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Mass balancing of rotating machinery can reduce noise, allow higher speeds, increase bearing life, and more. Here is an overview of the process and instrumentation.

Mass balancing compensates for less-than-perfect manufacturing. There would be no need for balancing if materials had uniform density, if holes could be bored exactly in the center, if perfectly round or symmetrical shapes could be machined, and if all assembled parts had exactly the same weight and were placed at the same radius.

Prior to 1880, machinists did limited balancing by trial and error without instruments. The technology of balancing was driven by higher speeds in the electric power generation industry and has leap-frogged the development of bearings. Better balancing required better bearings, and better bearings demanded better balancing to function to their full potential.

Mass balancing is routine for rotating machines, some reciprocating machines, and vehicles. Mass balancing is necessary if an operation or product requires quiet operation, high speeds, long bearing life, operator comfort, controls free of malfunctioning, or a "quality" feel.

Balancing machines

There are three basic types of balancing machines: static balancing stands, hard bearing machines, and soft bearing machines. Static balancing stands do not require spinning up and can correct for static or single-plane unbalance only. They are sensitive enough for grinding wheels. They feature low cost and safe operation.

Hard bearing balancing machines have stiff work supports, lower sensitivity, and more sophisticated electronics. They require a massive, stiff foundation where they are permanently set and calibrated in place. Background vibration from adjacent machines or activity can affect balancing results. They are used mostly in manufacturing production operations where fast cycle time is required.

Soft bearing balancing machines have flexible work supports, high sensitivity, and simple electronics. They can be placed anywhere, and can be moved without affecting calibration. Their flexible work supports provide natural isolation so nearby shop activity can continue while the machine still achieves fine balance levels. A belt-driven soft bearing balancing machine can always achieve finer balance results than a hard bearing machine. Every repair facility should have a soft bearing balancing machine and perhaps a static balancing stand.

A balancing machine is not difficult to make. The rotor must be supported and driven, and the motion measured. A fan wheel can be balanced by attaching it to a motor shaft and measuring the motion with portable vibration instruments while the motor is operated on a rubber mat. This homemade balancing machine can achieve results as well as a commercial machine, but without calibration benefits. And the balancing procedure will take longer.

The mechanical parts of soft bearing balancing machines have not changed significantly in more than 60 years. With few changes, the velocity pickups of 50 years ago are still the preferred sensors on balancing machines. The major changes have occurred in the electronics and computerization. A cost-effective solution to balancing is to purchase an old soft bearing machine and upgrade it with modern digital electronics.

Shop versus field balancing

Mass balancing can be done in a shop with the part mounted on a balancing machine. Or, it can be performed in-place in the field with the rotor mounted in its own bearings and driven normally.

Shop balancing is performed during the manufacturing process after the rotor is fully fabricated and prior to final assembly into its housing. It corrects for manufacturing variability so it spins up smoothly. Shop balancing also is done in repair facilities as one of the last steps in re-manufacturing.

Field balancing is done mostly for convenience to the equipment user because the rotor does not need to be removed. It is less convenient for the person doing the balancing because the instrument must be transported to the job site. Field balancing usually results in lower vibration because the balancing is done at final speed, with the machine's own bearings and drive system, and some site factors, such as aerodynamics, misalignment, and structural effects, can be accommodated. There are hazards such as loose balancing weights being thrown from a high-speed rotor.

In-house versus service contractor

Shop balancing can be performed in-house for quality control and for throughput in production operations. Balancing is a highly technical skill and requires specialized knowledge and expensive machines and instruments. If an operation cannot or chooses not to acquire and maintain the necessary skills and tools, then there are other alternatives.

Electric motor repair shops have balancing machines. If a rotor can be transported there and it fits on a machine, it can be balanced. Instruments are portable and they can be detached from the balancing machine for field balancing at a facility if there is access to the rotor so weight can be added or removed.

Field balance times average 4 hours and rates range from $60 to $200 per hour. Every field balance job is a time-and-materials task because of the unknowns of access, pre-existing faults, coordinating starts and stops, possible resonance, and how much balancing reduction is required.

Tooling up for balancing

It is possible to balance with no instruments, but it takes a long time and only gross improvements in balancing result. The two main types of field balancing instruments are tunable filters and digital analyzers.

Tunable filter instruments are easy to learn, easy to use, field proven, affordable, and capable of measuring to fine levels. Digital analyzers (FFT spectrum analyzers or other types) are more complicated, prone to operator setup errors, and usually more expensive.

Digital analyzers generally use a photoelectric sensor for phase measurement that is safer because the operator can stand back and close the door. Tunable filter instruments use a strobe light for phase measurement that requires visual access to the rotor in subdued light.

Tunable filter instruments make it easy to grasp the physics of the situation by simple and direct measurements, and balancing proceeds rapidly. But the instrument only takes measurements; the balance calculations must be done separately. The digital analyzer combines measurement and calculation, but physical relevance is lost, especially in two-plane problems. Balancing must proceed "by the numbers" with digital analyzers. The instrument used is the least significant factor to achieving good results. It is the instrument operator who interprets the measured data and responds.

There are various balancing methods-single-plane vector, four-run without phase, two-plane influence coefficient, static-couple, seven-run without phase, flexible rotor, and trial-and-error. The operator chooses the appropriate method initially based on original readings, then may switch to a better method if things are not going well. Balancers need additional training beyond reading the owner's manual. They especially need to be able to recognize a nonbalance problem and abandon the balance job in favor of some other solution.

Other accessories are required to conduct field balancing: an assortment of balance weights, a scale for weighing to 0.1 gram, a calculator, some wrenches and screwdrivers to disassemble panels, a flashlight, a padlock and safety tags, marker pens, and a battery powered hand drill. Shop balancing requires additional tools also: master calibration rotor, tapered arbors, and ANSI S2.19 specifications.

The down side

It is risky to work on a sick machine that is partially dismantled and being operated in a start-and-stop mode. Risks include failing to reposition a damper, leaving a tool inside, not securing a test weight sufficiently, or some other inadvertent slip that may cause a crash. The danger is to everyone standing by observing, especially if a test weight should fly off.

Balancing may not always work in the field to reduce vibration as well as it does on a balancing machine. There are a number of reasons: the influence coefficient method uses equations which are not entirely independent, the structural system may be nonlinear with resonance, other root causes of vibration exist, the system may be unstable, bearings may be worn, shafts may be distorted, or test weights may be ill-placed.

Balancing instruments are capable of measuring what is required and have reached a mature level. The methods of balancing have room for improvement. A self-balancing rotor is a wonderful idea, and some day they will be affordable for all common machines. But until manufacturing reaches a level of precision where balancing is not required, those involved in balancing will enjoy plenty of satisfaction from machines that are running smoothly after they perform their job successfully. **MT**

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