Rotor Safety Guide

Maximizing the safe operational life of your centrifuge rotors

ACCELERATING *answers*

BECKMAN COULTER
Life Sciences

Introduction

We all appreciate that regular care and maintenance is critical to keeping lab equipment running properly and extending its life. One item that's often overlooked for regular maintenance is the centrifuge rotor. These substantially built and carefully designed components experience stress, wear and damage that can not only shorten their bench life, but pose a safety hazard in the lab.

With even the best-designed, most-advanced rotor, its safety depends largely on those who operate it, maintain it and decide when it should be retired. This guide will walk you through the basics of rotor safety and maintenance so you can maximize the life of your rotor and minimize risk in your lab.

The stressful life of a rotor. Consider this: During rotation, an ultracentrifuge rotor may experience 1 million times the force of gravity. At this g-force, in effect, one gram will "weigh" 1,000 kilograms. It's easy to see how under these conditions even minor flaws can become significant threats, generating stresses greater than the rotor was designed to withstand.

Safety Starts with Design

Beckman Coulter Life Sciences designs rotors to meet the diverse needs of research, medical, industrial and bioprocessing laboratories. We rely on feedback from our customers to determine the rotor needs for various applications, and design products to fulfill them. Our engineering process is precise and meets rigorous standards to ensure both performance and safety. The basic steps of our engineering process include:

- Create solid model concepts and use finite element analysis (FEA) to simulate rotor stresses that will occur in daily use.
- Conduct dynamic characterization of the rotor, drive and centrifuge to ensure total system stability.
- Select ideal materials and geometry to optimize size, weight and required strength of the rotor.
- Fabricate prototype rotors and subject them to an extensive testing regimen.
  - Subject rotor to repeated cycle ups to maximum speed.
  - Conduct single-cycle burst tests to verify robustness of design and fragment containment.
- Perform laboratory protocols to verify that the rotor will achieve desired particle separations.

Only after a rotor meets all design criteria is it released to manufacturing for production. Rotors undergo stringent inspection at each stage of production, from forging to finished product. We then precisely balance each rotor and confirm its stability. The final step is a high-stress test that ensures the rotor will have a long, safe life in your laboratory.

Why Rotors Fail

To help prevent rotor failure, it's important to understand its causes. Misuse or abuse of equipment is often a culprit. Be sure to take steps to avoid damage and check your rotor for these possible issues.

Stress

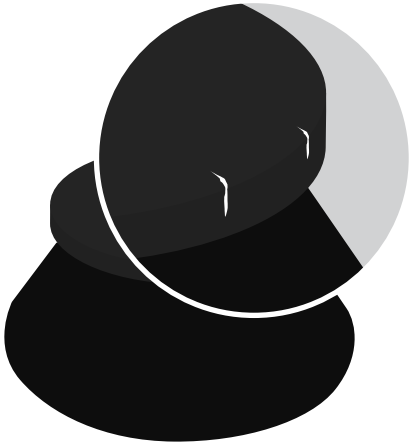
The centrifugal force created by high rotational speeds creates load or stress on the metal of the rotor. This actually causes the metal to stretch and change in size. Figure 1 shows the typical stress against this dimensional change for a typical rotor alloy.

We designate maximum speeds and sample density ratings for each rotor. These designations are intended to prevent this type of stress damage. Always observe these designations.

Metal fatigue

After a certain number of stress cycles, any metal structure will eventually suffer fatigue. When a rotor is repeatedly run up to operating speed and then decelerated, the cyclic stretching and relaxing of the metal causes changes in its microstructure. Depending on how close the rotor is operated to the elastic limit of the metal and how many alternating stress cycles it experiences, these small changes will eventually become microscopic cracks. With continued use, the cracks will enlarge and the rotor will eventually fail.

This is why rotors found in lower-speed centrifuges (such as the our high-performance and benchtop instruments) often have longer useful lifetimes. Rotors used in very high-speed centrifuges (such as our ultracentrifuges) are designed to operate very close to the elastic limits of their alloys and thus have a shorter useful lifetime. The table at the end of this guide provides an overview of the warranty period and retirement recommendations for each class of rotor.



