21世纪专业英语系列教材

机电数控英语

主编 杨克石 胡耀增
许 超 刘鸣涛
主审 林 晨 杨燕国

東北大學出版社
Northeastern University Press

机电数控英语

21 世纪专业英语系列教材

机电数控英语

主　编　杨克石　胡耀增

　　　　许　超　刘鸣涛

主　审　林　晨　杨燕国

东北大学出版社

·沈　阳·

图书在版编目（CIP）数据

机电数控英语／杨克石等主编．—沈阳：东北大学出版社，2010.8
ISBN 978-7-81102-851-5

Ⅰ．①机…　Ⅱ．①杨…　Ⅲ．①机电工程—英语—高等学校—教材　Ⅳ．①H31

中国版本图书馆 CIP 数据核字（2010）第 167156 号

出 版 者：东北大学出版社
地址：沈阳市和平区文化路 3 号巷 11 号
邮编：110004
电话：024－83687331（市场部）　83680267（社务室）
传真：024－83680180（市场部）　83680265（社务室）
E-mail：neuph@neupress.com
http：//www.neupress.com
印 刷 者：抚顺光辉彩色印刷有限公司
发 行 者：东北大学出版社
幅面尺寸：184mm×260mm
印　　张：9
字　　数：220 千字
出版时间：2010 年 8 月第 1 版
印刷时间：2010 年 8 月第 1 次印刷
责任编辑：刘　璇　　责任校对：孙　锋
封面设计：唐敏智　　责任出版：杨华宁

ISBN 978-7-81102-851-5　　定　价：20.00 元

前　言

机电一体化以机械和电子技术为基础，多门学科相互渗透、结合，使传统机械工业的技术结构、产品结构、功能和生产方式发生了巨大变化，工业生产从“机械电气化”进入了以“机电一体化”为特征的发展阶段。

本书共14个单元，分别从直流电机的历史、工作原理、闭环系统的速度控制和位置控制；可编程序控制器（PLC），交流调速驱动；液压基础；液压系统；液压传动等10个方面对机电专业相关的知识和理论进行了深入浅出的介绍。编写过程中注重用通俗易懂的英语词汇阐述专业知识，并利用背景介绍、技术变革渊源的注解对个别较难理解的知识点进行了补充讲解，避免生硬的“翻译英语”对学生学习机电专业理论和前沿知识造成困扰，使学生学得轻松、有趣，容易入门。

本书选材取自欧美文献原著，多数材料经过我校机电专业学生试用，编者根据学生的信息反馈，作了注解和注释，以帮助学生理解，同时尽力保持原文的语言风格。

本教材可作为高等专科学校、高等职业学院等院校机电一体化、数控技术应用专业英语教材或课外阅读材料，也可作为工程技术人员自学参考用书。

编写分工：杨克石，第1~3单元；胡耀增，第4~6单元；许超，第7~9单元；刘鸣涛，第10~14单元。全书由杨克石统稿，林晨、杨燕国主审。

青岛理工大学机械工程学院林晨教授为本书的编写提供了指导；初稿完成后，阅读了全部书稿，并指出了注释和翻译中的许多问题，在此对其表示感谢。

由于编者水平有限，加之时间仓促，书中难免存在错误和疏漏，恳请读者发E-mail到yangkeshi2001@126.com给予批评、指正。

编　者

2010年5月

目 录

Unit 1

DC Motors

1. History and Background

At the most basic level, electric motors exist to convert electrical energy into mechanical energy. This is done by way of two interacting magnetic fields—one stationary, and another attached to a part that can move. A number of types of electric motors exist, but most BEAMbots use DC motors in some form or another. DC motors have the potential for very high torque capabilities (although this is generally a function of the physical size of the motor), are easy to miniaturize, and can be "throttled" via adjusting their supply voltage. DC motors are also not only the simplest, but the oldest electric motors.

