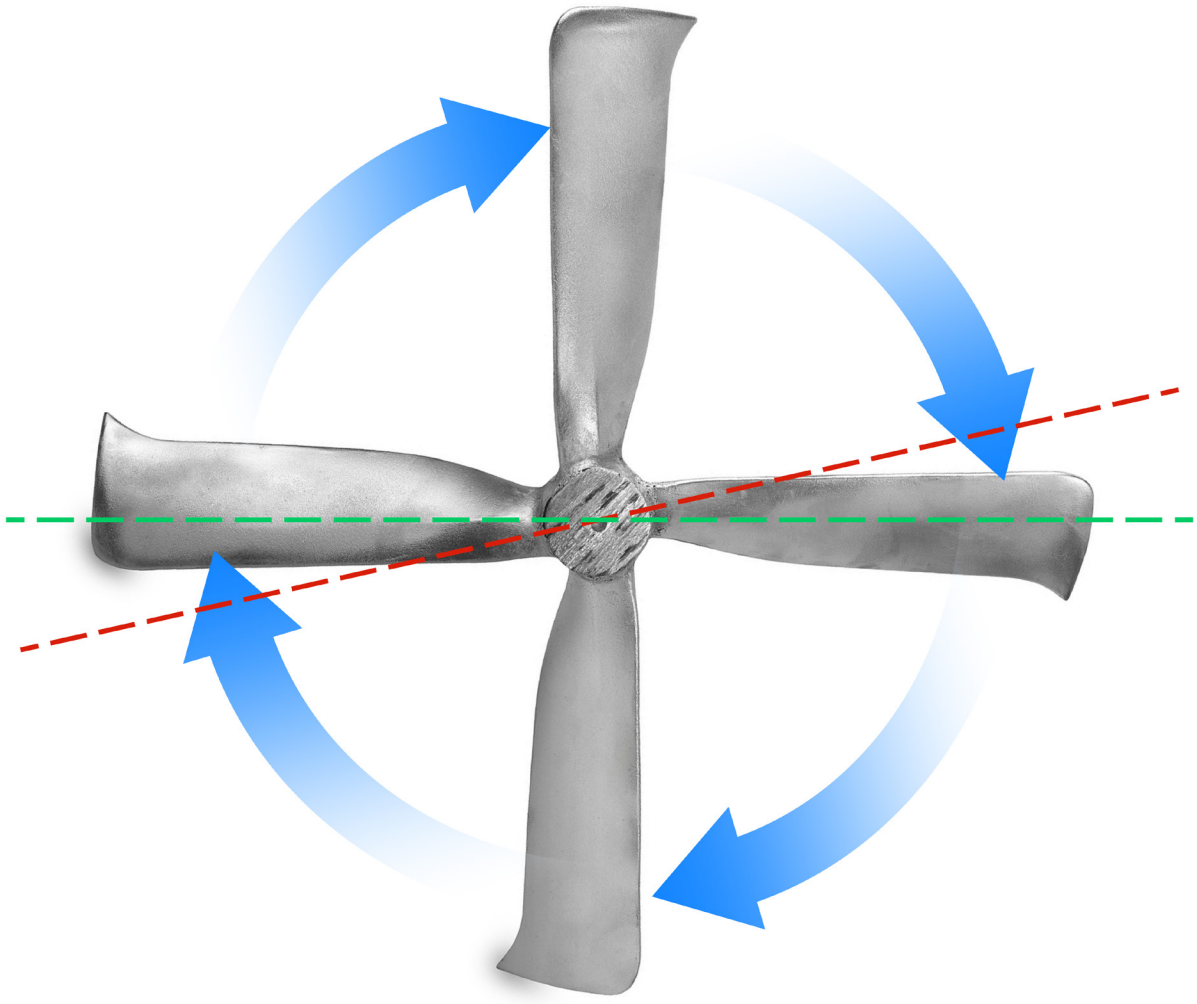
CASE STUDY

FINDING THE PERFECT BALANCE: CASE STUDY OF CONTINUOUS IMPROVEMENT IN CAST ALUMINUM FAN PROPELLER INSPECTION



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Introduction

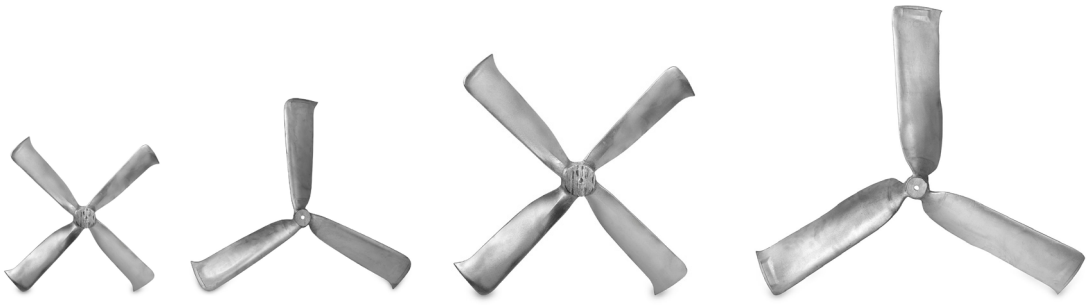
Eagle Aluminum specializes in permanent molding and greensand casting of aluminum products. In keeping with the Eagle Group's philosophy of continuous improvement, Eagle Aluminum's team is always looking for ways to improve our processes to achieve better quality, greater efficiency and reduced returns.

This case study focuses on a recent innovation that dramatically improved the return rate for a line of parts without adding to processing time.

Eagle Aluminum's Permanent Molded Fan Propellers

One of the major entries in Eagle Aluminum's portfolio is our line of **permanent molded** fan propellers. Produced for a major agricultural equipment company, these props come in a variety of shapes and sizes, ranging from 14" to 55" in blade span. For an overview of the manufacturing, design and finishing processes involved in these products, take a look at our previous Eagle Aluminum case study.

Here we describe a method of measuring the props as they cool that provides accurate feedback on their balance. While Eagle Aluminum previously used standard dynamic and static balancers to balance the propellers before sending them to a balancing firm for final machining, the new method incorporates linear measurements of blade thickness. This adjustment has led to a dramatic decrease in returns, and streamlined the overall supply chain for delivery of the parts.



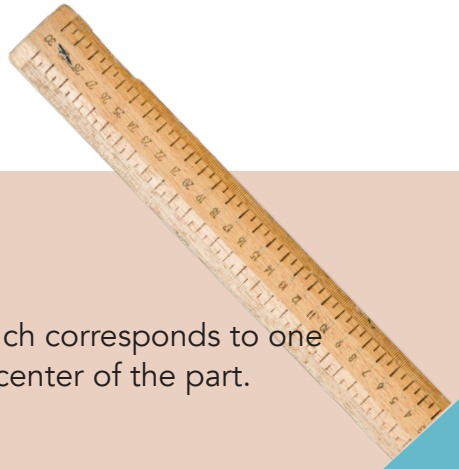
Finding the Perfect Balance