Cyclical stretching and relaxing of the rotor alloy causes microscopic changes in its structure, eventually leading to cracks and failure.

Stress corrosion

Corrosion is an aluminum rotor's worst enemy and the most common cause of failure of aluminum rotors, especially as they age. Corrosion happens when a metal surface is attacked by moisture, chemicals or alkaline solutions like cesium chloride or other salts. Corrosive substances eat away at the metal, forming pits. This means there's actually less metal available in the rotor to handle the stresses of operation. When corrosion occurs in a highly stressed area, like the bottom of a cell hole in a fixed-angle rotor, the increased load on the remaining metal creates what's called a stress concentrator. Repeated use will cause cracks to develop and the rotor will fail (Figure 2).

Stress corrosion will cause failure sooner and at a much lower level of stress than if the rotor were undamaged by corrosion. In the next section, we'll share some ways to prevent this common form of rotor damage.

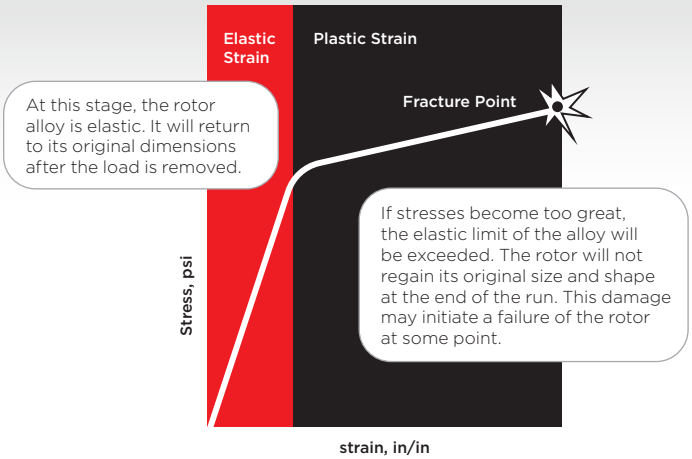


Figure 1. Stress/Strain Plot of a Typical Rotor Alloy.

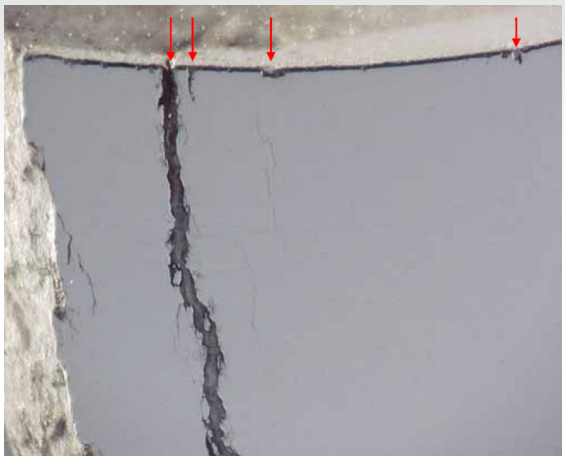


Figure 2. Corroded Aluminum Rotor.

Proper Use and Maintenance

Here are five tips for maximizing the life of your rotors.

1. Observe load and speed recommendations

All rotors are designed to carry a maximum load at a specific maximum speed, so be sure to follow all operational specifications in your rotor manual. Even one run made under conditions of excessive stress may significantly reduce the useful life of a rotor.

We continue to leverage the power of the platform:

- Prevent over-speeding by setting the proper run speed each time.
- Follow required speed reductions for:
  - Running high-density precipitated solutions
  - Plastic adapters
  - Half-filled, uncapped thick-wall plastic tubes (in fixed-angle rotors)
  - Stainless steel tubes
- Run swinging-bucket rotors with all buckets present and ensure sample leads are balanced.
- For rotors used with carbon fiber composite canisters, use all canisters at all times, even if there is no bottle inside.

If using a Beckman Coulter Life Sciences ultracentrifuge

Our ultracentrifuge rotors have an overspeed disk that prevent it from exceeding its maximum-rated speed through operator error or instrument malfunction. Operators should make sure:

- The disk is in good condition
- A speed-derating disk is installed (when required by warranty)

Rotor logging is not required by warranty except for **zonal and continuous flow ultracentrifuge** rotors. However, rotor logging is recommended as part of good laboratory practices.

