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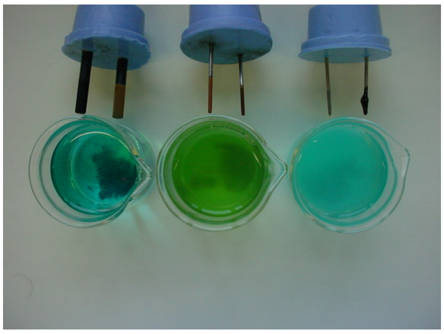
The inside surface of the test tube is coated with a silver amine $[Ag(NH_3)_2^+]$. This compound is reduced to form silver. Because the ions of the silver solution and the reducer only touch each other on the inside surface of the flask, the inside surface is the only place where silver metal forms

8 – Electrolisis of copper (II) chloride

$Cu^{2+} (aq) \rightleftharpoons Cu (s) + 2e^- \quad E^\circ = + 0,34V$

$2Cl^- (aq) \rightleftharpoons Cl_2 (g) + 2e^- \quad E^\circ = + 1,36 V$

$CuCl_2 (aq) \rightleftharpoons Cu (s) + Cl_2 (g) \quad E^\circ = - 1, 02 V$



Handmade Series Direct Current Motor

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Abstract. Using common materials, it is possible to build a variety of very simple – and yet functioning – electric devices. These devices can be used to verify Electromagnetism fundamentals. Electric currents within magnetic fields originate forces and that is the basic principle of operation of electric motors. This paper describes a universal series motor made with iron bars, insulated copper wire, two small brass plates, insulating tape, six screws and a couple of hoops. The motor is fed with a personal computer 12V DC switched power supply. Rotor speed can achieve several rotations per second.

Keywords. Electric Motors, Universal Series Motor.

1. Introduction

The device described in this paper (Fig.1) is a handmade *universal series motor* [1]. It is called *universal* because it works both with direct current (DC) or alternating current (AC) and *series* because the windings of the stator are in series with those of the rotor [2]. Both windings must have the same polarity.

An electric current flowing in a solenoid originates a magnetic field in the surrounding space and two magnetic fields interact with each other originating forces [3,4]. These are the Electromagnetism fundamentals that explain the principle of operation of the constructed motor. Direct current was used to feed it.

Materials used to build the motor are listed in Section 2. Construction details are given in Section 3. The principle of operation of the motor is explained in Section 4.

Figure 1. Handmade universal series motor

Conclusions are presented in Section 5, followed by the due acknowledgements (Section 6) and the list of references cited (Section 7).

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2. Materials used to make the motor

The following materials were used to build the motor:

- a 20cm x 20cm wood board;
- a 68cm x 10mm iron rod;
- a 18cm x 15cm x 3mm iron sheet;
- a 25cm x 10mm x 3mm iron bar;
- a copper wire with 10cm of length;
- 25m of varnished copper wire;
- a copper tube with 14mm inner diameter and 2cm of length;
- two handles, each with a 13mm hole;
- a roll of insulating tape;
- six medium screws.

3. Motor construction

To build the core of the stator a 53cm x 10mm iron rod is bent as shown in Fig. 2 and the 140mm sides of the resulting piece are covered with insulating tape.

Then, the stator windings are coiled over the insulated portions of the core, as shown if Fig. 3. Each winding is made of 200 turns of varnished copper wire Special care has to be taken in order to coil the windings in opposite directions, as Fig. 3 suggests. After this, the finished stator should look like the one depicted in Fig. 4.

The traverse bar of the rotor core is made of two equal 12,5cm x 10mm x 3mm iron bars. An arch is made at the middle of each bar (the side view of the bars is shown on Fig. 5). The bars are then fastened on a 15cm x 10mm iron rod using insulating tape, as shown in Fig. 6. The rod is previously insulated with tape (only its extremities are left without insulation).

