General Motor Knowledge
Motor Sounds
Lynn R. Dutro

What does a motor sound like? What should a motor sound like? Let's turn one of ours on and listen.
AC power in this country alternates 50 times or 50 cycles each second. This is also known as 50 Hz pronounced 50 "hurts". The revolving magnetic field this sets up in our motor changes from north to south each cycle. Each change flexes the magnetic structure of the motor. Two changes for each of the 50 cycles results in 100 flexes of the magnetic structure each second. This is the characteristic 100 Hz "Hum..mm" associated with ac induction motors. The more powerful the motor, the more powerful the "hum..mm".
The stator induces this same magnetic field into the rotor. But, the rotor "slips" or lags behind the stator's revolving field. The difference between the rotor speed and the speed of the revolving field results in a "beat" frequency. This is audible as a "wow.wow.wow", changing to a "wow.....wow" and finally to a "wow..ww" as the rotor approaches synchronization with the stator field. As the motor comes up to speed, harmonics cause variations in pitch such that the motor sounds like it is changing gears.
Our motor is running. So what do we hear? The "hum..mm" from the stator with a very slow and not quite as strong "wow......wow" from the rotor. What else? Wind noise from moving air? What else? The shaft sliding in the bearing? But, with a film of oil in the bearing, this is almost no sound at all. Certainly not like the screech of metal on metal or the grating sound of sandpaper on a table top. Is the retaining washer on straight or do you hear it "tap..tap..tap" on the square nylon thrust washer? Do you hear a "bump..bump..bump" as the hub bounces along on the end of a bearing post that is not smooth and flat? If the end-bump sounds like a "clang..clang..clang", one of the padded washers was left out. Do you hear a "tick..tick..tick" from the rotor striking something in the air gap? Or a scratching sound like everything was turning in a bucket of sand? Does the rotor run smooth and free? Or can you hear and feel it as the out-of-balance weight is thrown from side to side? Do you hear a rattle from a loose mounting screw? If the metal fan blade is loose, it will ring like a gong.
A happy motor should "hum..mm" merrily along.

If it sounds like a wreck, it is asking for your help.

General Motor Knowledge
Motor Performance Curves
Lynn R. Dutro

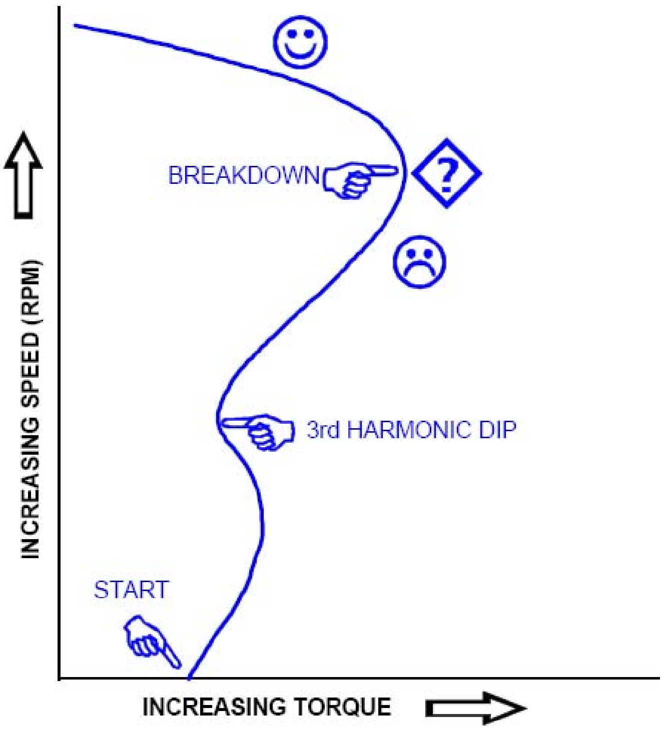
A motor performance curve is a picture showing the relationship between inputs and outputs. Let's choose motor speed in revolutions per minute (RPM) as a reference point and look at torque. Torque is a measure of the force a motor can develope to turn something.

Begin in the lower left corner of the picture. Draw a line of increasing speed up the page. This line begins at 0 RPM and extends to the synchronous or maximum speed, 1,500[1] RPM for a 4-pole motor (at 50Hz, 1.800 at 60Hz). If the motor is not energized and RPM is zero, torque is also equal to zero. The lower left corner of our picture becomes RPM = 0 and TORQUE = 0. Speed increases up the page so we will choose torque increasing across the page to the right.

Turn the motor on. Torque is developed in the rotor but the rotor has not started to turn yet. "Starting" torque is available to start the rotor turning and to accelerate it up to some operating speed. As speed increases, torque is affected by the various harmonics. Most noteable is the third harmonic. This harmonic is centered at one third the synchronous speed or 500[2] RPM. It's negative most effect is seen as a dip in torque at about 700[3] RPM. This is the infamous "third harmonic dip".

Torque will continue to increase as speed increases until a speed of maximum torque is reached. This is often refered to as "breakdown' torque. From this point upward as speed increases torque will decrease. At synchronous speed, torque will equal to zero.