If using a Beckman Coulter Life Sciences Avanti J Series centrifuge

Rotors are protected from dangerous single-cycle overspeed condition by magnets, windage or by the power limitations of the drive.

2. Guard against corrosion

Most rotors are made from titanium or aluminum alloys, which have high strength-to-weight ratios. Aluminum rotors and components are particularly vulnerable to corrosion.

Titanium rotors

- Resist corrosion
- Recommended if rotor will be used frequently with corrosive salt solutions (e.g., cesium chloride, potassium bromide)
- Will still include components made from aluminum and susceptible to corrosion, such as:
  - Lids
  - Spacers
  - Plugs
  - Knobs
  - Caps

Be sure to follow the aluminum rotor care recommendations outlined below for these aluminum components.

Aluminum rotors

- Less expensive than titanium
- More susceptible to corrosion, especially from alkaline solutions

Our aluminum rotors are anodized with a thin coat of aluminum oxide for protection. If this layer is scratched or damaged, corrosion will occur.

Cleaning and caring for aluminum rotors

- Clean only with special plastic-coated brushes (available from us).
  - Do not use ordinary bottle brushes with sharp wire ends—this could damage the anodized coating, creating a site for stress corrosion to begin.
- Wash components in a mild detergent such as Beckman 555, which will not affect the anodized coating.
  - Do not use alkaline detergents or cleaning solutions, which may remove the anodized coating.
  - Note: Most commercially available solutions designed for radioactive decontamination are highly alkaline.
- If corrosive materials have been run or spilled on the rotor, wash it immediately.
  - Be sure to wash buckets (from swinging-bucket rotors) or aluminum fixed-angle rotors when they have been used with uncapped tubes containing cesium chloride or other salts.
  - Any salt crystals not carefully washed away will corrode the metal.
- Never immerse the body of the rotor.
  - Only wash the buckets of a swinging-bucket rotor.
- Take care cleaning and drying hanger mechanisms, which can rust.
- After the rotor has been cleaned and dried thoroughly, air dry with buckets or cavities upside down.

3. Store rotors properly

Any moisture or other contamination present during storage is a potential source of corrosion.

- Store all fixed-angle, vertical tube and near-vertical tube rotors upside down.
- Store swinging-bucket rotors with bucket caps removed.
- Store all rotors in a dry environment, not in the centrifuge.

4. Check rotor classification

Before running a rotor, check the classification of your instrument to be sure it matches that of the rotor selected. Rotor/centrifuge compatibility is a function of:

- Rotor chamber size
- Type of overspeed protection
- Kind of chamber door
- Barrier ring

For our floor-model ultracentrifuges, the classification is stamped on the lid or top. These ultracentrifuges are classified according to the rotors that can be safely used in them.

5. Don’t use past expiration

Some rotors and components are permanently marked with an expiration date. **Do not use a rotor or component beyond its expiration date under any circumstances.** Components that carry an expiration date are highly stressed and there is a strong possibility the component could fail with prolonged use.

- Record the purchase date of each rotor and keep it on file.
- Note that the purchase date may be different from the manufacturing date shown in the rotor serial number.
- Carbon fiber canisters, carriers and some labware may carry expiration dates, usually engraved or molded into the component.
- Refer to individual rotor manuals for specific information on expiration dates.

Field Rotor Inspection Program (FRIP)

The Field Rotor Inspection Program (FRIP) is available to all owners of Beckman Coulter Life Sciences ultra- and high-performance centrifuges and was created to help labs:

1. Prevent premature failures by detecting stress corrosion, metal fatigue, wear or damage to anodized coatings.
2. Educate laboratory personnel about the proper care of rotors.

Through FRIP, one of our specially trained service technicians will come to your lab at your request and examine all your rotors. Using non-destructive methods such as fiber optics borescopy, they will inspect your rotors for signs of corrosion or other damage. If issues are found, repair or replacement may be recommended to help you avoid costly rotor failure.

