For unmanned vehicles that achieve hypersonic speeds, the performance of the combustion engine is paramount. Ball bearings play a pivotal role in the fuel delivery system. After calculating the basic rating life – the total number of revolutions before the first evidence of material fatigue occurs – Engineers select bearings that will meet the design or desired life. The life of a bearing under actual operating conditions before it fails or needs to be replaced for whatever reason is the bearing service life. And if that service, or useful, life precedes the desired time of operation for the vehicle, prohibiting it from reaching its destination, the dreaded MF occurs: mission failure.

For a manufacturer of the propulsion system (jet engines) for these unmanned, hypersonic vehicles, which travel more than five times the speed of sound, optimization is key. That means every facet of operations — every material, working condition, and controllable variable — must be optimized in order to achieve, and sustain hypersonic speeds where air molecules actually separate and high-temperature effects stress the vehicle and it's sub-systems.

"Anything that is mission-critical has to be 100% reliable," explained Steven Sanchez, Engineering Manager at AST Bearings. "The ability to accomplish the mission safely must be achievable and repeatable."

In its initial design of the engine, the manufacturer encountered a performance weakness: the bearing configurations selected yielded at most 30 seconds of vehicle life before experiencing a catastrophic failure (in some cases, bearing failure was almost immediate). Bearing failure at these high speeds results in fractured components and flying debris damaging other components, such as the turbine, and in turn, lead to complete engine failure.

The manufacturer sought a more durable bearing configuration beyond the standard product offering, one that would allow their vehicle to operate for longer. The manufacturer reached out to AST to find a solution.

AST engineers accepted the challenge, assuring the manufacturer that it could improve the bearing life significantly, targeting a factor of 10, a projection that, if achieved, would significantly expand the capability of the end user's vehicle.

"In the world of extreme," said Sanchez, "it's tweaking and optimizing that gets you across the finish line. You need a bearing expert who knows what to tweak and has the tools to determine and validate those optimizations."

Find out how AST engineers helped this manufacturer of liquid fuel pumps and gas compressors prevent mission failure in Mission Critical Success – Part 2. Coming February 21, 2020.

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AST helped the manufacturer of liquid fuel pumps and gas compressors achieve a more reliable bearing solution, one that eliminated premature failure.

The following is part two of a two-part post. Here's a recap of part one, which you can read here.

A manufacturer of the propulsion system (jet engines) for unmanned, hypersonic vehicles, was experiencing premature bearing failures that led to compromised vehicles' missions. They reached out to AST engineers for assistance. AST engineers accepted the challenge, assuring the manufacturer that it could improve the bearing life significantly, targeting a factor of 10, a projection that, if achieved, would significantly expand the capability of the end user's vehicle.

Small Changes. Big Results.

First, AST engineers considered the dimensional constraints, mounting options, and bearing size. A common approach would have been to simply deploy larger bearings, which would increase the calculated bearing life (the bigger the bearing, the greater the load capacity). But they quickly dismissed the idea, as the cost for the manufacturer to re-tool the manufacturing process of the contiguous components would have been prohibitive. As a result, AST engineers needed to design a solution that fits in the existing bearing space.

Next, utilizing their custom rolling element bearing analysis software, AST engineers modeled and ran multiple simulations to determine the elastic behavior of the vehicle's existing ball bearings, which would provide insights into the cause(s) of failure. After a comprehensive analysis, they discovered that extreme axial forces from the turbine were causing potential ball truncation and edge stresses. Engineers then applied those findings to proposed modifications and assessed their impact.

Having determined the failure mode and zeroed in on the root cause, AST engineers developed a series of design modifications. These changes were introduced incrementally and through the use of modeling and simulation, the effectiveness was validated. Relocation of one of the bearing sets along with changing the contact angle of the balls solved the axial loading issue. "Changing the distance between the bearings on one common shaft can greatly reduce the final loading per bearing; it was finding that 'sweet spot' that became the challenge," Sanchez said. A later simulation, focusing on operating and environmental conditions, led to changing from stainless steel to ceramic balls. This last tweak extended life a little further. Later testing with actual hardware proved to be a success.

"It's a very analytical process, you select one parameter and you change it incrementally to gauge behavior," said Sanchez. "Obviously, you're trying to make moves that don't make things worse. And as you make tweaks, you look for improvements that allow you to move onto the next sequence."

The entire process was collaborative, with AST engineers engaging with the manufacturer to confirm whether the suggested changes were practical. The entire process took roughly three months.

Collectively, those changes improved bearing life by a factor of 10, the optimization that AST engineers had hoped to achieve. The improvement eliminated premature failure in the bearings, delivering the performance boost that the manufacturer sought.

"We were able to greatly increase the capability of their vehicle," Sanchez said, "allowing them to deliver their payload successfully to its destination. Repeatedly."

Innovative Thinking. Innovative Solution.

For AST, it's not always about steering a client to an existing product; rather, it's finding a solution that solves a unique challenge that is the distinguishing AST value proposition.

Leveraging modeling software to modify positioning, contact angle, and materials, all while maintaining close contact with the client, made the AST design process a case study in providing *Value Beyond the Part™*. And it's this ability and willingness to assess a problem and consider customer requirements (and limitations) before developing a solution that distinguishes AST as an industry leader in ball bearing technology.

AST has developed a global network of partner manufacturers who will produce customized designs —unusual in the industry — ensuring the optimal performance of its customers' products.