The most desireable operating speeds are between synchronous and breakdown. If the motor load is greater than breakdown torque, the rotor stops turning because no more torque can be developed.



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[1] The sincronism RPM is defined as the maximum theoretical speed of a motor: RPM = $\frac{60 \bullet f \bullet 2}{p}$ - f= frequency; p=number of poles

[2] These numbers have to be considered as examples only

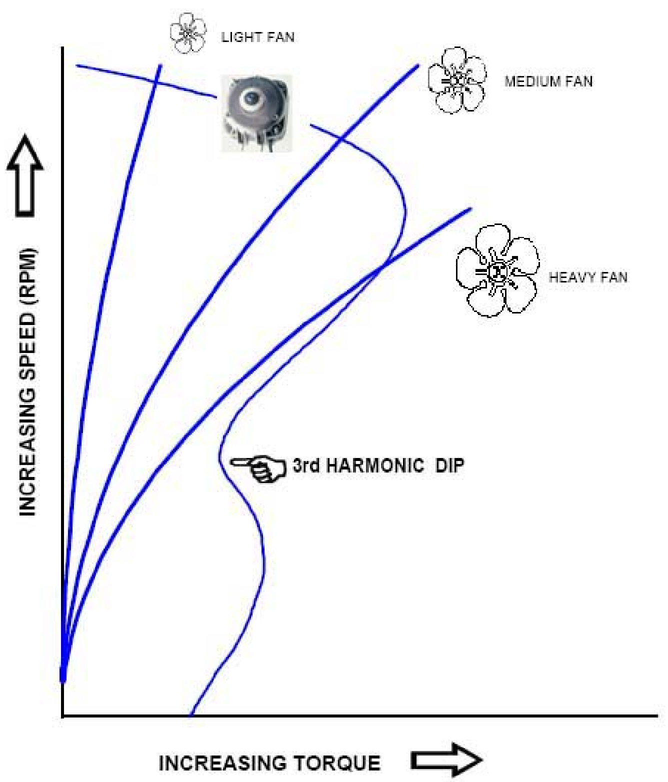
[3] These numbers have to be considered as examples only

General Motor Knowledge
Motor/Fan Performance
Lynn R. Dutro

Speed starts at 0 RPM in the lower left corner and increases up the page. Torque starts at 0, at the same place on the page as speed. Torque increases to the right across the page. The moment power is applied to the motor, RPM is still 0, while the motor develops some torque to start the rotor turning. This accelerates the rotor and speed increases. Torque and speed continue to increase with speed until torque reaches some maximum value. From this point, torque decreases as the rotor begins to revolve at the same speed as the magnetic field producing it.

A fan blade requires torque in an amount proportional to the square of the speed. The speed-torque requirements for three fan blades are shown drawn on top of the motor speed-torque curve. The motor fan combination will operate where these curves intersect. Here the motor speed-torque fulfills the speed and torque requirement of the fan blade. A light fan requires very little from the motor. It operates at or near the motor maximum speed and does not utilize the motor's maximum power output. A heavy fan may not allow the motor to develop its full potential or come up to speed. The medium fan is the better choice.

Think of the fan blade petal as a shovel. A child can move dirt with a small spade. An adult may take the same spade and dig faster but not move very much more dirt than did the child. Give the adult a shovel and scoop for scoop more dirt will be moved than with the small spade. If the shovel is so large that the adult must dig slowly, resting between scoops, it is again likely that not much dirt will be moved.
It is also likely that the adult will overheat and quit.
The motor and fan blade should be matched for best efficiency. This is easily done by overlaying the speed-torque curves of the motor and fan blade.



General Motor Knowledge
Motor Performance
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Remember our motor speed-torque curve. Speed starts at 0 RPM in the lower left corner and increases up the page. Torque starts at 0, at the same place and increases to the right across the page. Remember also, a fan blade requires torque in an amount proportional to the square of the speed. The speed-torque requirements for three fan blades are shown drawn on top of the motor speedtorque curve. The motor fan combination will operate where the fan curve crosses the motor curve. A light fan requires very little from the motor. A heavy fan may not allow the motor to develop its full potential. We decided that a medium fan is the best choice. Let's see why.

At any point along the motor speed-torque curve, torque multiplied times the speed, multiplied times a conversion number to get the units right is equal to WATTS OUTPUT. WATTS OUTPUT divided by the WATTS INPUT then times 100% is equal to the PERCENT EFFICIENCY. I have done the arithmetic and calculated a percent (%) efficiency curve for our motor performance curve. Percent efficiency starts at 0 in the lower left corner and increases to the right just as we did for torque. Note the speed where the medium fan curve and the motor performance curve cross. I have drawn a dotted line through this point. The motor efficiency at this speed (continue along the dotted line until it crosses the % efficiency curve) is very nearly maximum. At this point we are getting the MOST out of our motor/fan combination for the LEAST amount of power input. By following a similar process you can see that both the light fan and heavy fan will cause the motor to operate at a point of lower efficiency. This kind of graphical analysis is used to aid our customers in selecting desirable motor/fan combinations.