Fora Half A Bearing Failing – An Investigation into Causes

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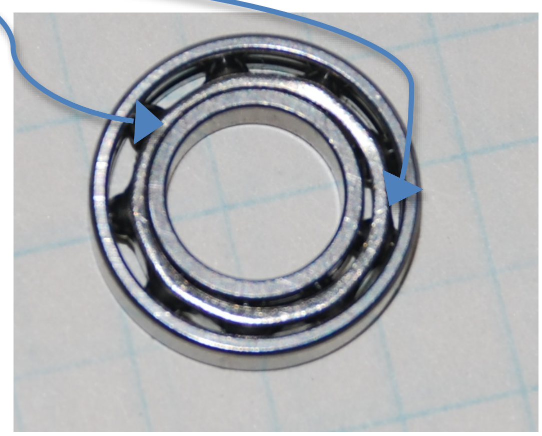
Introduction

This is the first of what I hope to be a series of articles on improving Half A engine performance. The motivation for this first article is bearing failures in the Fora Half A engines.

Background

For the past two seasons I have experienced an issue with rear bearings in the Fora Half A engines. Take a close look at the photo and you will see an uneven wear pattern on the retainer ring.



The first time I experienced this I thought the cause was unbalanced props. I use the engines for practice and bashing. On these engines I used repaired glass props, but I did not balance them.

I will typically pull an engine apart and check the bearings when I have a difficult time getting it to hold a setting. A few years ago, Pete Athans told me about this when I was having problems with a Cyclon holding a setting. Both the Fora and Cyclon, turn between 30,000 and 35,000 RPM.

This year I pulled two Fora Half A engines apart to clean them after they went into the ground and loaded up with dirt. I was surprised to see that the bearings were failing. Each of these engines had about 30 runs on them, or an hour of run time. Fuel is 10% nitro, 20% synthetic oil and 70% methanol. They were run with balanced props. After each day of flying they were oiled. During the off-season they are stored in a heated dry environment.

I posted photos and information on the MACA web site and asked for input. One person reported a similar problem. There were theories about the cases being flawed. Other theories had to do with cheap bearings.

At the 2017 Bladder Grabber, I talked to Don Jensen about this bearing problem. Don had experienced the same problem. This led us to talking about there might be an out of round condition on the crankshaft. An earlier version of the Fora engines had a problem with the crank pin that caused the connecting rod to fail.

At about this time in my quest to find out what is going on, Gene Pape jumped on board and began digging into the problem. Gene has an extensive knowledge on engines. It has been an enjoyable adventure working with Gene. Gene will be putting an article together on his testing and findings.

I wanted to fully understand what was going on and put a nice equation to it – my inner geek. I began by was letting my fingers walk through Google to see if I could gain some insight. Much of the literature focuses on roller bearings, and I have taken the liberty to extract it, where applicable, to ball bearings.

A side note is that when I start an article I will use the writing of the article to go through the analysis. This work has consisted of observing the failures, dimensional measuring, and field-testing.

The following is from Tesla and I find useful in chasing answers to problems.

"By that faculty of visualizing, which I learned in my boyish effort to rid myself of annoying images, I have evolved what is, I believe, a new method of materializing inventive ideas and conceptions. It is a method which may be of great usefulness to any imaginative man, whether he is an inventor, businessman, or artist.

Some people, the moment they have a device to construct or any piece of work to perform, rush at it without adequate preparation, and immediately become engrossed in details, instead of the central idea. They may get results, but they sacrifice quality.

Here, in brief, is my own method: After experiencing a desire to invent a particular thing, I may go on for months or years with the idea in the back of my head. Whenever I feel like it, I roam around in my imagination and think about the problem without any deliberate concentration. This is a period of incubation.

Then follows a period of direct effort. I choose carefully the possible solutions of the problem. I am considering, and gradually center my mind on a narrowed field of investigation. Now, when I am deliberately thinking of the problem in its specific features, I may begin to feel that I am going to get the solution. And the wonderful thing is that if I do feel this way, then I know I have really solved the problem and shall get what I am after.

This feeling is as convincing to me as though I already had solved it. I have come to the conclusion that at this stage the actual solution is in my mind subconsciously, though it may be a long time before I am aware of it consciously.

Before I put a sketch on paper, the whole idea is worked out mentally. In my mind, I change the construction, make improvements, and even operate the device. Without ever having drawn a sketch, I can give the measurements of all parts to workmen, and when completed these parts will fit, just as certainly as though I had made accurate drawings. It is immaterial to me whether I run my machine in my mind or test it in my shop."