During a FRIP visit, we'll also give a formal presentation to your staff about maintenance procedures, rotor damage and what can happen when rotors are compromised. This information helps reinforce good laboratory practice to reduce stress corrosion, especially for aluminum rotors. **Contact your local Beckman Coulter Life Sciences representative or visit beckman.com to schedule a FRIP session.**

Not sure if your rotor is damaged?

Sometimes rotor corrosion is easily visible with the naked eye (Figure 2), but other times it isn't. If you have doubts about the condition of any Beckman Coulter Life Sciences rotor, you may return it to our production facility in Indianapolis, Indiana, where it will be inspected free of charge. Before shipping the rotor, please contact your local representative for specific instructions. A written statement must accompany each rotor, indicating that it is free of any pathogenic or radioactive contamination and is safe to handle.

Rotor Retirement

Even the most well-designed and maintained rotor will eventually reach the point where it could fail during operation. Corrosion, stress corrosion and metal fatigue—invisible to the naked eye—eventually take their toll. Consider retiring any rotor that has reached the end of its warranty period.

Some important fatigue life precautions are built into our rotors and instruments. For example, our ultracentrifuges are designed to contain the physical destruction from a rotor failure, and our high-performance centrifuges have been designed and tested to ensure a normal fatigue life that extends beyond the number of cycles that could ever be run during the seven-year warranty cycle. But these extra safety measures cannot take the place of careful retirement practices. Even if damage is contained, a rotor failure can mean the loss of valuable samples and severely damaged instruments—a gamble that could be costly. The table below lists warranty years and recommendations for retirement by rotor type. Please refer to the rotor's "instructions for Use" manual for current information.

Ultracentrifuge rotors	Warranty years*	Retire after Years	Retire after Runs
Swinging-Bucket	5	10	2,400
Titanium Fixed-Angle, VTi & NVT	5	12	6,000
Aluminum Fixed-Angle	5	10	2,400
TL & ML Series	5	12	N/A
Airfuge Rotors	1	10	N/A
Ti 15 Zonal & Continuous Flow	5 yrs. or 2,000 runs	10	2,000
Analytical, Titanium	5	12	6,000
High-Performance rotors			
Avanti J Series	7	15	50,000
J6 Series	7	15	50,000
JLA-12.50	7	15	24,000
JLA Canisters	7	7	N/A
General purpose / Benchtop			
Allegra Series	7	10	N/A
Allegra V-15R Rotors	7	10	50,000
Spinchron DLX	7	10	N/A
Microfuge Series, Aluminum	7	10	N/A
Microfuge Series, Plastic	1	5	N/A

*This warranty is valid for the time periods indicated from the date of shipment to the original buyer by Beckman Coulter Life Sciences or an authorized representative.

Please note: *Beckman Coulter Life Sciences warrants our rotors and centrifuges against defects in materials and workmanship. However, each warranty is based on the concept of a Beckman Coulter Life Sciences designed and tested rotor/centrifuge system in which the characteristics of the rotor, drive, instrument and containment have been carefully matched to ensure safe operation. We do not warrant our rotors if they're used in other manufacturers' centrifuges and do not warrant our centrifuges when used with other manufacturers' rotors.*

We hope this guide helps you better maintain your rotors and understand when they should be retired and replaced. With some simple care, attention and good practices, you can expect a useful and safe life for every rotor in your lab.

If you have any questions about the care and condition of your rotors, or wish to schedule a Field Rotor Inspection Program visit, please contact your local representative or visit **beckman.com**

*A list of suitable detergents is given in the "Appendix A: Chemical Resistances" in the following publications. This information is also available in Chemical Resistances, IN-175. This list of common laboratory chemicals and their effect on rotor and tube materials should always be consulted if the possible interaction is in doubt.

Rotors and Tubes for Preparative Ultracentrifuges, publication LR-IM-24

Rotors and Tubes for Tabletop Preparative Ultracentrifuges, publication TLR-IM-9

Rotors and Tubes for J2, J6, and Avanti J Series Centrifuges, publication JR-IM-10

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For Beckman Coulter's worldwide office locations and phone numbers, please visit Contact Us at **beckman.com**
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