Alternator Antics

Having bought our first alternator from Swayambhu Shakya, we tried to figure out how an alternator works. After a few discussions with Swayambhu and a web search, we determined that there are four connections that must be made to an alternator: 1) ground (the case), 2) positive (a post coming out of the top of the alternator), 3) the alternator's field, and 4) the alternator's regulator. During operation, charge flows from the alternator to the battery through the positive post. The field is connected to an indicator light or resistor and then to the battery's positive terminal. This supplies the initial charge that the rotor needs to produce electricity. It should only be connected during operation (to avoid running the battery down) and, in a car, is connected through the ignition switch. Once the alternator is running and producing electricity, the current to field is internally supplied, and no current flows from the battery to the field. The regulator connection is made to the battery's positive post as well. The regulator connection does not draw current, but acts as a kind of internal voltmeter. An internal circuit attempts to keep the voltage difference between the regulator connection and ground at 14.4V, the optimal charging voltage for a 12V battery. It does this by regulating the current flowing to the internal field connection. At first we wondered why a third and separate connection to the battery's positive terminal was needed for the regulator. However, we realized that this allows voltage-drawing components (such as diodes or other devices) to be placed in series with the battery without changing the 14.4V placed across the battery terminals. The real question was whether an alternator could successfully be run outside of a car at speeds lower than the typical car idle speed. We bought a new alternator from a Maruti Suzuki 800 (the ubiquitous Kathmandu taxi) for about 2500 Rs. It is run off the car engine with a gear ratio of about 3:1. The taxis apparently idle at a speed of 700 rpm, which means we needed 2100 rpm at the alternator to replicate slowest conditions. The alternator pulley has about a 2" diameter, giving us a 13:1 ratio between the bike wheel and pulley. With estimated *ghatta* speeds at 60-90 rpm, we would get about 1000 rpm at the alternator - well below its typical idle speed. We used the stationary bike in our "lab" to conduct tests on the alternator. Results were very much mixed, as there were a wide variety of variables we had to contend with in testing alternator performance. For one, we began by using the low quality wire that is readily available in Kathmandu to connect the battery to the alternator. Eventually we determined that the wire was interfering with current flow and our tests. We replaced it with cable from "Prakash Cable", which is used to electrically wire houses. Secondly, the alternator regulates voltage only, not current. At a set voltage, the current is determined by the state of charge of the battery. We were using a very old, barely functional (only 300 Rs) used car battery. At a steady voltage, the current would vary by well over an amp, and it was difficult to determine how much power we could expect from the alternator at *ghatta* speeds. It took us a while, but eventually we convinced ourselves that the current variation was a product of the battery, and not the alternator being run at low speeds. If the alternator is generating 14.4V, increasing the

Testing in the Lab

rpm does not affect the output power. The real problem we encountered with running an alternator at low speeds was with the current flowing from the battery to the field connection. In a car, the field connection is wired from the positive terminal of the battery, then to the ignition switch, then to a small incandescent warning light, and then finally to the alternator. The ignition switch is easy to duplicate with a small mechanical switch. The incandescent warning light, however, is a bit more complicated. In addition to serving as a warning to the driver (current flowing to the field from the battery signifies that the alternator is not charging), this light also limits the amount of current that can flow to the field connection. In an alternator, electricity is produced by a combination of current flowing through the field and the rotation of the rotor's coil. Initially, more current or more rpms means more electricity. Initially, this electricity is entirely unregulated. The incandescent light fixes the current at 0.15A through the field. With this amount of current, a fairly high rpm is needed before enough electricity is generated to turn the alternator "on." It will not function in any way before a threshold speed. This threshold speed will be lowered if more current initially flows through the field. In this case, a lower rpm will produce the same amount of electricity and turn the alternator "on" at a lower speed.

At first, we just shorted the field connection directly to the battery's positive terminal. There are two reasons this should not, in practice, be done. The first is that this results in a very large current flow. We measured 3A flowing through the field connection with the car battery connected. Although the current flows only for a brief period of time, it can be too great for a lesser quality alternator to handle, and can blow the field coil apart. Over the course of our experiments, we purchased 3 alternators: 2 good quality and one of poor quality. The lesser quality alternator was damaged beyond our ability to repair it after shorting the field coil to the car battery. The second problem with connecting the field directly to the battery is that it produces a very large electromotive force (emf), which acts counter to the motion of the rotor. It is very difficult to initially turn the alternator with such a large current flowing through the field. In the lab, this meant that we had to pedal the stationary bike very hard initially to overcome the emf. This was further complicated by having to increase the belt tension to prevent slippage. Once the alternator started, however, we were able to resume normal pedaling with normal belt tension. At the *ghatta*, this was even more problematic. While we could put charge into a very dead motorcycle battery (which could not source much current at all), we could not charge a car battery. There was not enough force to get over the initial "induction hump," as we called it, and the stone ground to a halt against the load of the alternator. (During this test, we again learned the importance of welding the bike rim directly to the piece connecting it to the shaft. We had drilled and threaded a hole into the metal. This was fine for a while, but eventually the strain was too much, and the threads failed.) The trick to charging a full car battery was to find the right combination of resistors to replace the light. Too low a resistance, and the *ghatta* would never be able to get over the induction hump of the electromotive force. Too high a resistance, and the alternator would never turn itself on at *ghatta*operation speeds. The resistors also had to be rated for the amount of current flowing through them, which - in reality - meant using several resistors in parallel to share the current flow. Key Lessons Learned from this Test:

- Never use substandard wires when trying to do electrical work
- The amount of power a battery draws during recharging is determined not only by the voltage placed across its terminals, but also the "state of charge" of the battery
- Alternators can be operated at speeds lower than a car's idle speed (although efficiency probably decreases)
- The amount of current flowing to the alternator's field coil determines when the alternator will turn itself "on" and begin producing current
- The amount of current flowing to the alternator's field coil will equally determine how difficult it is to overcome the coil's electromotive force and begin turning the rotor