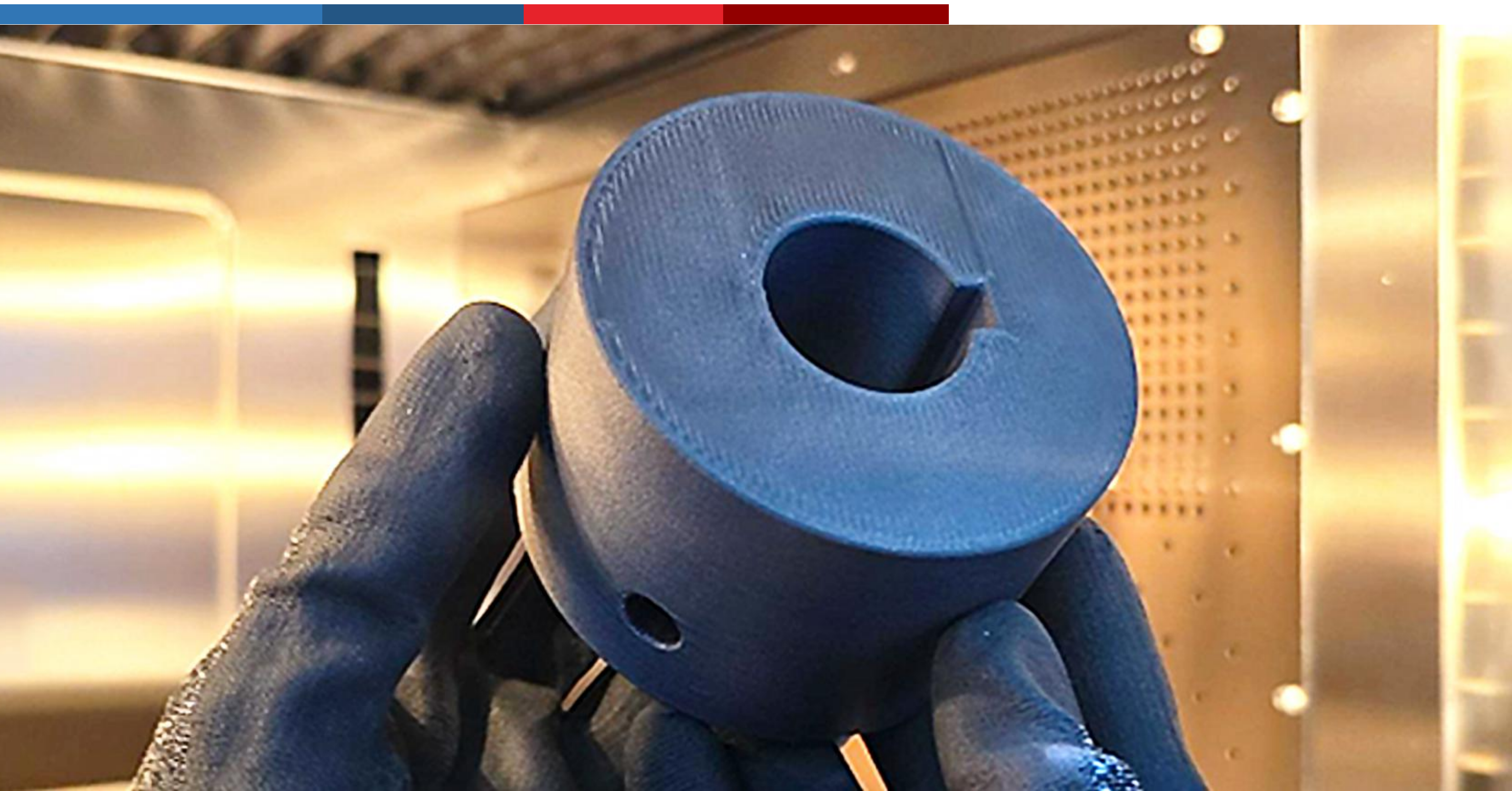
CASE STUDY

Enhancing Mist Pump Efficiency and Durability with Additively Manufactured PEEK Bushing



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Introduction

Mist pumps, as critical components of mist fire suppression systems, play a vital role in enhancing safety measures in industrial facilities by providing efficient fire suppression capabilities. These specialized pumps generate the high pressure required to discharge a fine water mist, creating an effective medium for controlling and extinguishing fires while minimizing water damage. Beyond fire safety applications, mist pumps are utilized for cooling and humidifying processes across various industries, including oil and gas. The reliability and performance of these pumps are essential to maintain operational continuity and safety standards in high-stakes industrial environments.

