very small percentage of soft phase, can embed larger dirt particles than a tri-metal bearing?

KOPELIOVICH: Yes, because there is no overlay. With the tri-metal bearing, its embedability is limited by the thickness of the overlay.

HAVEL: Not necessarily. I mean, we have lead and tin in the intermediate layer of tri-metal bearings just like you have tin in an aluminum bearing. And I don't see where the limited embedability in a tri-metal bearing is limited to only the overlay layer.

KOPELIOVICH: Yes, but the copper bearing's intermediate layer is much harder than an aluminum bearing.

MCKNIGHT (MAHLE Clevite): What's the Vickers hardness of the aluminum?

KOPELIOVICH: It is about 30 HV.

MCKNIGHT: Okay. The Vickers hardness of our cast copper/lead intermediate layer – I checked this before I came here – is anywhere from 40 to maybe 70 or 80. So it's essentially the same hardness as this aluminum facing that you are talking about on the bi-metal bearing.

JAMES (King Engine Bearings): Actually that isn't quite accurate because the only reason why your tri-metal bearing or OUR tri-metal bearing, for that matter – we have a few types of tri-metal bearings with different overlays – but the only reason why our tri-metal bearings even ARE tri-metal is because you cannot run them against the crankshaft without having a conformable material on top. The intermediate layer is actually harder than the crankshafts. So if you could run it without Babbitt, you'd have bi-metal copper/lead bearings, but you don't.

So what happens is when you have particles in the oil stream that have to get embedded, they have three places to go. They could try to get embedded against the crankshaft into the crankshaft surface, which doesn't happen; they could get flushed out between the bearing and the crankshaft journal; or they can get embedded into a softer material. Now, when you are talking about a bi-metal aluminum alloy bearing, for example, ours with silicon or without silicon, that material is definitely softer than the crankshaft journal. And the depth is about twelve-thousandths of an inch.

So if you are going to talk about embedability as a characteristic of a bearing, you need to talk about two parameters, one is the softness of the metal or the hardness, and the other is the depth. So, John, if you have a tri-metal bearing in a conventional application that's only eight-tenths of an inch thick, how are you going to embed a particle that's a thou-and-a-half or two-thou? That particle can't get embedded into the intermediate layer, because if the intermediate layer were softer than the crank journal, then you wouldn't need the Babbitt on top of the intermediate layer.

STURK: The intermediate layer is much softer than the crank.

KOPELIOVICH: By the way, the hardness of the intermediate layer, according to my results – and I have looked at this a lot of times for different kinds of copper/lead alloys – is not less than 80 HV. If it is 40 HV, I have a doubt that its fatigue strength is higher than 80-100 psi. Because the same intermediate layer is used also in Sputter bearings where the load is extremely high, about 20,000 psi. With its hardness of 40 HV it can't withstand such high loads. So this is one of the advantages of the intermediate, that it be strong. And there is a soft overlay on each surface so you have a combination of softness and hardness. And this is the advantage of such kind of material. But there are some disadvantages.

One of the disadvantages is the thickness of the overlay. It is limited. And because of its limited value, there are some problems with misalignments with foreign particles at certain areas of the bearing because it may vary. On the other hand, this material has better fatigue strength than aluminum silicon, a little bit higher, and it has excellent anti-seizure properties when everything is okay.

When the misalignments are small and distortions are small and there is no large particles contaminating the oil, this material is excellent. It may work an unlimited time if everything is okay. But if there are some misalignments and distortions, the thickness of the overlay becomes problematic.

JAMES: Because once the overlay is reduced because of metal-to-metal contact, that immediately is reducing the particle size that you are able to put into a bearing. Keep in mind, we all manufacture both categories of bearings, and I don't think any one of us here is going to say that one bearing is good, the other bearing is bad.

I think what we're really discussing is for a particular application which construction of bearing and which material combination is best. Because even within the bi-metal or the tri-metal construction categories, there are variances because of the materials that are selected.

So all we are saying is that if you, first of all, recognize we have all gotten plenty of tri-metal bearings back that had the Babbitt overlay removed, there was seizure, the crankshaft was damaged, sometimes destroyed, because the intense friction that occurred between the contact with the crank journal and the copper/lead to bronze intermediate layer wound up doing all this damage. So we know that it is not desirable to have a tri-metal bearing operating in a bi-metal state because the top layer has been removed.

Now, depending upon how dramatically or how thoroughly that top layer is removed in all of our tri-metal bearings, you are getting closer and closer to probable failure, approaching catastrophic failure depending on how much is removed.