The basic principles of electromagnetic induction were discovered in the early 1800's by Oersted, Gauss, and Faraday. By 1820, Hans Christian Oersted and Andre Marie Ampere had discovered that an electric current produces a magnetic field. The next 15 years saw a flurry of cross-Atlantic experimentation and innovation, leading finally to a simple DC rotary motor. A number of men were involved in the work, so proper credit for the first DC motor is really a function of just how broadly you choose to define the word "motor".

torque: *n.* the measure of a force's tendency to produce torsion and rotation about an axis, equal to the vector product of the radius vector from the axis of rotation to the point of application of the force and the force vector 扭矩，转矩

flurry: *n.* a stirring mass, as of leaves or dust; a shower 风雪，乱舞
a flurry of: 一系列

2. Michael Faraday (U. K.)

Fabled experimenter Michael Faraday decided to confirm or refute a number of speculations surrounding Oersted's and Ampere's results. Faraday set to work devising an experiment to demonstrate whether or not a current-carrying wire produced a circular magnetic field around it, and in October of 1821 succeeded in demonstrating this.

Faraday took a dish of mercury and placed a fixed magnet in the middle; above this, he dangled a freely moving wire (the free end of the wire was long enough to dip into the mercury). When he connected a

fabled: *adj.* made known or famous by fables; legendary, existing only in fables; fictitious

refute: *tr. v.* disprove to deny (a claim, charge, allegation, etc.)

battery to form a circuit, the current-carrying wire circled around the magnet. Faraday then reversed the setup, this time, with a fixed wire and a dangling magnet—again the free part circled around the fixed part. This was the first demonstration of the conversion of electrical energy into motion, and as a result, Faraday is often credited with the invention of the electric motor. Bear in mind, though, that Faraday's electric motor is really just a lab demonstration, refer to Figure 1-1, as you can't harness it for useful work.

dangle: *v.* to hang loosely and swing or sway to and from 摇摆；悬垂

Also note that if you plan on repeating this experiment yourself, you should use salt water (or some similar non-toxic but conductive liquid) for the fluid, rather than mercury. Mercury can be very hazardous to your health, and requires stringent precautions on its use.

mercury: *n.* a chemical element; mercury is a poisonous silver-white liquid metal, used in thermometers 汞；水银

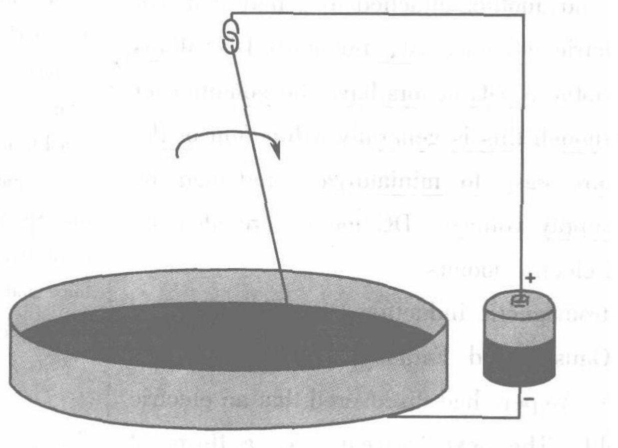

Figure 1-1 Faraday's Electric Motor

3. Joseph Henry (U. S.)

It took ten years, but by the summer of 1831 Joseph Henry had improved on Faraday's experimental motor. Henry built a simple device whose moving part was a straight electromagnet rocking on a horizontal axis. Its polarity was reversed automatically by its motion as pairs of wires projecting from its ends made connections alternately with two electrochemical cells. Two vertical permanent magnets alternately attracted and repelled the ends of the electromagnet, making it rock back and forth at 75 cycles per minute, refer to Figure 1-2.

Henry considered his little machine to be merely a "philosophical toy", but nevertheless believed it was important as the first demonstration of continuous motion produced by magnetic attraction and repulsion. While being more mechanically useful than Faraday's motor, and being the first real use of electromagnets in a motor, it was still by and large a lab experiment.

