Appendix J Example Reports

This appendix is intended to give examples of formal laboratory reports. The format details may vary from one particular classes to another, so these are not intended to be used as "templates." Students in a given class should refer to the Laboratory Manual for that class, if there is one, for format and other particulars required for that class or by that instructor. For example, students in EE283 Measurement Lab should consult the example "Ohm's :Law" laboratory report example in the class Laboratory Manual. (However, note that that manual, for the example laboratory report section, figure and table numbering in that example conform to the chapter in a book format, since the report is one of the chapters, while yours should be simply "Figure 1" and "Table 1" and so forth because your laboratory report stands on its own.) In the examples below, the figure and table numbers are given as for a normal lab report.

These reports were generated from instructional material, actual student reports, or a combination of both. The students who contributed these reports were good students. Even so, they still had things to learn. The same is true also of the other materials. So, not everything in these reports is necessarily correct or to be recommended. After each report is a Comments section that points out problems and issues that could have perhaps been handled better.

The reports in this appendix are:

1. "Comparison of Series and Shunt DC Motors" (a demonstration experiment, EGR222)
2. "Frequency Characteristics of Resistors, Inductors, and Capacitors" (experiment, EE283)
3. "Experiment RD3: View Factor" (experiment, ME326)
4. "Stefan-Boltzmann Law" (experiment, ME326)
5. "Field Effect Transistor Characterization" (a characterization, EE252)
6. "Vibration Analysis of a Fiberglass Bow" (a characterization, ME322)
7. "The No Load Cantilevered Beam Modeled as a Spring/Mass System—Effective Mass Considerations (Application: Piper Cub Airplane Wing)" (a characterization, ME???)
8. "Traffic Signal Controller" (a design exercise, EE241, example)
9. "Forge Design" (a design exercise, ME342)
10. "Strain Gage Based Force Transducer on a Beam with Multiple Boundary Conditions" (a characterization or experiment, ME 398-A)

Thanks to former students Tom Wychock, Wyatt Culler, Andrew Bergey, Matt Parmenteri, Ryan Rozaieski, Mike Vamos, and Nick Rosati for their contributions of these examples. Most of the reports are left as they were in the originals, though in some places spacing has been modified to squeeze out unnecessary blank space to make this document several pages shorter.

Comparison of Series and Shunt DC Motors

<name>

EGR222

May 24, 2008

Abstract

An experiment was conducted to compare the characteristics under varying loads of shunt and series wound DC motors. The motor used was that of a toy train locomotive, with a load varying by the number of cars pulled. In one series data was taken with the windings in series configuration, and the other case in shunt. As expected, the speed dropped more rapidly with the series wound configuration, but the differences were not as large as expected, and the series configuration was more efficient.

1. Background

A test question in EGR222 asked what kind of motor maintained the same speed regardless of load up to the limit of its performance. The correct answer was intended to be an AC synchronous motor, with the assumption of a constant frequency supply. However, more than half of the students answered “a DC shunt wound motor” or the equivalent. Some even cited the textbook which indeed stated that a DC shunt motor’s speed was almost independent of the load (Bolton). One could also say the same of an AC induction motor. However, “almost” is not exactly the same speed. This experiment was conceived to demonstrate to the class that the shunt wound motor’s speed is not independent of load, but it is more nearly so than that of a series wound motor.

The “motor” utilized for the experiment was that of an Ives 3241 “Wide Gauge” (2 1/8 in., the same as Lionel Standard Gauge) locomotive from c. 1924 (Greenberg). The locomotive was already missing its normal reverse unit, so no damage was done to its value by adding a switch to enable it to run in either series (normal) or shunt mode. The locomotive was originally intended to run on AC with operating Voltages up to about 20 Volts as a series, or “universal” motor, and in that era the ability to also run from DC (typically an automobile battery) was useful since AC utility power was not so universally available as now. For the experiment operation in both modes was DC, since shunt wound motors are not effective with AC.

2. Procedure

An Ives No. 3241 locomotive was modified as shown in Figure 1 to allow operation in either series or shunt mode. A circular test track (of circumference 129 inches at the center rail) was set up powered by a Hewlett Packard 6267B Power supply, rated up to 40 Volts and 10 Amperes. (Attempts to run in shunt mode with a smaller supply failed.) The Voltage on the supply was set such that both the series and shunt wound configurations achieved the same speed, would both operate under a maximum load of three additional cars, and that the unloaded speeds were the same. The Voltage chosen for series operation was 9.0 Volts, as measured by the meter on the power supply. (The minimum Voltage that would allow readings at all load levels was chosen to minimize dissipation in the motor, particularly in shunt mode.) The locomotive was operated in series mode with no additional load, one, two, and three additional cars. The cars used for added load were an Ives No. 191 coke car, a No. 191 tank car, and a No. 195 caboose. All of the cars were in heavily used condition, and no special efforts were made (such as oiling) to reduce their load on the locomotive. The time to make five circuits of the track was recorded for each of the four operating conditions. The times were kept manually using a watch inscribed "Disney, Quartz" bearing the likeness of Mickey Mouse. The same procedure was then repeated using the shunt configuration, with 8.0 Volts giving an unloaded speed close to that of the unloaded series case..

