"Rating Tools Based on Ratings"

A Guide to Power Tools Motors and what the Ratings Indicates

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Introduction Chances are you have been at your local hardware store or tool distributor wondering what information tool literature and nameplates are really telling you about particular models and how do you figure out how to use this information to make an intelligent purchasing decision. Tool manufacturers want you to know the capabilities of a particular tool, but they also want to play up the strengths of a particular model especially when compared to the competition. The information put on tool nameplates and literature can be useful, providing one has a good understanding of what this information means.

In most applications, there are two types of motors used in 120 volt corded power tool applications. These are the Universal (AC & DC) and the Induction (AC only) motors. This article will not cover motors that may appear in limited usage such as Switched Reluctance motors nor will it cover the Permanent Magnet DC motors used in battery operated tools.

The most important item to keep in mind from this article is that heat is the primary enemy of an electrical motor. If heat buildup can be kept to a minimum, a tool motor will easily last the life of the unit. A properly designed motor should not stress the insulation system by allowing too much heat to build up within the motor.

I. Hand held Power Tools

Universal Motor Description

Portable hand held tools are powered by Universal motors. The term "Universal" comes from the fact that these motors can be operated on either AC or DC voltage. One should be aware of the fact that portable hand held electric tools with speed control devices or other electronic controls will be rated for AC voltage only. This is due to the constraints of the electronics and switches, not the motor.

A universal motor is a series connected motor consisting of two major components. The stator (or field) is the non moving part of the motor. The stator is made of copper windings wound on a stack of thin, high quality, magnetic steel laminations. The stator is connected to the rest of the motor circuit via lead wires and/or terminals. The armature is the rotating member and is supported by either ball bearings or bushings on each end of the shaft. Like the stator, the armature is made of copper wire wound on a stack of laminations. Each winding coil in the an-nature is fused to a commutator made of copper bars pressed on one end of the shaft. The armature is electrically connected to the rest of the motor circuit via carbon brushes riding on the commutator. Figure One outlines the components of a universal motor

The universal motor spins at high revolutions per minute (RPM), typically in the range of 22,000 - 25,000 RPM. There are new motors being designed to operate at over 35,000 RPM. These high speed characteristics are what make this motor style so desirable for small applications. A lot of horsepower (HP) can be generated from a small motor package because HP is dependent on RPM.

To illustrate this point, the equation for Horsepower is:

Equation #1 $$HP = \frac{\text{Torque (lb. -ft.)} \times RPM}{5250}$$

In other words, the higher the RPM generated for the same torque output, the higher the HP.

These high rpm's also help with motor cooling. A fan is mounted on the armature to move air through the tool. This air will draw the heat generated by the motor out and away. As will be seen later, cooling has a definite bearing on nameplate values.

Hand Held Power Tool Nameplate Ratings

Listed here are the items found in tool nameplates and literature and an explanation of what each item means.

1. AMPS — My experience with amp ratings indicates there is a lot of confusion in the marketplace as to what this rating indicates. Some of this is due to a lack of understanding of motor characteristics but unfortunately, some of this misunderstanding is due to purposefully misleading information advertised by manufacturers. We have all seen advertising literature with phrases like "delivers 8.0 full amps of power!" This is not correct terminology.

A universal motor is not a very efficient machine. In some cases up to 50% of the electrical energy a tool is using is not converted into useful torque, but rather is lost as generated heat. The amp rating indicates the electrical current load the tool is capable of carrying for a theoretically indefinite amount of time without degrading the motor insulation system or other electrical components. In a UL rated product, a motor insulation system is designed to withstand, typically, 105 degrees C (Celsius) temperature for approximately 20,000 hours. After that, the insulation system will break down causing motor failure. Since the average tool is designed for life capability in the 100's of hours, a well designed power tool motor should provide trouble free function throughout the life. This is providing the motor loading is within the design range of the insulation system.

The motor is designed for the desired rating, and then verified through testing under laboratory conditions that the motor will remain at or below 105 degrees C when loaded to this design nameplate amp rating.

There are many factors that effect a tool amp rating. The motor should be designed with enough active materials (i.e. laminations, windings etc.) to insure over-temperature conditions will not exist when the tool is used as intended. Motor rpm's will also affect the amp. rating. A faster motor means more air will be moved through the tool to help draw the generated heat out of and away from the tool. The quality of the fan/ventilation system design also will affect the motor cooling.

The amp rating gives the user a feel for how effective the motor design and cooling systems are. The amp rating should not be construed to indicate how "powerful" a motor is. The amp load is an effect of how hard a motor is being worked, not a contributing factor to the motor power.

2. Horsepower — Motor horsepower ratings for hand held power tools usually indicate the maximum power a particular motor design is capable of generating. This does not mean that a 2 HP circular saw could be loaded to 2 HP all day long and continue to perform without failure. What this means is that when loaded under laboratory conditions for a short time (prior to the motor heating up), this motor can generate enough torque at a high enough RPM to equal 2 HP (see equation #I).

If a motor were to continue to be operated at this peak HP load, it would shortly burn out due to the significantly higher currents than designed for moving though the system. The typical universal motor will operate during normal operation at 40-70% of the peak horsepower value.

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A user can compare horsepower ratings to determine which tool may have a stronger motor but keep in mind, the tool gearing will also have an effect on the actual "Reserve Power" available.