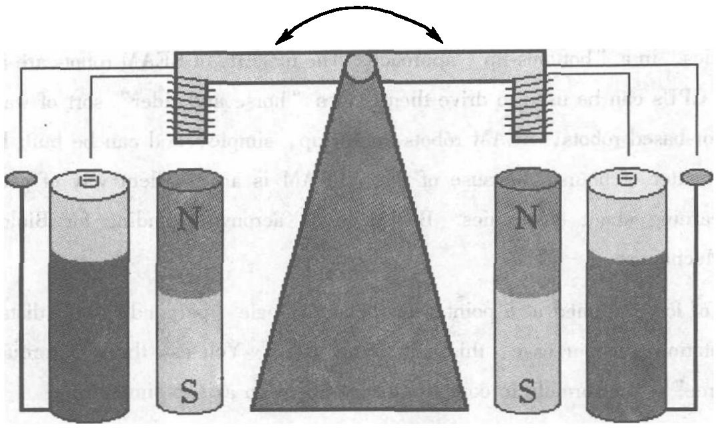

Figure 1-2 Joseph Henry's Motor

4. William Sturgeon (U. K.)

Just a year after Henry's motor was demonstrated, William Sturgeon invented the commutator, and with it the first rotary electric motor—in many ways a rotary analogue of Henry's oscillating motor. Sturgeon's motor, while still simple, was the first to provide continuous rotary motion and contained essentially all the elements of a modern DC motor, refer to Figure 1-3. Note that Sturgeon used horseshoe electromagnets to produce both the moving and stationary magnetic fields (to be specific, he built a shunt-wound DC motor).

commutator: *n.* a device used to reverse the direction of flow of an electric current. 换向器

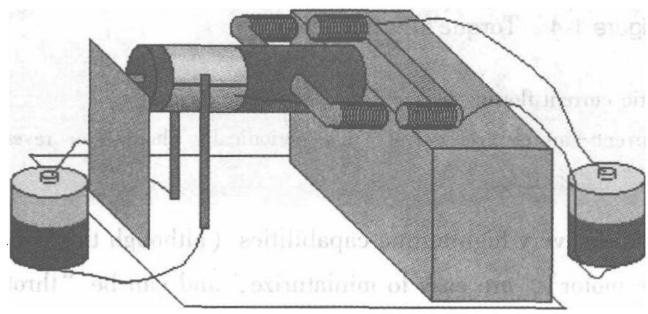

Figure 1-3 William Sturgeon's Motor

Many later experimenters contributed a number of further refinements; let's skip forward in time to see just how a modern DC motor works.

Notes

BEAM is a school of robotics, in a "bottoms-up" approach. The majority of BEAM robots are non-computerized (although simple CPUs can be used to drive them, in a "horse and rider" sort of way). Unlike many traditional processor-based robots, BEAM robots are cheap, simple, and can be built by a hobbyist with basic skills in a matter of hours. Because of this, BEAM is an excellent way of getting started in robotics, and of learning about electronics. BEAM is an acronym standing for Biology, Electronics, Aesthetics, and Mechanics.

Torque is the combination of force applied at a point with the right angle (perpendicular) distance from that point to the axis of rotation (in our case, this will be an axle). You can think of torque as being essentially a "twisting force". The formula to compute torque about an axis is simply this:

$T = F * d$, where T = Torque; F = Force (here, the force applied perpendicular to the axis); d = Distance.

In 2 dimensions, you can visualize this simply, refer to Figque 1-4:

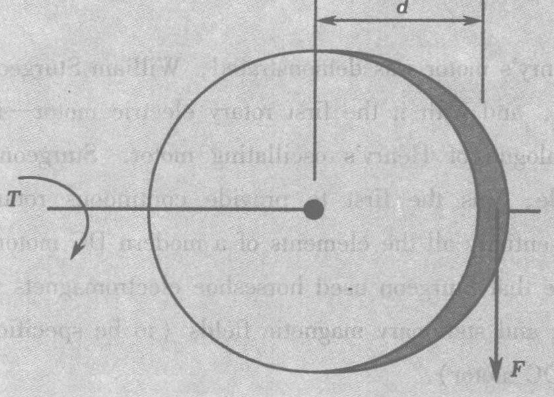

Figure 1-4 Torque's Explanation

DC: Direct Current—an electric current flowing in one direction alone. 直流电。

Compare AC: Alternating Current—an electric current that periodically changes or reverses its direction of flow in a circuit. 与交流电进行比较。

① DC motors have the potential for very high torque capabilities (although this is generally a function of the physical size of the motor), are easy to miniaturize, and can be "throttled" via adjusting their supply voltage.