Bearings

These bearings are 9x17x4 (mm) and are the same size (external dimensions) as those used on the Cyclon. Although the rear bearing is the same size for both the Fora and Cyclon, there is a subtle difference in the bearings – the bearing cage.

The Fora uses a “W” type cage and the Cyclon a “J” type cage.

The Fora bearing only captures the balls on one side of the retainer whereas the Cyclon bearing captures both sides of the balls. The Fora bearing retainer is called a “W” type. The cage snaps in from one side over the balls and is usually not used in high-speed applications. ***We have high speeds.***

The Cyclon bearing uses a “J” type where a two-piece ribbon consisting of two halves are assembled one half from one side and the other half from the opposite side. Fold down tabs secure the two halves. Here is a photo showing the fold down tabs.

Fora Cages

The Fora cages are failing. Fortunately we have not experienced balls being released. The following is an email from Yaro and gives some insight into the business side of engines.

“First of all the quality engine to engine is not something strange in this 0.8cc model, but all of Fora engines. I guess it leads to their production tolerances. In my understanding Fora as a company is more focused on mass engines production at bottom price range rather than limited production of hi-end engines at to price range. As from I see to make all the engines run great they would probably cost 50-80% more than now. And I very doubt flying folks would be buying engines for fun at 200 bucks and up each. Since 0.8cc engines class have not been worldwide class and the mostly used in the USA I very doubt Fora would be interested to change anything as even to me, to persuade them to make a batch I had to invest money for 100 plus engines otherwise they showed zero interest to the project. The guys make money and they are into something that brings a buck I can't blame them. For me, as businessman it's hasn't been good investment as I still have 60% of that batch in stock and that is really slow cash flow. I probably will give up on that.

I understand you and some other fliers are willing to see a really good performance of this engine, but I just don't see that happening as you can't really expect much of the 140-150$ engine. Add good Swiss bearings and the price will jump by 30 dollars right away. And just to get that special bearings (I'm talking about C4 play) you would need to buy 2000-5000 pcs at least so the bearing manufacturer could even speak with you about it. I guess that is the reason why they have been using cheap bearing in this engine. It's not that simple my friend.

So that is why engines fine tuners are still in the business as they make that piece of junk work and I probably good running engine is worth that money they ask for their job (normally it's 100 plus)."

The existing bearing uses the least expensive cage possible. Steel cages are stamped out of fairly thin sheet metal, much like a cookie cutter, and then bent to their final shape in a die. A die is made up of two pieces of steel that fit together, with a hole the shape of the finished part carved inside. When the cage is put in between and the die is closed, the cage is bent to the shape of the hole inside. The die is then opened, and the finished part is taken out, ready to be assembled.

Cage Damage

The following is a discussion of cage damage from the "Web" with my observations (noted in bold) of what I have observed on the Fora bearing.

If, on examination of a failed bearing, the cage is found to be damaged, it may in many cases prove difficult to ascertain the cause. Usually other components of the bearing are damaged too and this makes it even more difficult to discover the reason for the trouble. However, there are certain main causes of cage failure - vibration, excessive speed, wear and blockage.

<u>Vibration -</u> When a bearing is exposed to vibration, the forces of inertia may be so great as to cause fatigue cracks to form in the cage material after a time. Sooner or later these cracks lead to cage fracture. ***I have not seen cage fracture.***

<u>Excessive speed- If</u> the bearing is run at speeds in excess of that for which the cage is designed, the cage is subjected to heavy forces of inertia that may lead to fractures. ***Again no observed cage fractures. We are dealing with high speeds and the factory supplied bearings may not be able to sustain the high speeds. See the discussion on "W" type cages below.***

<u>Wear-</u> Cage wear may be caused by inadequate lubrication or by abrasive particles. ***I think there is adequate lubrication getting to the bearing.***

Although these are ball bearings an interesting fact about rolling bearings is the cage is always made of softer material than the other components of the bearing and consequently it wears comparatively quickly. As the cage pockets increase in size, due to wear, the rolling element guidance deteriorates and this also applies to the cage in cases where the cage is centered on the rolling elements. The resultant forces may lead to cage failure within a short space of time. **We are seeing cage pocket enlargement.**

Blockage- Fragments of flaked material or other hard particles may become wedged between the cage and rolling elements, preventing the latter from rotating round its own axis. This leads to cage failure.

Physical Analysis

Cages in bearings are subject to severe acceleration and retardation, in conjunction with fluctuations in speed, cages are affected by forces of inertia. These give rise to considerable pressure between the contacting surfaces, with consequent heavy wear. I took one of the damaged bearings apart and tried to fully understand what was going on.