Now, if we are looking at the bi-metal bearings that we are all making today, especially when you have silicon mixed in with it, that bi-metal top surface, the top layer is about twelve-thousandths thick. We all know it's just a matter of reality that when you have a conformability situation, there is a misalignment that's causing the bearing surface to be worn thin in any particular area, because you are dealing with a homogenous alloy, you're not in any danger.

You're not in an eight ten-thousandths of an inch danger or even six ten-thousandths of an inch danger of going to catastrophic failure because you have worn out that top layer. The fact of the matter is that if your top layer is an aluminum bi-metal material that has either a 30 or a 40 HV hardness, you are going to conform the top layer without causing any scorching or any damage to the crank journal and you are not going to have any type of premature bearing failure.

And that's one of the reasons why all of us have seen that in the real world when you have these compromised situations – let's call them adverse situations – that the matter of choosing a bearing is not dependent upon how the bearing works when everything is perfect in the operating engine. I think every one of us, in order to have the best interest of the marketplace in mind, wants to develop a bearing and offer a product that will have increased longevity, increased durability under adverse conditions.

I think that's the subject matter that we need to focus on; which type of bearing is going to offer it best under what situations? And all Dimitri is saying is that when you listen to the differences in the materials and the construction, there is a lot to be said that a bi-metal bearing under certain adverse conditions is going to perform better and is not going to fail as quickly compared to a tri-metal.

STURK: Every bearing material selection is a compromise, every one. You always have to balance hard phase characteristics and soft phase characteristics every time.
I’ll go back to the ‘80s or even a bit before the 1980s when tri-metal bearings were really the material of choice everywhere for original equipment. The big concern in the □‘80s with the introduction of bi-metal aluminum was its embedability characteristics. That was the number one concern.

But I think over the years the aluminums have shown that they can take a heck of a lot of dirt and keep on going.

HAVEL: Well, that’s true. And back in those early aluminum bearing days, if you remember the first aluminum alloy ever introduced was 20 percent tin aluminum. It had no silicon in it. And you had 20 percent soft phase, which probably had the potential to embed a lot more dirt than today’s aluminum alloys with considerably less tin content and silicon content.

STURK: Right. But to sit here and argue that tri-metal bearings can’t take debris is somewhat ridiculous because they have been in the market longer than anything else has and they have a proven track record.

JAMES: Nobody has said that a tri-metal bearing cannot absorb debris. So let’s set the record straight about that, first of all. And second of all, ever since the ‘70s we have all seen the statistic about what is the number one cause of bearing failure. The statistics that have been put out by people sitting right here at the table is that roughly half of all bearing failure is caused by debris. It’s caused by dirt.

So our comment on that would be well, if in fact the tri-metal bearing works as well as it does, then that statistic wouldn’t exist today. Because if it was handling the debris as well as we would like to claim it did, you wouldn’t have the number one failure being dirt. It would be something else.

STURK: Historically I would say that’s true, that debris has been the number one cause of failure.

HAVEL: I don’t think that the reason that debris is the number one cause of failure is because tri-metal bearings can’t handle it. I think it’s just because that is by far more prevalent than any other adverse condition that we encounter.

KAUFMAN: Bob, you mentioned historically. Has that changed?

STURK: Engine builders have recognized this. I can recall going into GM in the ’80s trying to sell aluminum bearings and the plant manager was ready to kill me because “I’ve got to build surgically clean engines.” And today’s engines really are built surgically clean.

I think the number one problem in bearings today is not – at least with production engines and production rebuilders – is not debris but high speed performance and seizure performance. That’s what we all fight for. And that’s really where I think the Babbitted tri-metal bearings are very good. To get an aluminum bearing to have that kind of surface action at very high speeds has been difficult.

KOPELIOVICH: Tri-metal is really very good. It has excellent anti-seizure properties, best of all other materials, as long as the overlay exists. When the overlay is worn out, there is metal-to-metal contact with intermediate having very, very low seizure resistance.

STURK: Once the overlay is removed from the copper/lead bearing and the bronze is exposed, now we have other issues to really worry about: and the main one is corrosion.

HAVEL: And I wanted to add a comment that Michael made a little while ago that if we didn't need an overlay on our copper/lead bearings, we would be running bi-metal copper/lead bearings. We did for years, back in the '50s and '60s we had copper/lead bearings. They had fifty percent lead content. And they were great bearings, but corrosion was the problem. But the bearing was highly susceptible to corrosion, because there was nothing in there to prevent the lead phase and the copper phase from being corroded for different reasons, lead versus lead versus copper.

That was the main reason for its demise, not because of its inability to function as a bearing and its possessing or not possessing bearing qualities needed to function under normal operating conditions aside from corrosion.

Next Question: How does the alloy and construction of a bearing impact its durability? *(see Bearings Q2 transcript)*