直流电动机能够输出很高的扭矩（尽管扭矩大小取决于直流电动机的物理尺寸），直流电动机很容易小型化，直流电动机也可以通过调整电源电压来进行“控制”。

② Also note that if you plan on repeating this experiment yourself, you should use salt water (or some similar non-toxic but conductive liquid) for the fluid, rather than mercury. Mercury can be very hazardous to your health, and requires stringent precautions on its use.

另外请注意，如果你自己计划重复这个实验，你应该使用食盐水（或类似的无毒导电液体），而不是汞。汞对你的健康非常有害，并要求在其使用上有着严格的预防措施。

Supplementary

Michael Faraday, Sept. 22, 1791, Newington, Surrey, England; Aug. 25, 1867, Hampton Court

Early life: Michael Faraday was born on Sept. 22, 1791 in a poor and very religious family in the country village of Newington, Surrey, now a part of South London. His father was a blacksmith who had migrated from the north of England earlier in 1791 to look for work. His mother was a country woman of great calm and wisdom who supported her son emotionally through a difficult childhood. Faraday was one of four children, all of whom were hard put to get enough to eat, since their father was often ill and incapable of working steadily. Faraday later recalled being given one loaf of bread that had to last him for a week. The family belonged to a small Christian sect, called Sandemanians that provided spiritual sustenance to Faraday throughout his life. It was the single most important influence upon him and strongly affected the way in which he approached and interpreted nature. Faraday himself, shortly after his marriage, at the age of 30, joined the same sect, to which he adhered till his death. He kept science and religion strictly apart, believing that the data of science were of an entirely different nature from the direct communications between God and the soul on which his religious faith was based.

Faraday received only the rudiments of an education, learning to read, write, and cipher in a church Sunday school. At an early age, he began to earn money by delivering newspapers for a book dealer and bookbinder, and at the age of 14, he was apprenticed to the man. Unlike the other apprentices, Faraday took the opportunity to read some of the books brought in for rebinding. The article on electricity in the third edition of the Encyclopaedia Britannica particularly fascinated him. Using old bottles and lumber, he made a crude electrostatic generator and did simple experiments. He also built a weak voltaic pile with which he performed experiments in electrochemistry.

He was also among other young Londoners who pursued an interest in science by gathering to hear talks at the City Philosophical Society. Faraday's great opportunity came when he was offered a free ticket to attend chemical lectures by Sir Humphry Davy at the Royal Institution of Great Britain in London. Faraday went, sat absorbed with it all, recorded the lectures in his notes, and returned to bookbinding with the seemingly unrealizable hope of entering the temple of science. He sent a bound copy of his notes to Davy along with a letter asking for employment, but there was no opening. Davy did not forget, however, and, when one of his laboratory assistants was dismissed for brawling, he offered Faraday a job. His first assignment was to accompany Sir Humphry and his wife on a tour of the Continent, during which he sometimes had to be a personal servant to Lady Davy. Then Faraday began as Davy's laboratory assistant and learned chemistry at the elbow of one of the greatest practitioners of the day. It has been said, with some truth, that Faraday was Davy's greatest discovery.

Figure 1-5 Faraday Announcing His Discovery to His Wife on Christmas Morning, 1821

Figure 1-6 Michael Faraday with His Wife Sarah

When Faraday joined Davy in 1812, Davy was in the process of revolutionizing the chemistry of the day. Antoine-Laurent Lavoisier, the Frenchman generally credited with founding modern chemistry, had effected his rearrangement of chemical knowledge in the 1770s and 1780s by insisting upon a few simple principles. Among these was that oxygen was an unique element, in Which it was the only supporter of combustion and was also the element that laid at the basis of all acids. Davy, after having discovered sodium and potassium by using a powerful current from a galvanic battery to decompose oxides of these elements, turned to the decomposition of muriatic (hydrochloric) acid, one of the strongest acids known. The products of the decomposition were hydrogen and a green gas that supported combustion and that, when combined with water, produced an acid. Davy concluded that this gas was an element, to which he gave the name chlorine, and that there was no oxygen whatsoever in muriatic acid. Acidity, therefore, was not the result of the presence of an acid-forming element but of some other condition. What else could that condition be but the physical form of the acid molecule itself? Davy suggested, then, that chemical properties were determined not by specific elements alone but also by the ways in which these elements were arranged in molecules. In arriving at this view he was influenced by an atomic theory that was also to have important consequences for Faraday's thought. This theory, proposed in the 18th century by Ruggero Giuseppe Boscovich, argued that atoms were mathematical points surrounded by alternating fields of attractive and repulsive forces. A true element comprised such a single point, and chemical elements were composed of a number of such points, about which the resultant force fields could be quite complicated. Molecules, in turn, were built up of these elements, and the chemical qualities of both elements and compounds were the results of the final patterns of force surrounding clumps of point atoms. One property of such atoms and molecules should be specifically noted: they can be placed under considerable strain, or tension, before the "bonds" holding them together are broken. These strains were to be central to Faraday's ideas about electricity.