3. RPM — Revolutions per minute (RPM) is fairly obvious but there are a few points to be aware of. The RPM's listed will almost always be under no load conditions. The Universal motor by itself, cannot maintain constant speed as the torque requirements increase. Electronics are being added to tools to maintain a constant speed throughout the motor's speed-torque curve. In tools with electronics, the motor design has been modified so the motor is capable of operating at the higher speed-torque points without overheating.

A comparison of tool nameplate rpm's will **not** indicate which tool has a faster motor. This is because the gear ratios within each tool may be different and the rpm's listed will always be for the complete tool, not the motor. The gear ratio is the number of times an armature revolves for each revolution of the tool spindle. Gear ratio is not usually an advertised value.

Stationary Power Tools

Induction Motor Description

Stationary tools such as bench grinders, radial arm saws and drill presses are usually powered by induction motors. Induction motors operate on AC voltage only.

Like universal motors an induction motor is made up of two major components, however this is where the similarities end. The stator is the non moving component that is made of laminations and windings. The winding construction is different than the universal motor because there are many more winding coils in the induction than in the universal motor. The rotor is the spinning component in the induction motor. The construction of a rotor is different than an armature. A rotor has laminations designed with holes. A rotor is cast and the holes are filled with aluminum. There are no copper windings in a rotor. The name "Induction" comes from the fact that the voltage is not applied across the rotor via electrical connection but rather an electrical field is induced into the rotor by the windings in the stator. Figure two details an Induction motor components.

Induction motors are manufactured by numerous companies and the competition has created a wide array of low cost power sources available for tool use. The ratings on these motors have a different format than the information on universal motors ratings in hand held tools.

Induction Motor Nameplate Ratings

1. Horsepower — This is probably the most important rating **on** these types of motors. Unlike the universal motor, the horsepower rating on an induction motor indicates the **usable, not peak,** work load the motor is capable of attaining. The induction motor will perform at this workload without over-heating the insulation system for a theoretically "indefinite" amount of time, As stated earlier, a well designed motor/insulation design will last for 20,000 hours. Temperature tests are performed to verify the motor insulation system will not be subjected to detrimental heating when loaded to the HP rating.

The peak HP on these motors will normally be 1.5-2.5 times larger than the rated HP. In induction motors, this rating is usually the first factor to look for when comparing similar units. A motor with the larger HP rating usually will be able to handle greater overload situations or run cooler (and therefore operate longer) under normal use.

2. Amps — An induction motor amp rating is the electrical current drawn by the motor when operating at the rated horsepower load. This amp value is given to assist the user in assuring an appropriately sized voltage supply line is feeding the unit. A user should know the electrical current required by the motor under load, so that the voltage supply line is verified as capable of carrying this current without causing either: 1) an excessive voltage drop to the motor or 2) heating of the supply line causing a hazard.

3. RPM — Unlike universal motors which can be designed for almost any RPM, induction motor RPM is based of the supply voltage frequency. Most 60HZ induction motors used in stationary tools are either 2 pole (3600 RPM) or 4 pole (1800 RPM) machines. Induction motors are capable of maintaining close to no load RPM for much of the usable torque range. This means these motors will operate at close to 1800 or 3600 RPM even when loaded to rated HP. A comparison of RPM will not be very usable because, as in universal motors, the connection method of the motor to the unit (either through belts or gearing) will cause changes in performance characteristics that will not be evident through nameplate comparison.

There is one interesting side note for an induction motor RPM discussion. Because HP is dependent on both RPM and torque (see equation #l), a faster motor will require less torque to achieve the same HP rating. Since torque is generated by the active materials in the motor, less torque means less active materials will be required for a 2 pole machine than a similarly rated 4 pole machine. Therefore a I HP, 2 pole motor should cost less than a I HP, 4 pole motor.

4. Efficiency — For intermittent use tools, efficiency is not as important as with continuous use applications. Induction motors are much more efficient than universal motors. The efficiency rating on a nameplate will indicate how much of the electrical energy is getting converted into usable torque at the rated HP. Efficiency ratings may be part of an induction motor nameplate. Typical induction motor efficiencies will range from the mid seventies for standard efficiency units to upper nineties for some high efficiency three phase motors. If operating costs of the unit are important, a similarly rated motor with a higher efficiency rating will cost less to operate than another motor with a lower efficiency rating.

5. Service Factor — Sometimes a tool manufacturer will place a motor on a unit that has some reserve power designed in. This can be determined by looking for a motor Service Factor (SF) rating. For example: a 1 HP motor with a SF of 1.0 is capable of operating at only I HP continuously. A I HP motor with a SF of 1.15 is capable of operating at 1.15 UP continuously. In other words, the I HP, 1.15 SF motor is really designed as 1.15 HP motor. To determine actual power capabilities multiply the HP rating by the Service Factor. A motor with a Service Factor may be beneficial for two reasons: 1) the motor will have additional reserve power available for overload situations and 2) the motor will operate at cooler temperatures during normal operation which will result in longer life.

Keep this in mind when comparing similarly designed units. If available, a motor with a Service Factor may be a desirable feature.

Other nameplate items an induction motors nameplate might include are briefly listed here.

Watts: Indication of the true electrical power a motor needs to operate.

Power Factor: Due to the inductive characteristics of all motors that lead to losses, power factors are an indication of true power (Kilowatts) to apparent power (KVA). This is not normally an important consideration for a tool purchaser.

KVA Code: This gives an indication of the voltage supply line capability needed to insure safe startup for the unit in question.