You will notice on the retainer ring low points and high points. The high point occurs at the ball. The retainer ring has an opening to capture each ball. The first thought to come to mind is there is an up force being applied that is resisted by the ball but not by the gap between the balls thus causing the difference. Glass half full. There could be a down force being resisted by the ball but not by the space between the balls. Glass half empty.

When I rolled the balls on a flat glass surface, there is a noticeable flat spot on the ball. Both the inner and outer race is grooved. There are 9 balls in the bearing.

The outer race is fixed. Assuming no movement between the inner race and the shaft, the inner race rotates with the crank. If there is one high spot on the crank then each of the balls will get hit with the same force. This should make the deformation symmetrical; but it is not. It is more oblong. So what is causing the oblong shape?

When viewed from this side it appears that the inner race is not centered. Since the balls ride between the inner race and the outer race for this to happen the balls would have to significantly deform. I have noticed some flattening but nothing to shift the inner race. I have measured the inner and outer race and established that the inner race is centered. There are nine balls in the bearing. When I rotate the inner race, I can get the retainer to contact the inner race at four of the ball positions. In other words 44% of the retainer is contacting the inner race way. The first bearing that failed had 66% contact.

What you are seeing is the deformation of the retainer. If you look carefully you will see the retainer contacting the inner race.

Both the outer race and the inner race are grooved for the balls. Looking at the groove of one of the outer races I could see impressions of the balls. Looking at the ball groove on the inner race, I can see where the groove has gotten wider.

The cage is .007 inch thick at the tabs. Using drill bits I found the largest diameter hole to be .101 inches and the smallest to be.097 inches. The ball diameter is.092 inches.

If we assume the balls are not deforming and we know they stay centered between the outer and inner race, then what is causing the deformation of the retainer. When new, all the balls are centered and retained by the cage. During the course of running the engine, the cage at the ball will start to enlarge. When this happens the cage at that position will move down on the ball. Although the sample size is two, this occurred on adjacent balls and not at random. I went back and looked at a photo of the bearing failure in 2014 and it also had a six ball pattern. Neither Gene nor I have experienced cage failures where the balls came out of the cage. Because the engines were having problems, I took them apart and replaced the bearings. This was done because I felt the bearing was rough and it was since the cage was rubbing against the inner raceway of the bearing.

If the rings of a deep groove ball bearing are fitted out of alignment with each other, the path of the balls has an oval configuration. If the cage is centered on the balls, it has to change shape for every revolution it performs. Fatigue cracks then form in the material and sooner or later they lead to fractures.

There is a similar case when a thrust ball bearing is fitted together with radial plain bearings. If clearance arises in the plain bearings, the washers of the thrust bearing become displaced in relation to each other. Then the balls do not follow their normal path and heavy stresses may arise in the cage.

Forces of inertia affect cages in bearings subject to severe acceleration and retardation, in conjunction with fluctuations in speed. These give rise to considerable pressure between the contacting surfaces, with consequent heavy wear.

Conclusion

Let me begin by saying that a sophisticated lab filled with expensive equipment would be nice to have; I do not think it would invalidate the results. To answer the question of the crank pin I replaced the bearings in three of the Foras. One Fora got a used Cyclon “J” bearing and the other two new “J” type cage bearings

(Boca Bearing MR689(X)). The retainers are steel. I have taken these apart and there is no damage to the any of the cages. From these test there have been no con rod failures and therefore the crank connecting pin is not an issue.

The cage pocket is deforming and ultimately makes contact with the inner race. We do not know the tolerances of the cage material. The most likely cause of events is that one of the balls begins to open up a cage pocket. The ball impacting the cage in the rotational direction would cause this. The dimensions stated above are from used bearings. It would be nice to set up a test with a new bearing and tear the engine down after each run and see when the pocket starts to open.

Since the cages are stamped we do not know the tolerances on the pockets. We do not know what level of tool maintenance is done which could cause one of the ball pockets to be larger.

If you look carefully at the cage, you will see material build up at on the cage pocket. This has occurred on all the pockets. We know the cage material is softer than the balls. I did not note what direction the bearing was facing when I removed it. I asked Gene if he recalled and he said the open side of the cage faces forward.

As stated above in **Cage Damage**, if on examination of a failed bearing, the cage is found to be damaged, it may in many cases prove difficult to ascertain the cause. When we tach an engine we get a value for RPM, but is this a steady state value or are there minor fluctuations that we do not see on the tach? If this is occurring then the cage could be slowing down relative to the balls and start to open up a pocket. The thrust of the prop would cause a force against the shaft, which in turn would translate to a force between the bearing and the case. Over time this could explain the build up of material between at the front of the cage.

Regardless of the cause, the bearings are failing and need to be replaced. Yaro has found affordable replacement bearings with nylon retainers. These and are available from www.aerohobby.ca