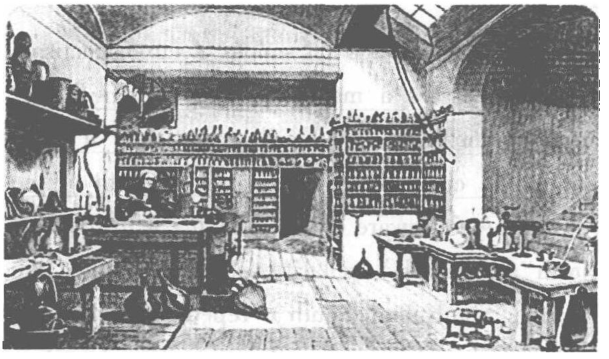

Figure 1-7 Faraday at Work in His Bottle-Lined Laboratory in the Basement of the Royal Institution in London.

Variable Speed Drives

The speed of a motor can be controlled by using some type of electronic drive equipment, referred to as variable or adjustable speed drives. Variable speed drives used to control DC motors are called DC drives. Variable speed drives used to control AC motors are called AC drives. The term inverter is also used to describe an AC variable speed drive. The inverter is only one part of an AC drive, however, it is common practice to refer to an AC drive as an inverter, refer to Figure 1-8.

Figure 1-8 Solar Micro-Inverter System

Before discussing AC drives, it is necessary to understand some of the basic terminology associated with drive operation. Many of these terms are familiar to us in some other context. Later in the course we will see how these terms apply to AC drives.

Unit 2

Principles of Operation

In any electric motor, operation is based on simple electromagnetism. A current-carrying conductor generates a magnetic field; when this is then placed in an external magnetic field, it will experience a force proportional to the current in the conductor, and to the strength of the external magnetic field. You are well aware of from playing with magnets as a kid, opposite (North and South) polarities attract, while like polarities (North and North, South and South) repel. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion.

proportional: *adj.* properly related in size, degree, or other measurable characteristics; usually followed by "to" 相称的; 成比例的; 均衡的, 常与 to 搭配使用

Let us start by looking at a simple 2-pole DC electric motor, refer to Figure 2-1 (here the right part represents a magnet or winding with a "North" polarization, while the left part represents a magnet or winding with a "South" polarization).

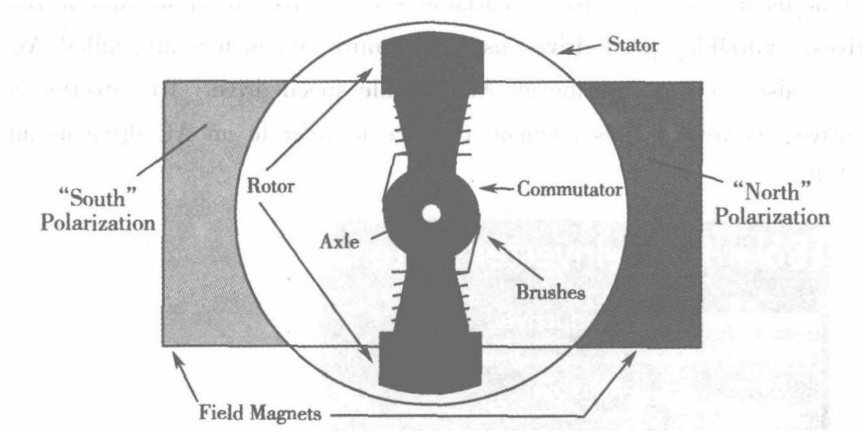

Figure 2-1 2-Pole DC Electric Motor

Every DC motor has six basic parts——axle, rotor (a. k. a., armature), stator, commutator, field magnet (s), and brushes. In most common DC motors (and all that BEAMers will see), the external magnetic field is produced by high-strength permanent magnets. The stator is the stationary part of the motor—this includes the motor casing,