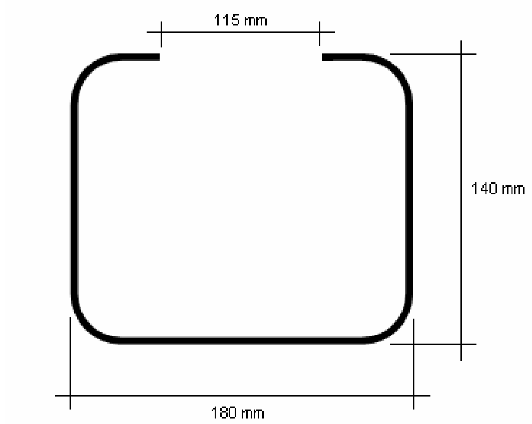

Figure 2. Core of the stator

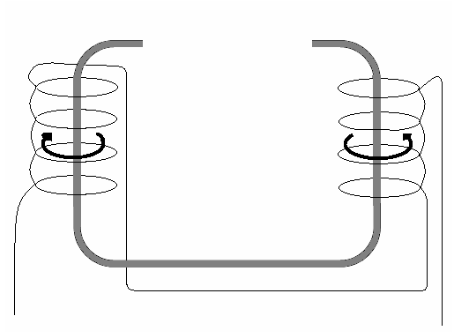

Figure 3. Making the windings of the stator

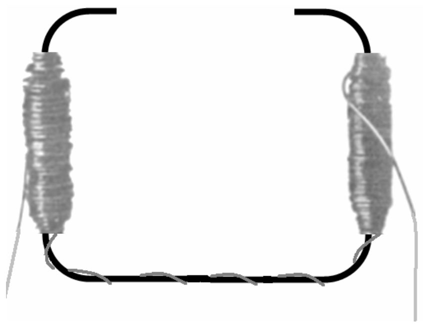

Figure 4. Final aspect of the stator

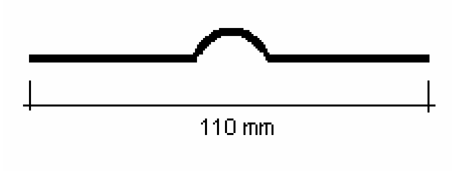

Figure 5. Side view of the iron bars used to make the traverse bar of the rotor core

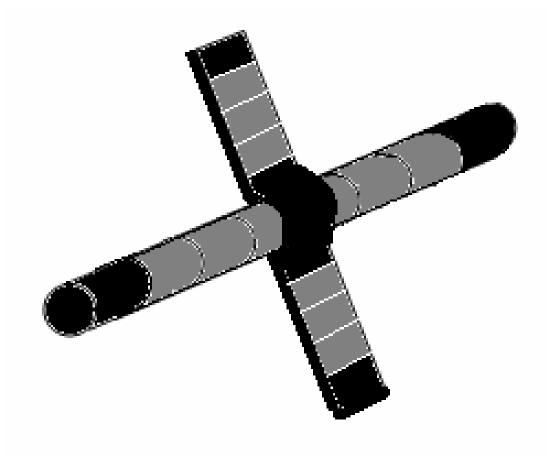

Figure 6. Core of the rotor

The rotor windings are coiled over the insulated portions of the traverse bar of the

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rotor core (Fig. 7). Each winding is made of 200 turns of varnished copper wire Special care has to be taken in order to coil the windings in the same direction, as Fig. 7 suggests.

A copper tube is cut to half. Each of the resulting halves is connected to one of the terminals of the rotor windings. The two halves are then fastened on the rotor, forming the collector. The finished rotor looks like the one depicted in Fig. 8.

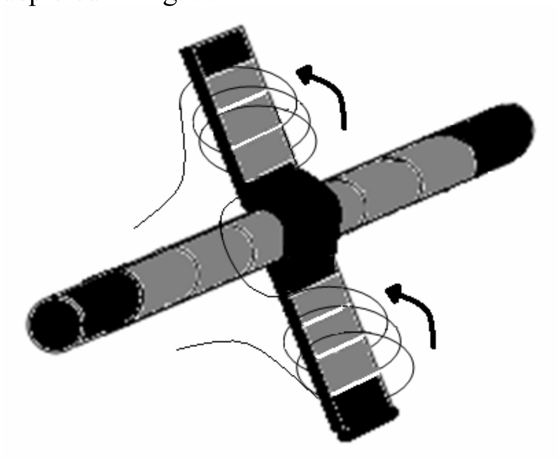

Figure 7. Making the windings of the rotor

To hold the rotor, two identical pieces of 3mm iron sheet were made according to the blueprint depicted on Fig. 9.

Two terminals of the stator windings are connected to a personal computer 12V DC switched power supply. The other two are leaned on the collector. Connections must be made according Fig. 10. Rotor speed can achieve several rotations per second.

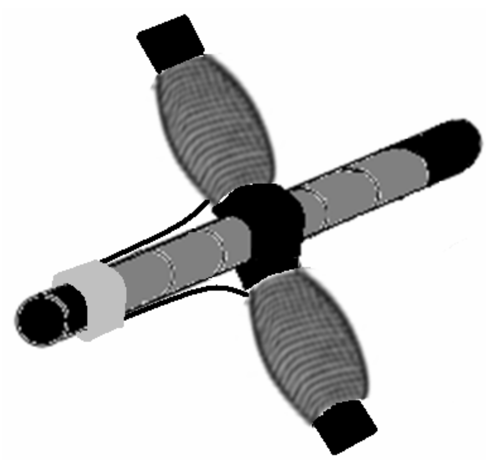

Figure 8. Final aspect of the rotor

4. Motor operation

Feeding the windings of the stator with a constant current originates a constant and uniform magnetic field in the space between the two magnetic poles shown in Fig. 11.