Fan propellers need to be properly balanced in order to prevent noisy operation and excessive vibration that may lead to early equipment failure. Eagle Aluminum works with a supply chain partner that provides final machining and balancing, but we're accountable for every part that leaves our facility. It's our job to provide parts that are balanced within an agreed-upon tolerance range, so we need to know immediately if any of our parts fall outside that range.

When we inspect propellers for balance, we must consider two planes: rotational and lateral. **Rotational balance** refers to the evenness in weight distribution as the propeller rotates around a central axis. Extra material on any of the fan blades will produce an imbalanced reading, as will some casting defects. **Lateral balance** corresponds to the angle at which the blades connect to the center of the prop. If one or more blades are bent, this can also lead to an imbalance.

The **dynamic balancer** employed by Eagle Aluminum is a standard piece of equipment used to inspect rotating parts. It works by spinning the parts rapidly and measuring any deviations with electronic sensors. The balancer delivers readings in **ounce-inches**, and can provide information on both rotational and lateral planes.

Eagle Aluminum also makes use of a **static balancer,** which works by attaching the propeller via a molded pinhole at its geometrical center to a rotational ball bearing apparatus. The propeller is placed with the heaviest blade parallel to the ground, then allowed to move freely. Based on the number of blades and an agreed-upon tolerance range, a balanced prop will rotate a certain number of degrees. Imbalanced props will under-rotate or over-rotate.