Among the various pump components, the pump shaft bushing plays a particularly crucial role in ensuring smooth and efficient performance. Bushings serve as bearings within the pump system, reducing friction between moving parts and absorbing shock loads during operation. They are typically manufactured from specialized materials such as polymer composites, bronze, or advanced ceramics, selected specifically for their wear resistance, low friction coefficients, and durability under high-pressure conditions. These properties are essential for pump reliability, as they effectively mitigate the adverse effects of cyclic loads, vibrations, and thermal stress. A well-designed bushing not only extends the operational lifespan of the pump but also minimizes maintenance costs and reduces operational downtime. In mist system pumps, where precision and consistent performance are paramount, the role of bushings becomes even more critical in maintaining system efficiency and reducing the risk of component failure.

Problem Statement

RusselSmith received a request from one of its valued customers to replace a pump shaft bushing that had experienced material failure due to prolonged operation in a highly saline environment.

The table below shows the working conditions of the pump shaft bushing:

Table 1: Operating Conditions of Mist Pump Bushing

Operating Temperature	+20/30 deg. Celsius
Operating Power	30.1 kW
Rotational Speed (RPM)	980
Corrosive Environment	Saline Environment (Offshore)

The chloride concentration in the saline environment could have exacerbated the failure process of the bushing through stress corrosion cracking. The failed bushing was made of carbon steel, and it was necessary to replace it with a material possessing enhanced corrosion resistance and strength to withstand the environmental interactions associated with service. Additionally, the mass of the pump bushing was a critical factor, as selecting a lighter material would enable reduced rotational inertia and reduced bearing load, thereby improving energy efficiency.

Our Solution

Our approach was strategically anchored on three core considerations: optimizing the strength-to-weight ratio, increasing fracture toughness, and enhancing resistance to environmental degradation. The pump bushing was manufactured using a carbon-reinforced polyether ether ketone (PEEK) composite through the Fused Filament Fabrication (FFF) method.

To ensure optimal performance, our team conducted a comprehensive material and design evaluation. One significant modification involved increasing the counterbore depth to enhance the hold and seating of the bolts, ensuring they remain secure without loosening from the bushing. Additionally, the wall thickness was increased, and the thread height was extended, while maintaining the distance between the thread base and the inner diameter of the bushing unchanged. Precise dimensional allowances were also applied to account for potential shrinkage or expansion during the 3D printing process. These refinements ensured that the composite material met the stringent performance requirements of the operational environment.

During the printing workflow, the reinforced PEEK filament was pre-dried in an HT dryer at 120°C for 8 hours to eliminate moisture and ensure optimal print quality. Key printing parameters included an extrusion diameter of 0.6 mm, a printing speed of 2,100 mm/min, an extrusion temperature of 440°C, an infill density of 100%, and a build chamber temperature of 160°C.

To address the impact of radial forces exerted by the bolts on the bushing wall, the layer thickness was optimized. This adjustment ensured the material could withstand the maximum radial loads generated by the bolts at the motor pump's operating speed, thereby enhancing the bushing's structural integrity and performance.

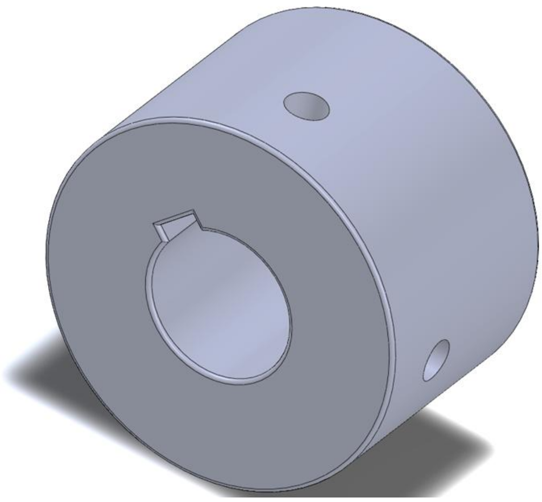

Figure 1: 3D Model of the Pump Bushing

The Result

The additively manufactured pump bushing was successfully integrated into the mist system pump and has performed reliably under standard operating conditions, ensuring both operational efficiency and safety of the facility. The customer expressed satisfaction with the bushing's functionality and durability, highlighting that it met all operational expectations. As shown in Figure 2, the bushing exhibits excellent surface smoothness, a critical factor for ensuring optimal system performance.

This project demonstrated that the Carbon-reinforced PEEK filament used in the 3D-printed bushing not only matched the mechanical performance of the original component but also introduced additional advantages. These included enhanced wear resistance, which can extend the service life of the component, lead to reduced production lead time, and result in improved material efficiency. The success of this deployment reveals the emerging position of additive manufacturing as a robust solution for producing high-performance industrial components, further solidifying its role in driving innovative and sustainable maintenance strategies.