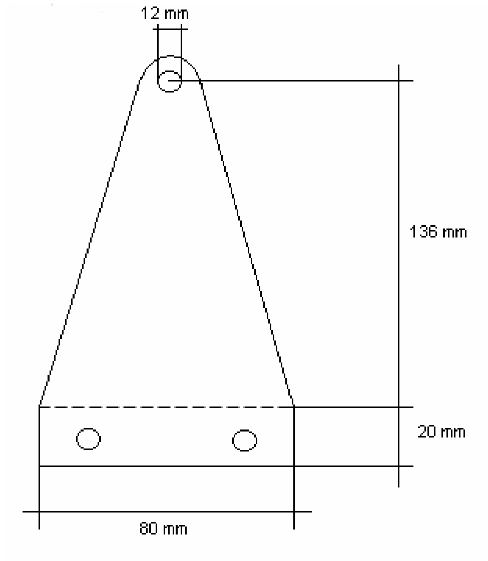

Figure 9. Support of the rotor

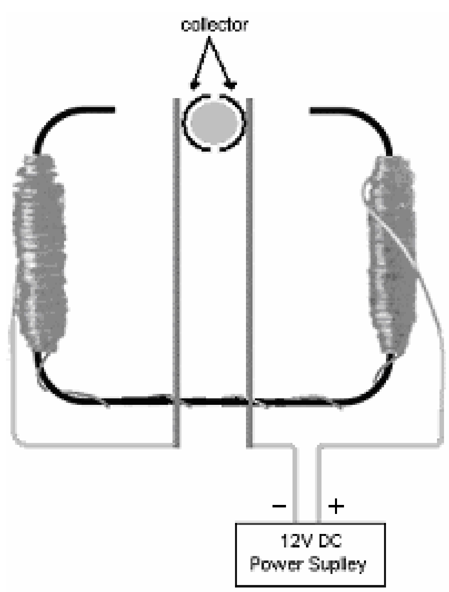

Figure 10. Connections of the stator windings terminals

When the rotor is connected in series with the stator, the current passing in the stator windings flows through the rotor windings, too, creating a second magnetic field around it. Since the rotor is within the magnetic field of the stator, the two fields interact with each other, originating forces that move the rotor. These forces, which determine the sense of rotation of the rotor, are such that opposite poles attract each other and similar poles repeal each other (Fig. 12).

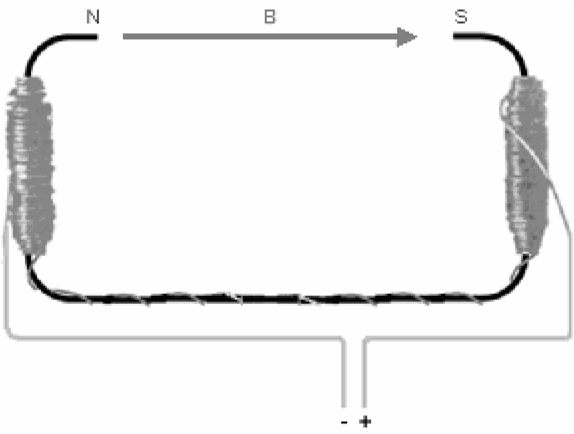

Figure 11. Magnetic field of the stator

When the rotor reaches the position depicted in Fig. 13, the current flowing in its windings falls to zero due to the connections between collector and brushes. There are no forces in this situation. However, the rotor keeps turning due to inertia. Immediately after, its current is re-established but with the opposite direction, which changes the polarity of the magnetic field of the rotor. Forces appear again, keeping the rotor turning in the same direction (Fig. 14). Without the polarity change of the magnetic field of the rotor – which occurs every half turn – the rotor would stop in the position shown in Fig. 13.

5. Conclusions

A handmade universal series motor has been presented. The device, very suitable for science fair events, was built with common materials and can be used to verify Electromagnetism fundamentals that explain the operation of all electric motors. Feeding the motor with 12V DC makes the rotor turn at a speed of several rotations per second.

6. Acknowledgements

The authors are grateful to João Sepúlveda and João Luíz Afonso for the explanations and to Cátia Chamusca for the revising of this paper.