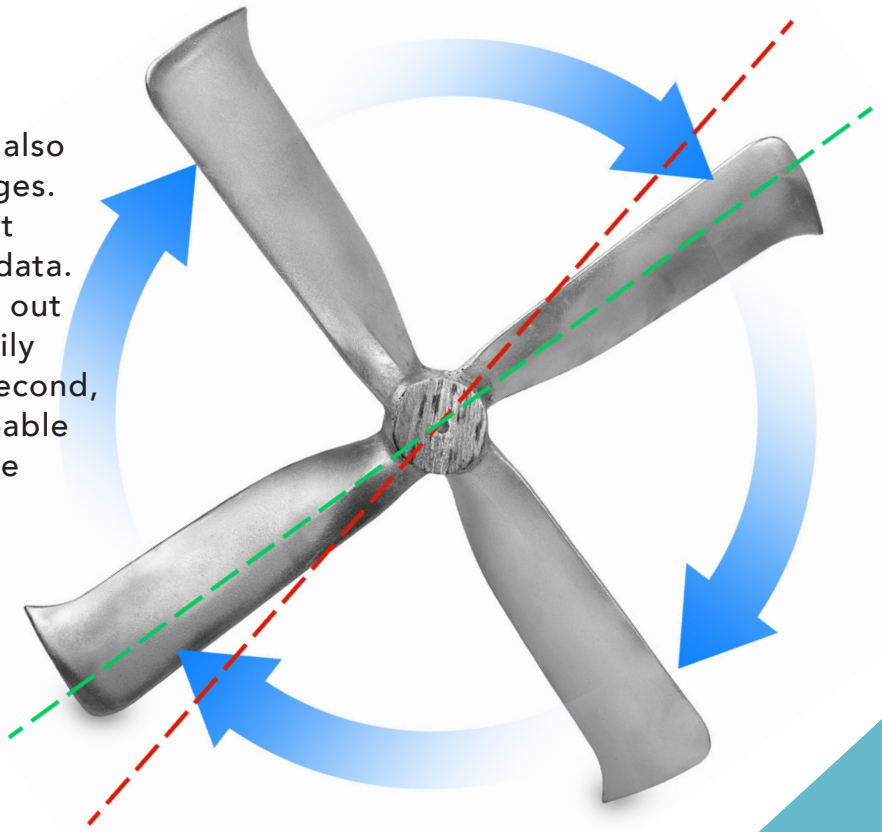
UNDERSTANDING OUNCE-INCHES

Ounce Inches (oz/in) are the units of balancing. One ounce inch corresponds to one ounce of extra weight located one inch from the geometrical center of the part.

Balancing Challenges

Both of these techniques provide some useable data on the balance of our propellers, but they also present a number of issues. The **dynamic balancer** requires different tooling for different size props, leading to higher start-up costs and more complex changeovers. We also faced challenges related to inconsistent readings between our machines and those of the balancing company. While the props we were shipping out were still within the tolerance range, our measurements were often slightly off from the numbers provided by the balancing company's machines.

While the **static balancer** is a simple solution that provides basic feedback on balance, it also presents a number of challenges. First, the static balancer is not capable of providing precise data. Operators can tell if a prop is out of balance, but they can't easily see how far out of balance. Second, the static balancer is only capable of measuring imbalance on the rotational plane; it cannot provide feedback on laterally imbalanced blades. Third, the placement of the prop on the balancer (and the expected rotation) also depends on the number of blades. Three and four-blade configurations are easy to mount, but for props with five or more blades it is difficult to find the correct initial position. The system also fails to give precise feedback as to which blade is the cause of an imbalance, or if multiple blades are affected.