rotor: *n.* a part of a machine that turns around a central point 转子, 转动部件

stator: *n.* The stationary part of a motor, dynamo, turbine, or other working machine about which a rotor turns (发电机的) 定子; 定片

as well as two or more permanent magnet pole pieces. The rotor (together with the axle and attached commutator) rotates with respect to the stator. The rotor consists of windings (generally on a core), the windings being electrically connected to the commutator. Figure 2-2 shows a common motor layout—with the rotor inside the stator (field) magnets.

The geometry of the brushes, commutator contacts, and rotor windings are such that when power is applied, the polarities of the energized winding and the stator magnet (s) are misaligned, and the rotor will rotate until it is almost aligned with the stator's field magnets. As the rotor reaches alignment, the brushes move to the next commutator contacts, and energize the next winding. Given our example 2-pole motor, the rotation reverses the direction of current through the rotor winding, leading to a "flip" of the rotor's magnetic field, driving it to continue rotating.

geometry: *n.* 几何（学）; 几何结构

align: to place in a line or orrarge so as to be parallel or straight 排整齐; 校准; (尤指) 使成一条直线 ~ (sth) (with sth)

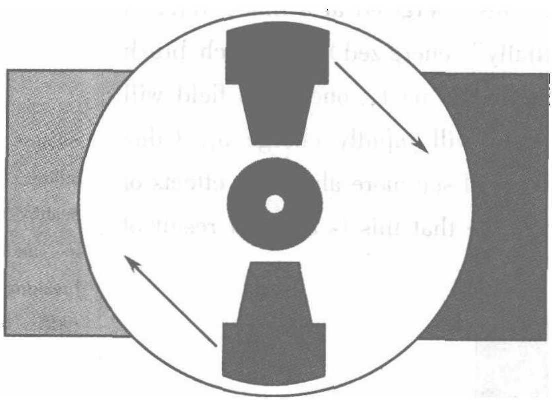

Figure 2-2 A Common Motor Layout

In real life, though, DC motors usually have more than two poles, (three is a very common number). In particular, this avoids "dead spots", refer to Figure 2-3 in the commutator. You can imagine how with our example 2-pole motor, if the rotor is exactly at the middle of its rotation (perfectly aligned with the field magnets), it will get "stuck" there. Meanwhile, with a 2-pole motor, there is a moment when the commutator shorts out the power supply (i. e., both brushes touch both commutator contacts simultaneously). This would be bad for the power supply, waste energy, and damage motor components as well. Yet another disadvantage of such a simple motor is that it would exhibit a high amount of torque "ripple" (the amount of torque it could produce is cyclic with the position of the rotor).

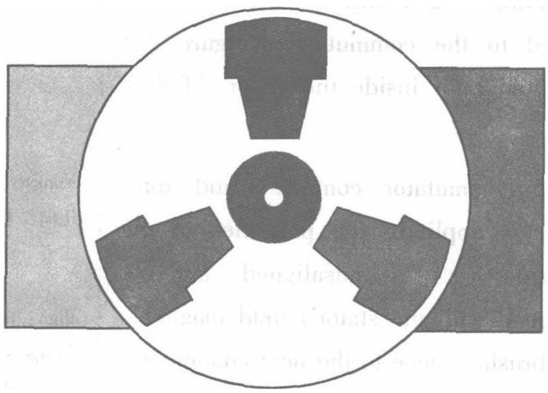

Figure 2-3 3-Pole DC Electric Motor

Since most small DC motors are of a 3-pole design, let us tinker with the workings of one via an interactive animation. You will notice a few things from this—namely, one pole is fully energized at a time, refer to Figure 2-4 (but two others are "partially" energized). As each brush transitions from one commutator contact to the next, one coil's field will rapidly collapse, as the next coil's field will rapidly charge up (this occurs within a few microseconds). We will see more about the effects of this later, but in the meantime you can see that this is a direct result of the coil windings' series wiring:

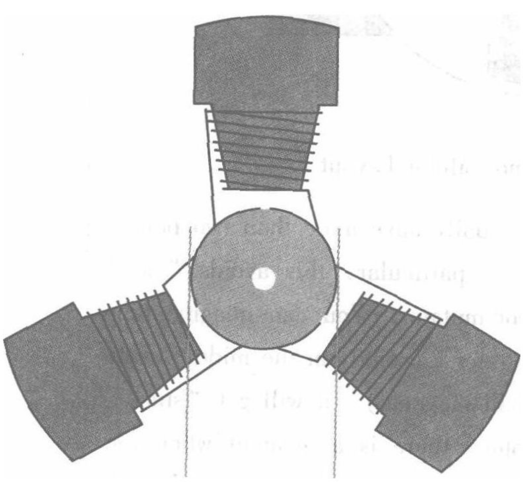

Figure 2-4 3-Pole Motor Wiring

There is probably no better way to see how an average DC motor is put together, than by just opening one up. Unfortunately this is tedious

ripple: *n.*

1. a small wave on the surface of a liquid, especially water in a lake, etc. 波纹；细浪；涟漪
2. a thing that looks or moves like a small wave（外观或运动）如波纹的东西

collapse: *v.* an abrupt failure of function or health. to fall down or fall in suddenly, often after breaking apart（突然）倒塌，坍塌

tedious: lasting or taking too long and not interesting 冗长的；啰嗦的；单调乏味的

work, as well as requiring the destruction of a perfectly good motor.

Luckily for you, I have gone ahead and done this in your stead. The guts of a disassembled Mabuchi FF-030-PN motor (the same model that Solarbotics sells) are available for you to see here (on 10 lines / cm graph paper). This is a basic 3-pole DC motor, with two brushes and three commutator contacts.

The use of an iron core armature (as in Figure 2-5) is quite common, and has a number of advantages. First off, the iron core provides a strong, rigid support for the windings—a particularly important consideration for high-torque motors. The core also conducts heat away from the rotor windings, allowing the motor to be driven harder than might otherwise be the case. Iron core construction is also relatively inexpensive compared with other construction types.

armature: *n.* a part in an electric motor that is inside a coil which carries electric current (电机的) 电枢，转子

But iron core construction also has several disadvantages. The iron armature has a relatively high inertia which limits motor acceleration. This construction also results in high winding inductances which limit brush and commutator life.

inertia: *n.*

1. lack of energy; lack of desire or ability to move or change 缺乏活力；惰性；保守
2. a property (= characteristic) of matter (= a substance) by which it stays still or, if moving, continues moving in a straight line unless it is acted on by a force outside itself 惯性

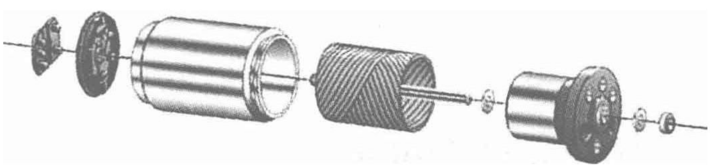

Figure 2-5 Iron Core Construction

In small motors, an alternative design is often used which features a "coreless" armature winding. This design depends upon the coil wire itself for structural integrity. As a result, the armature is hollow, and the permanent magnet can be mounted inside the rotor coil. Coreless DC motors have much lower armature inductance than iron-core motors of comparable size, extending brush and commutator life.

The coreless design also allows manufacturers to build smaller motors; meanwhile, due to the lack of iron in their rotors, coreless motors are somewhat prone to overheating. As a result, this design is generally used just in small, low-power motors. BEAMers will most often see coreless DC motors in the form of pager motors.

Again, disassembling a coreless motor can be instructive—in this case, my hapless victim was a cheap pager vibrator motor. The guts of this disassembled motor are available for you to see here (on 10 lines/cm

hapless: *adj.* not lucky; luckless; unfortunate 倒霉的；不幸的