Understanding the Unbalanced Nature of Mechanical Equipment

Mechanical equipment plays a crucial role in various industries and affects almost all manufacturing facilities. Imbalance occurs when the center mass of a rotating component does not coincide with its axis of rotation. It can result from various factors, including manufacturing defects, improper assembly, wear and tear, process buildup, mechanical looseness, and changes in operating conditions.

Imbalance refers to the uneven distribution of mass within rotating components, causing vibrations, reduced efficiency, and potential damage including structural damage. This report aims to provide a comprehensive understanding of imbalance in mechanical equipment, what can be balanced, detection of imbalance, the two types of Imbalances, effects, correction of imbalance and the benefits of having your mechanical equipment properly balanced. Common examples of unbalanced mechanical equipment include fans, pumps, turbines, and rotating shafts.

Vibration isn't Always Due to Imbalance
Just because your machine is vibrating doesn't automatically mean the **problem is imbalance**. There's about an 80% chance that when we get a call for a fan that is vibrating it's going to be a balance issue and a 20% chance it's something else. And what could that something else be?

The problem might be …

- Loose mechanical connections, such as bolts or welds
- Problems with couplings
- Structural issues
- Bearing defects
- Slippage of belts and/or sheaves
- A cracked rotor
- Resonance conditions
- Other motor problems

For fans, vibration can often be traced back to either a build-up of dust/process on the blades, a shaft that's bowed because of temperature differentials across the fan or cracks in the fan due to fatigue.

Benefits of Balancing:

- Increased Mean Time Between Failure (MTBF)
- Extended service life
- More efficient operation
- Smoother running equipment
- Reduced noise and vibration

Balancing is often included as part of a **predictive maintenance** plan.

What Can Be Balanced?
Rotating equipment such as motors, generators, pumps, and fans can (and really should) be balanced. Specific components within this equipment that need balancing depend on what type of equipment we're talking about. The most commonly balanced mechanical components include rotors, rotating shafts, impellers, fan blades, and even flywheels.

Balanced vs Unbalanced
For a balanced system, the only force needed to hold it in place as it rotates is something to support its weight. When the object is rotating it doesn't generate any forces on the bearing beyond its weight, which is what the bearing is designed for.

When an imbalanced object rotates, it generates centrifugal forces. Something to keep the object in place, and that responsibility falls on the bearings. While the object is rotating, any point on the bearing will be experiencing non-axial fluctuating forces. And those forces accelerate wear and reduce the useful life of the bearings.

Effects of imbalance: The presence of unbalance in mechanical equipment can have several detrimental effects, both on the equipment itself and the surrounding environment. These effects include:

1. Vibrations: imbalance induces excessive vibrations at the shaft's running speed often referred to by analysts as 1X, leading to increased stress on bearings, shafts, structural damage to the surrounding infrastructure and other components.
2. Reduced Efficiency: imbalance causes uneven loading of bearings and results in increased frictional losses. This leads to decreased overall efficiency, increased energy consumption and reduced performance of the equipment.
3. Premature Wear and Tear: Excessive vibrations and uneven loading can accelerate the wear and tear of components such as bearings, couplings, belts, seals, gears and supporting structure. This results in increased maintenance requirements, downtime, and potential catastrophic failures.
4. Safety Hazards: imbalance can compromise the safety of operators and nearby personnel. High levels of vibrations and potential equipment failures pose risks of accidents, injuries, and even fatalities.

Detection of imbalance: Detecting imbalance in mechanical equipment is essential to prevent further damage and ensure optimal performance. Vibration isn't always due to imbalance.

Vibration analysis is key to determining if the vibration is caused by imbalance. More specifically, spectrum analysis via a fast Fourier transform (FFT) and phase analysis is performed by a certified vibration analyst will reveal the most likely source of the vibration. Vibration analysis can be performed using handheld devices or integrated into the equipment's control system. Northwest electric has spared no expense when it comes to vibration data analysis and balancing. We utilize the industry's leading data collector, the 2140 from Emerson Technologies.

Two types of Imbalances:
There are two types of imbalances: static and dynamic and both of these are critical.

Here are three key facts to remember:

- An object must be statically balanced before it can be dynamically balanced.
- A statically balanced object can still be dynamically balanced.
- A dynamically balanced object is also statically balanced.

These provide good reasons why both static and dynamic balancing are important when addressing vibration in rotating equipment.

Static Balancing:
Of the two types of balancing, static balancing is the easiest to understand and the easiest to perform. Basically, if the center of gravity of a rotating system lies on its axis of rotation, that system is said to be statically balanced. When that condition is met, it means that the object can remain stationary (static) as long as the axis is horizontal. Nothing is needed to keep it from turning. In short, rotational equipment that has static balance isn't going to rotate on its own no matter what angle the axis is at.

When an imbalance exists, the axis tends to rotate. It may have to be at a certain angle for that to happen, but that is still considered imbalance.

Static balancing can take place in the field, or it can be performed in a shop using a static balancing machine. Field balancing assesses the object's balance as it rests on its own bearings and support structure. Some basic calculations can be performed to determine how much mass needs to be added and where it needs to be placed to achieve static balance.

Dynamic Balancing:
Unlike static balance, dynamic balance (often synonymous with rotor balancing) is related to a rotating object in motion. When an object is dynamically balanced, it remains balanced even when it's turning. Imbalance occurs when mass is not symmetrically distributed about the system's axis of rotation.

How Dynamic Balancing Works:
First, keep in mind that balancing is performed for rotational equipment at normal operating speed and under operating conditions. Now here's a quick overview of how dynamic balancing works:

1. Vibration measurements are taken while the system is rotating at a high speed.
2. The unbalanced force resultant is calculated based on the vibration data.
3. Masses are added or removed from the rotating object to align its mass center with the axis of rotation.

To determine the unbalanced force vibration measurement and analysis are needed. Accelerometers are mounted on the bearing housing to collect data. The data is then interpreted by an analyst. The level of vibration is proportional to the magnitude of the imbalance forces.

To determine direction of the resultant force, a vibration analyst will compare phase of the vibration signal with a standard periodic signal from another reference point on the rotating system (Phase analysis).

Combining the magnitude of the imbalance force with the direction defines the unbalanced force vector. This information allows the rotating system to be balanced by adding strategically placed counterweights.

Correction of imbalance: Once imbalance is detected, corrective measures should be taken to minimize its effects and restore optimal performance. Some common methods for imbalance correction include:

1. Balancing: Balancing involves adding or removing mass from the rotating component to bring its center of mass in line with the rotation axis. This can be achieved through static balancing (adding weights) or dynamic balancing (using specialized equipment to determine the precise amount and location of imbalance).
2. Alignment: Misalignment of rotating components can also contribute to imbalance. Ensuring proper alignment through laser alignment systems or other alignment techniques can help reduce imbalance effects.
3. Maintenance Practices: Regular maintenance and inspection of mechanical equipment can help identify and rectify imbalance issues before they escalate. This includes checking and replacing worn-out bearings, lubrication, equipment fatigue, looking for process buildup, and proper assembly.
4. Cleaning: Uneven or excessive buildup can and often will cause buildup. It is important to clean and visually inspect the equipment before balancing.

Conclusion: Understanding the imbalanced nature of mechanical equipment is crucial for ensuring their reliable and efficient operation. Imbalance can lead to various negative effects, including elevated vibrations, reduced efficiency, premature wear, and safety hazards. Therefore, regular monitoring, detection, and correction of imbalance are essential. By implementing appropriate detection techniques and corrective measures, industries can enhance the lifespan, performance, and safety of their mechanical equipment, leading to increased productivity and reduced downtime.