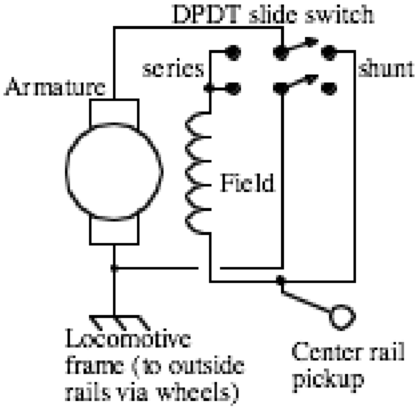

Figure 1 Locomotive circuit

3. Results

The resulting time measurements for 5 circuits of the track obtained are given in Table 1. For purposes of designating the load, the locomotive counts as one unit and each additional car counts as a unit. These results are represented graphically in Figure 2.

In order to better relate these data to normal speed vs. torque characteristics. The speeds were converted to scale miles per hour (mph) using an assumed 1/40 scale as shown in equation 1:

$$\text{Speed}_{\text{mph}} = \frac{(129\text{ in/circuit})\ (5\text{ circuits})\ (1/12\text{ in. per ft.})(1/5320\text{ ft. per mile})\ (40\text{ scale})}{(\text{time in seconds})\ (1/60\text{ sec per min})(1/60\text{ min per hour})} \quad (1)$$

Table 1 Series and Shunt Times

Load (cars)	series time sec.	shunt time sec.
1	23	25
2	27	25
3	30	28
4	48	33

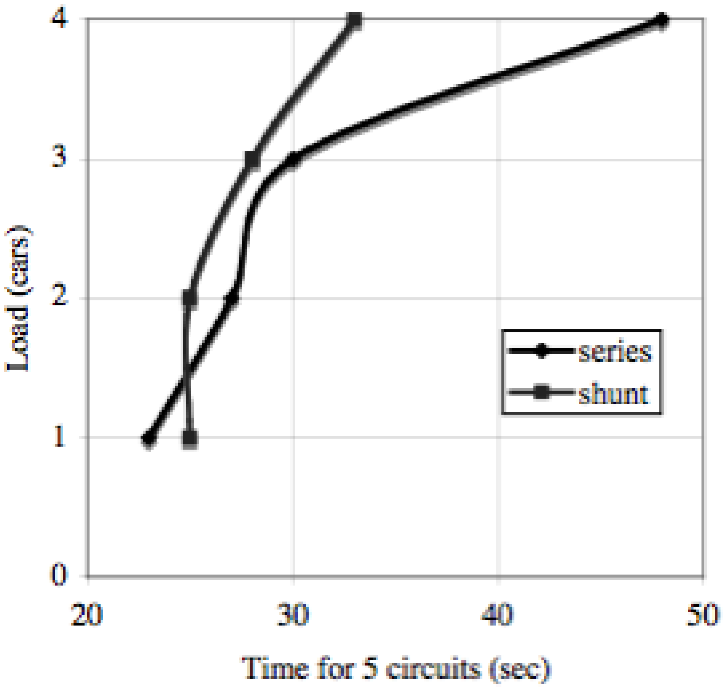

Figure 2 Time for 5 circuits as a function of load for series and shunt configurations

The five circuits amounts to .404 scale miles, giving 63 mph maximum speed, and other speeds inversely proportional to times scales down from that. Figure 3 shows load versus speed for the two motor configurations.

The current drawn by the locomotive from the power supply was observed using the ammeter of the power supply. However, the current could not be measured with any degree of precision due to current surges as the locomotive traversed the sectional track. At each mechanical junction the current would sharply drop and then bounce back. Estimated values for the series configuration of the motor were about 2.4 Amperes, and for shunt configuration 8 Amperes, with neither value changing enough to measure with changing load.