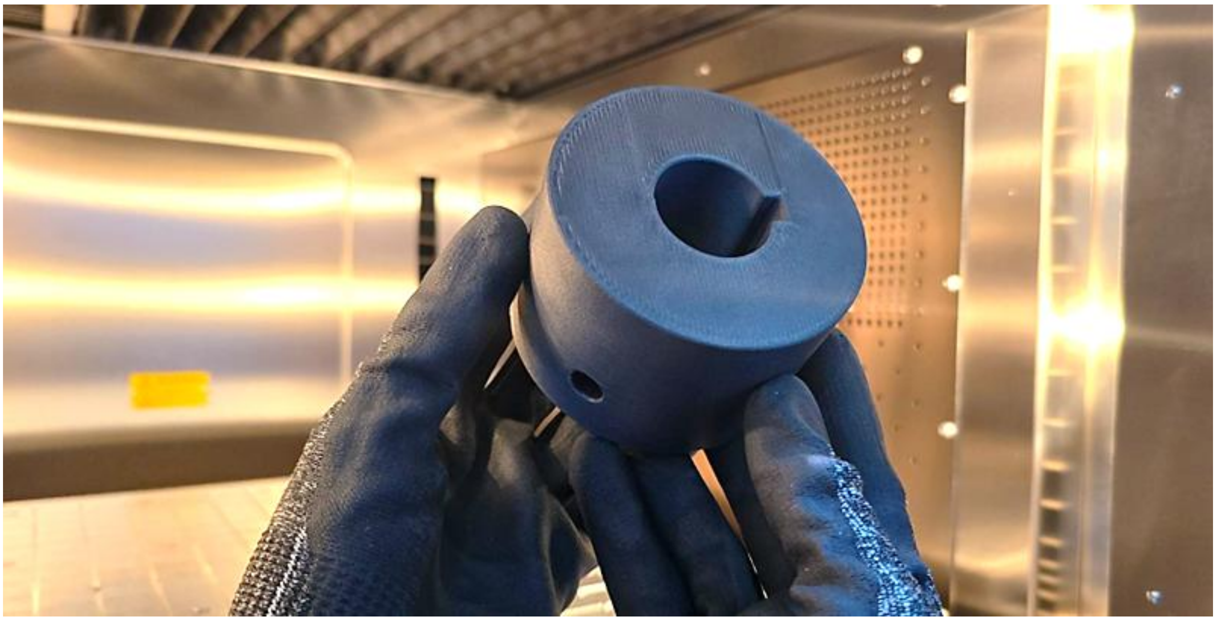

Figure 2: 3D Printed Carbon-reinforced PEEK Motor Pump Bushing

Sustainability Impact

The implementation of the carbon-reinforced PEEK pump bushing using additive manufacturing demonstrates significant sustainability advantages beyond the immediate technical benefits. This manufacturing approach aligns with broader industrial sustainability goals through multiple pathways of environmental impact reduction.

The additive manufacturing process improves material efficiency by utilizing only the precise amount of material required for the component. Unlike traditional subtractive manufacturing methods that generate substantial waste through machining operations, the FFF technique applied in this project resulted in minimal material waste.

The localized production capability enabled by additive manufacturing further enhances the sustainability profile of this legacy component replacement effort. By manufacturing the component near its point of use, the carbon footprint associated with international transportation was substantially reduced. This localized approach to component replacement eliminates the need for extensive logistics operations that would otherwise be required when sourcing specialized parts from distant manufacturers.

Additionally, the design enhancements incorporated into the additively manufactured bushing - including the optimized counterbore depth, increased wall thickness, and extended thread height, all contribute to increasing the component's service life expectancy. This extended durability translates to reduced material consumption over the pump's lifetime, fewer replacement interventions, and consequently, a lower overall environmental impact through the entire life cycle.

This case study demonstrates that additive manufacturing represents not merely an alternative production method but a fundamentally more sustainable approach to industrial component replacement. By simultaneously addressing material efficiency, transportation impacts, component durability, and energy utilization, the technology aligns with circular economy principles and supports industries' transitions toward more environmentally responsible maintenance practices.

RusselSmith is committed to reshaping the African industrial landscape through resilient, innovative, and sustainable solutions. By leveraging industrial additive manufacturing, RusselSmith is minimizing material waste, contributing to carbon emission reduction, improving operational uptime in industries that it serves, and optimizing resource utilization, thus aligning with global sustainability objectives.

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FOR THE FUTURE OF ENERGY

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