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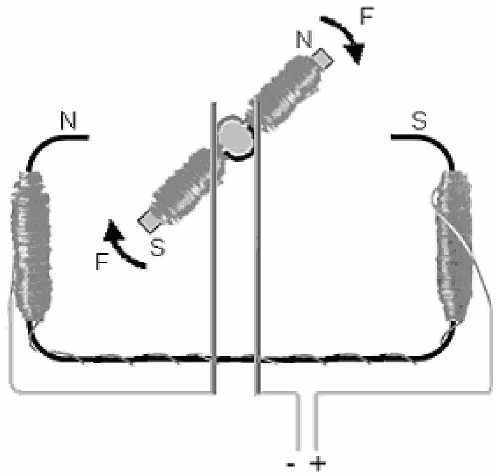

Figure 12. Forces actuating on the rotor

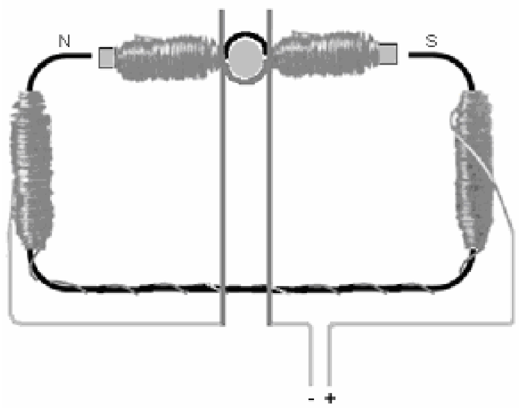

Figure 13. There are no forces actuating on the rotor

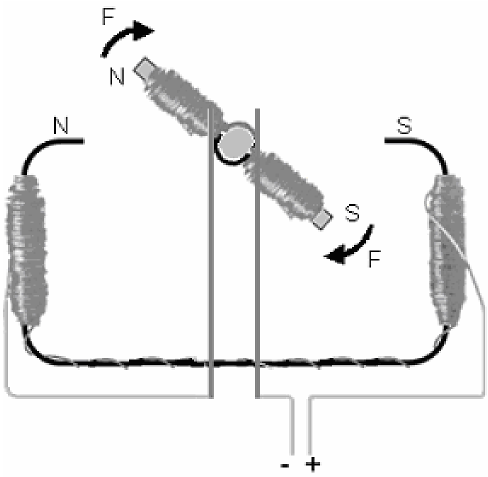

Figure 14. Forces actuating on the rotor after a polarity change of its magnetic field

Slewing Crane With Electromagnet

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Abstract. This paper describes a slewing crane with electromagnet, operated by three three-phase induction motors. A switchboard described in a separate paper, which also depicts the electromagnet construction details, drives the motors and the electromagnet. From its seat – mounted on the crane – an operator can make the crane arm slew left or right. The electromagnet can be moved back, forward, up or down. The crane is made of iron, has a height of 3m and a length of 2,5m. Such proportions make it very suitable for science fair events.

Keywords. Electromagnet, Slewing Crane.

1. Introduction

A slewing crane equipped with an electromagnet is a very useful tool to move ferromagnetic pieces from a place to another. This paper describes such a crane, built for science fair events. Its first public appearance was the *Robótica 2006* festival (Fig. 1). Building this kind of equipment improves construction skills and promotes the study of Electromagnetism fundamentals, such as Biot-Savart's law [1, 2].

2. Crane dimensions and operating details

The crane has a weight of 395 kg, a height of 3m and a length of 2,5m. The base is a 1,20m x 1,20m square. More detailed dimensions are shown in Fig. 2.

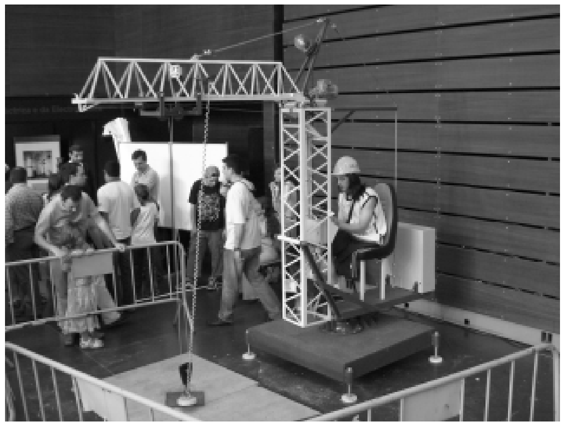

Figure 1. Crane operating at *Robótica 2006* festival

Three three-phase induction motors, each one equipped with a reduction gear, produce the crane movements.

A switchboard located at the rear of the crane controls the motors and the electromagnet. The switchboard and the electromagnet are both described in a separate paper. A control panel is located on the front part of the crane, where the operator has a good view of the pieces to handle. From a comfortable seat (Fig. 2), the operator can make the crane arm slew left or right. The electromagnet can be moved back, forward, up and down (Fig. 3).

For safety reasons, the crane is only allowed to slew within an 180º angle. This results in a working space whose top view has the shape depicted in Fig. 5.

The electromagnet (Fig. 6) and the structure of the crane are strong enough to elevate a weight of 50kg to a height of 2m from the ground.