The Solution: Cooling Fixture-Mounted Gages

To overcome the challenges presented by static and dynamic balancers, Eagle Aluminum developed an entirely new method of providing data relating propeller balance. **Instead of using balancing machines, we now use linear gages that measure blade thickness in fixed locations.**

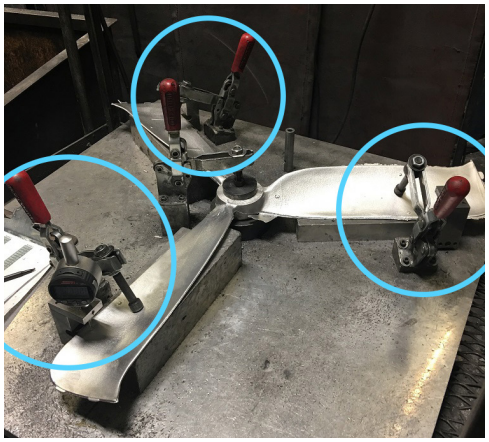
We started with a batch of returns from the balancing company. We knew from their feedback that the balancer readings in ounce-inches varied too much between the heaviest and lightest blades, leading to imbalanced rotation. By taking linear measurements of the length, width and thickness of each blade on each prop, we were able to determine the weight of each thousandth of an inch of blade thickness. We were then able to determine exactly how much variation in thickness was allowable between the thickest and thinnest blades.

Since we place props into cooling braces to maintain their lateral balance as they cool, we decided to attach gages directly to the cooling braces. Gages at fixed, corresponding locations measure the thickness of each blade.

Linear gage measuring blade

While our previous tolerance ranges were based on dynamic balancer readings (oz/in) or static balancer readings (degrees), our new tolerance ranges are based on linear measurements in thousandths of an inch. Because of the strong correlation we found between blade thickness and overall balance, our new readings are both more precise and easier to obtain. Furthermore, we are now able to record and save measurements on every blade we produce. This allows us to maintain accountability throughout the molding process, and may provide us with additional insights toward process improvement down the line.

The balancing company is still responsible for making final adjustments through machining, but Eagle Aluminum is now able to send parts downstream with greater confidence. **As expected, returns have been reduced significantly, by close to 90%.**



Above: propeller installed in cooling fixture with gages attached

Keeping it Lean

Eagle Aluminum's production of fan propellers is already a lean operation. As outlined in this case study, each operator carries out three main tasks in each cell. First, the operator pours the casting. After pouring, the part is transferred to a cooling fixture that forces it to hold its shape while it cools. Another shot is poured while the previous part cools in the fixture. The operator then removes the cooled part for cleaning and gate removal, and inserts the freshly molded part into the cooling fixture to repeat the process.

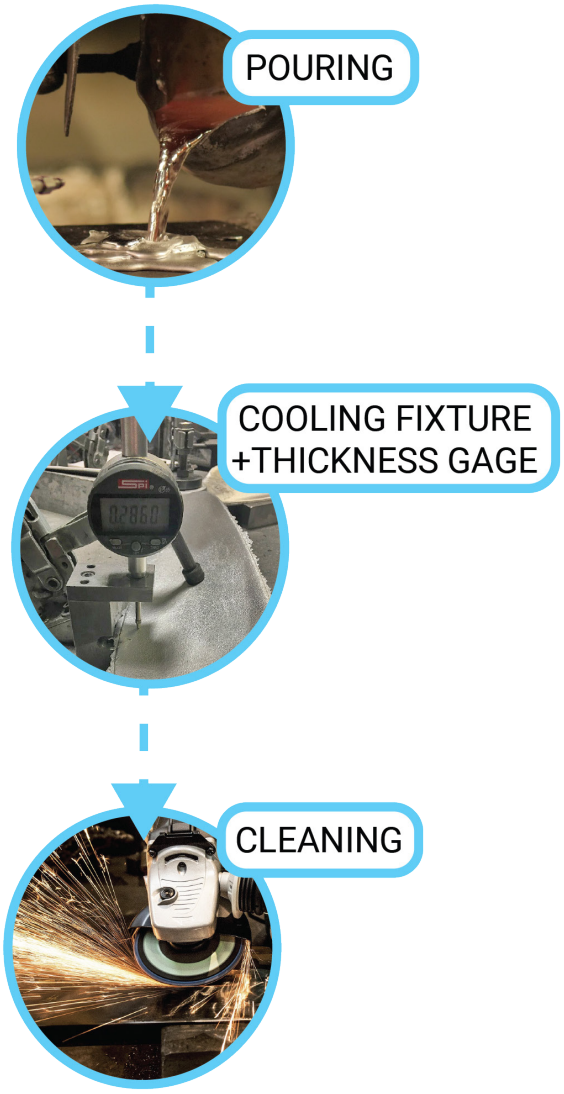
With the old method, balancing had to take place after cooling and cleaning were both complete. Operators were able to perform the inspection in the same cell without forming a production bottleneck, but the new solution is even leaner. The operator can now take accurate measurements of the thickness of the fan blade as the blade cools.