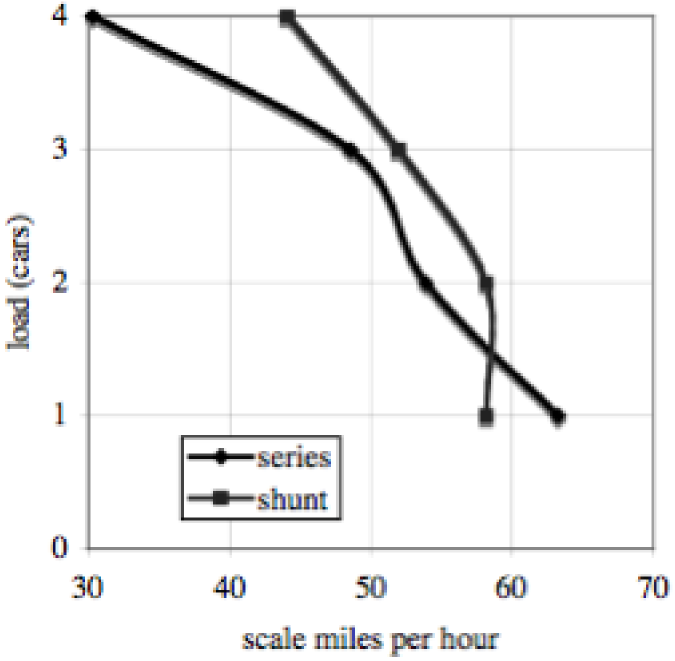

Figure 3 Scale speed versus load for series and shunt configurations

It was noticed that the motor heated rapidly in shunt configuration. It was clear that most of the energy was being dissipated as heat in the windings, and that such operation for any extended period would damage the motor.

Conclusions

It is obvious that the shunt wound motor does not, in fact, maintain a constant speed with a varying load, even with the source Voltage remaining constant. However, neither motor configuration was completely consistent with what would normally be expected. For a series motor, the load – speed curve was expected to be of roughly 1/xy shape. While that is true for the lower loads, the data point for the full load of locomotive plus three cars is significantly lower than expected. It is likely that this is due to the nonlinear nature of actual mechanical friction. The Voltage chosen for the experiment is not very far above the stall Voltage for either configuration. While the shunt configuration did achieve higher speeds at each load with one or more cars, and dropped off much more slowly with load than the series configuration, the shunt motor drew much more power (about three times as much!) to achieve nearly the same results. Some of this extra power would have been additional connection losses between the power supply and the motor. However, it is clear that the shunt configuration is inferior in efficiency for this motor, which was designed with windings to be used in series mode. A motor with a field winding with many more turns, for a smaller shunt current, might well outperform the series motor significantly on DC.

A sampling of the data points, the operation of the locomotive and the locomotive with three cars, was demonstrated to the EGR222 class on April 8, 2008.

References

Bolton, W., Mechatronics*; Electronic Control Systems in Mechanical and Electrical Engineering*, 3rd ed., Longman, Essex, England, 2003, p171.

Greenberg, Bruce C., *Greenberg's Guide to Ives trains, 1901-1932*, Vol. 1, 2nd ed., Greenberg publishing, Sykesville, MD, 1991, pp. 43, 53-55, 90-93, 99.

Remarks:

This report uses a 'hanging indent" style for references that is closer to what seems to be found today in journals and conferences than the Chicago style. Notice that in Table 1 the font was imported along with the data from an Excel spreadsheet; it would have been better to first change the font and size to Times 12, as in the rest of the document. However, sometimes an evenly spaced font (in which all characters use the same horizontal spacing) is desirable for tables, and Times does not have that property.

Notice that the procedure section contains some results, such as the Voltage setting that would give equivalent no extra load speed for the two different motor wiring configurations. This is OK since it is a calibration step, and thus legitimately part of procedure.

The equation is given only for the most complicated mathematical manipulation. It is assumed that the typical reader can do basic unit conversions, such as seconds to hours, without needing details. In the results section, the raw data is presented first, then manipulated into a form that the reader might expect. Here, the transformation is to load versus speed. Motor characteristics are typically given in torque versus speed (Bolton), which isn't the same. The infer torque, one would have to add another step, and assume that torque is equal to speed times the load. However, that requires an assumption of the linearity of friction, so the results were left in the form given, which is relatively easy to understand and is sufficient to make the point that speed does change with load, even if that load is a resistance rather than a torque.

The graphics leave something to be desired: better resolution. Line graphics imported directly from Excel or another line graphics program would have been better. These are JPEG images that were pasted in. Furthermore, they are at lower resolution than is desirable for good reproduction on paper (to keep the document size down). (There's a bad error in Figure 1!)

It would have been nice if this report had been more thorough. Apparently no electrical measurements were made to find the respective resistances of the armature and field coils, or the resistance in transmission from the power supply to the motor proper. It would have been helpful to know what the Voltage across the motor and the current through the motor for each trial. With additional effort the locomotive could have been instrumented with meters having long RC time constant filters to overcome the electrical noise from track commutation. These extra details might have allowed a more precise efficiency comparison between the two configurations. A figure showing the experimental configuration would have been most helpful.