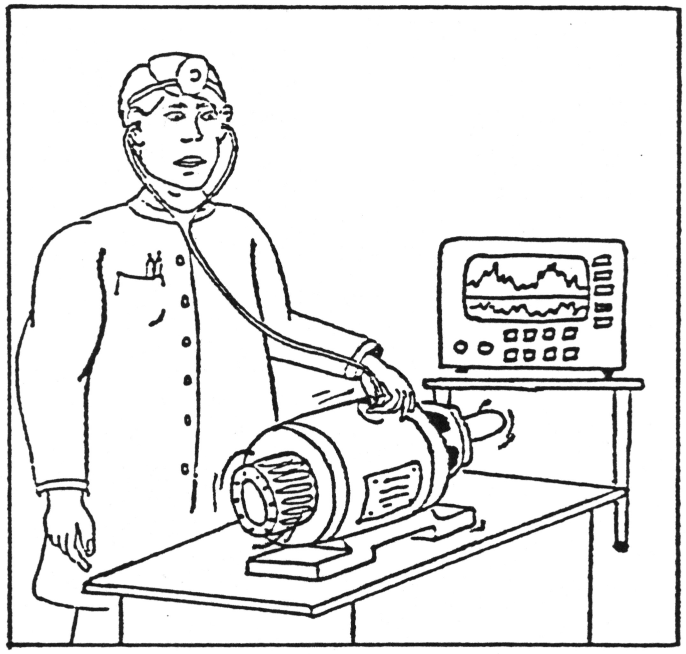
Why Not Resonate?

By Victor Wowk, P.E.

Mechanical resonance is usually considered "bad" for machines. Many standards specify that any natural frequencies shall be 10 to 20 percent away from operating speeds. Maybe we should rethink this.



Electrical engineers have done wonderful things with the concept of resonance. They have designed oscillators, filters, and amplifiers that are the foundations of modern electronics. Mechanical designers have done similar good things with spring isolators, which are mechanical filters. All musical instruments, whether wind or stringed, are resonance amplifiers. Most everyone reading this has a resonance machine on their wrist in the form of a watch, either mechanical or electronic (with a crystal oscillator). Military aircraft altimeters and sensitive pressure sensors use a resonant acoustic cavity to detect pressure changes, which cause a shift in the natural frequency. The A.S.O.S. freezing-rain sensor at the approach end of busy runways detects the collection of ice on a vibrating metal tube because the mass accumulation causes its natural frequency to drop. A child's scooter was made in the 1950's which was propelled by the rider hopping up and down on a beam that was connected to an eccentric rear axle. The child quickly learned that timing the rhythms of up and down hopping translated into forward motion. All of these are examples of mechanical devices which apply the concept of resonance to advantage. Little has been done with resonance on rotating machines, except to avoid it. I am posing a question here —"Can we employ resonance to extract more electrical energy from a ton of coal?"

I will take the liberty to answer my own question—yes. Vibration test engineers have noticed a reduction in power required at resonance. They have observed a decrease in electrical power going into a shaker table at the natural frequency of the table. The table motion, peak-to- peak amplitude, is controlled by a motion sensor attached to the table top, which controls power- in to maintain the selected amplitude. At resonance, it commands less electrical energy-in to keep up the same motion amplitude. So how do we apply this to a turbine/generator unit?

The answer is not so clear at this time, but engineers and operators are certainly aware of rotor critical speeds. The mass and stiffness of the rotors are adjusted to operate between the first and second critical speeds where a 180° phase shift is used advantageously to get a partial self- balancing effect. At exactly the natural frequency we get only a 90° phase shift between the driving force and response motion. This phenomena is used to design dynamic absorbers, sometimes called auxiliary mass dampers. These are stationary components attached to non- rotating structures to absorb excess energy at resonance. Indeed, any passive resonating component coupled to the bearings can absorb and dissipate resonant energy. But this is wasteful. I am asking if this excess energy can be harnessed to produce useful output.

At first glance, it appears that we could attach a small electrodynamic generator at the places of high motion to "generate" a little more electricity. We might also design a cooling fan or oil circulating pump that is powered by a resonating part. The "excess" energy can then be used for some useful work, rather than be directed into the ground, and beating up the bearings on the way. These devices would utilize drumming panels or other auxiliary structural parts whose shaking motion would have been wasted anyway. But how about the main rotor and its bearing supports?

Historically, it has been considered undesirable for the main rotor or its bearing support to resonate because it induces alternating bending stresses in the rotor, which leads to fatigue cracking. But suppose the bearing supports were not rigid, but have a natural frequency which matches the rotor critical speed. This becomes a two degree of freedom system with two springs, which can exchange energy. The energy exchange can deliver a rhythmical pulse to the rotor at the right time in its cycle, in the right direction, utilizing the 90° phase shift. The energy that would have produced large contact forces at the bearings, can now be used to assist rotation. The design changes required to make this happen are that the bearing supports would no longer be rigid. This has major implications.

- This affects the rotor critical speed, which will now be lower.
- The coupling between driver and driven machines will need to be able to accommodate more motion.
- The bearing supports are subject to fatigue damage, but the rotor will now be relieved of that risk. This rotor mass and stiffness may be downsized.

Theoretically, this all seems possible and we have practical examples of mechanical resonance being used to advantage. How to implement this concept for power generation would require building a small demonstration machine as a working prototype to convince some of the skeptics.

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