Not only does the new method provide more accurate balance data, but it also eliminates the need for a station in the manufacturing cell.

Stations in Lean Cell

OLD METHOD

NEW METHOD



Three Reasons Why Our Fixture-Mounted Gages Work

Since balance depends on both rotational and lateral movement, Eagle Aluminum's fixture-mounted gages need to guarantee precision across both planes. Our thickness-gage technique might not provide useable information in other manufacturing systems, but the following three points explain why it works with Eagle Aluminum's setup.

- **First,**, Eagle Aluminum's design and casting methods are optimized to eliminate casting defects. As a casting method, permanent molding is able to produce parts to very tight tolerances. If a part deviates from its expected thickness even by a tiny amount, it's clear that something went wrong during production.

- **Second,** the cooling fixture that incorporates these gages is designed to prevent bent fan blades. For propellers that cool in the fixture, lateral imbalance is not an issue.

- **Third,** final balancing often involves removal of material from grind pads on propeller blades by our supply-chain partner. Length is also determined by machining stock from the end of the blades, but thickness is the responsibility of the foundry.

Left: Eagle Aluminum operator mounts prop in cooling fixture

Benefits to the Whole Supply Chain

When one link in the supply chain improves their processes, the entire supply chain benefits. In this case, Eagle Aluminum ships all inspected propellers to a balancing company. The balancing company finishes the parts through machining, including a final balance calibration. They then send the propellers to the OEM manufacturer, who assembles them with a housing and a motor and prepares them for final sale.

If Eagle Aluminum ships an out-of-spec part to the balancing company, the balancing company sends it back as a return. The challenge with previous measuring methods was that returns would come back to Eagle Aluminum several days after they'd been sent. Now we get immediate, reliable feedback on the quality of our parts in-house. Our operators can quickly resolve any molding issues, and we can dramatically reduce the number of returns from the balancing company.

Furthermore, the new balance inspection method has improved machinability by eliminating the need for a pinhole at the center of each casting. The pinhole was necessary to mount the prop on the dynamic and static balancers, but it sometimes created problems in both molding and final machining, which are both solved by eliminating the pinhole.

Eagle Aluminum benefits most directly from the improvement: the established correlation and immediate, quantitative feedback allow us to adjust our process immediately, resulting in fewer returns. For the balancing company, the improvement means the props they receive have less variation, saving them time and costs on delivering balanced parts. For the OEM company, it means shorter average lead-time for every batch of parts.

This case study is just one example of how a philosophy of continuous improvement and a lean approach to manufacturing can provide far-reaching benefits to the entire supply chain.

Glossary

For more metalcasting and machining terms and definitions, check out the Eagle Group Metalcasting & Machining Glossary online:

https://eaglegroupmanufacturers.com/glossary/

Dynamic Balancer: a tool used to test balance in rotational parts by rotating the parts and measuring vibrations through a suspension system.

Lateral Balance: the evenness in weight distribution across a flate plane.

Ounce Inches (oz/in): the units of balancing. One ounce inch corresponds to one ounce of extra weight located one inch from the geometrical center of the part.

Permanent Molding: a casting process employing reusable molds, as opposed to molds constructed of sand or refractory materials.

Rotational Balance: the evenness in weight distribution as an object rotates around a central axis.

Static Balancer: a tool used to test balance by affixing a part to a pin and allowing it to rotate freely around a central axis.

About Eagle Aluminum Cast Products, Inc.

Based in Muskegon, Michigan, Eagle Aluminum Cast Products, Inc. is a versatile aluminum foundry and pattern shop that specializes in permanent mold and greensand casting.

Eagle Aluminum is part of the Eagle Group, which is made up of three foundries and a CNC machining house. Together, the Eagle Group provides outstanding customer service and quality machined castings using several different processes and a wide range of alloys.

To learn more, visit us on the web at

www.eaglealuminumcastproducts.com

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