Current and parallel action

Peng Kuan 彭宽 titang78@gmail.com

5 June 2013

Here is an improved parallel action experiment. In **Theory about parallel action experiment** blogspot academia, I have shown that a coil rotates under a magnetic force parallel to current, which is not predicted by the Lorentz force law. But that experiment did not clearly exclude the action of Lorentz force. The present experiment is designed in such a way that the coil turns in one direction under the parallel action force and in the other direction under the Lorentz force. The experimental result shows that the coil turns in the direction of the parallel action force (see the video https://www.youtube.com/watch?v=8z4UD_4d_Wo).

The setup is shown in the photograph below (Figure 1). The paper arrow attached on the coil indicates the direction of the current. The magnetic field of the magnet is modelized by a loop of equivalent current. The arrows drawn on the magnet indicate the direction of the equivalent current. When the led blinks the current is on and the coil moves. The video shows that the coil is attracted to the magnet when the current in the coil is in the same direction than the nearest equivalent current and repulsed when they are in opposed directions.

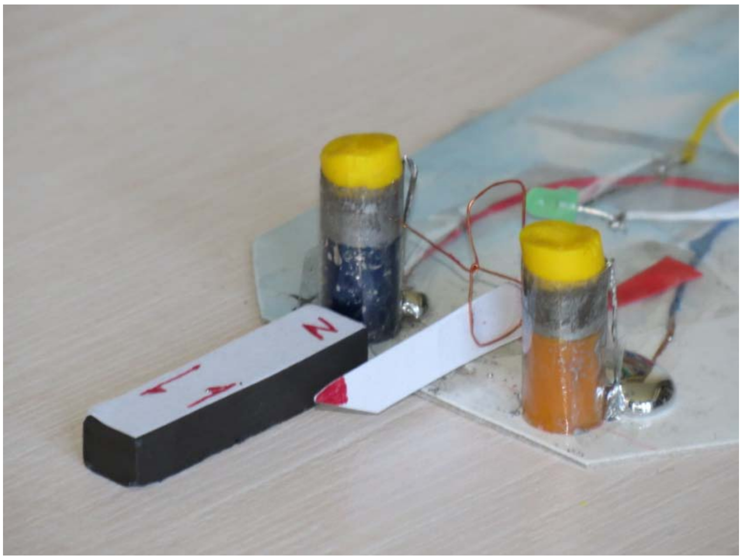

Figure 1

Figure 2 shows the mechanics of magnetic parallel action. The corrected magnetic force law given in **Unknown properties of magnetic force and Lorentz force law** blogspot academia defines the differential Ampere's force as:

$$d\vec{F}_{Ampere} = -\frac{\mu_0}{4\pi}\left(d\vec{I}_1 \cdot d\vec{I}_2\right)\frac{\vec{r}}{r^3} \tag{1}$$

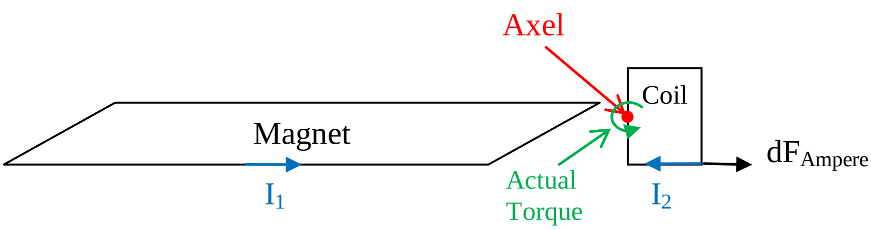

Figure 2

In the above expression, $d\vec{I}_1$ and $d\vec{I}_2$ are 2 current elements, $\vec{r}$ is the radial vector joining them. Ampere's force is opposed to the radial vector $\vec{r}$, meaning that 2 parallel currents attract and 2 opposed currents repulse, as dF_{Ampere} in Figure 2 shows.

Figure 3 shows the action of the Lorentz force. In order to make the Lorentz force pushes the coil in the wished direction, the axel is not situated at the center of the coil, but is attached on the left side.This way the Lorentz force would turn the coil clockwise rather than counter clockwise.

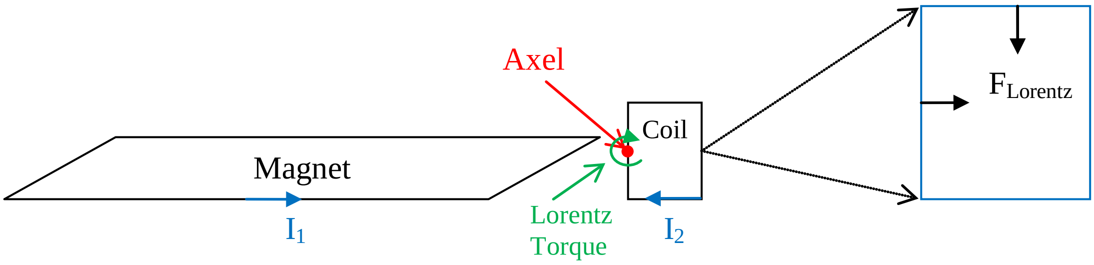

Figure 3

As the video shows that the coil is attracted to the magnet when the current is in the same direction than the nearest equivalent current and repulsed when they are in opposed directions, the prediction of the corrected magnetic force law fits well the experimental result. The prediction of the Lorentz force law contradicts the experiment. We conclude that the corrected magnetic force law is correct and the Lorentz force law is wrong.

The above qualitative explanation is confirmed by the computation of the torques done by the Lorentz force and the parallel action force. An elementary torque about the axel, $d\vec{T}$, is produced by an elementary force $d\vec{F}$ on the lever arm $\vec{L}$:

$$d\vec{T} = \vec{L} \times d\vec{F}$$

The total torque on the coil, $\vec{T}$, is obtained by integrating $d\vec{T}$:

$$\vec{T} = \int_{Coil} \vec{L} \times d\vec{F}$$

The elementary Lorentz force between 2 current elements, $d\vec{I}_1$ and $d\vec{I}_2$, is given by the following equation:

$$d\vec{F}_{Lorentz} = \frac{\mu_0}{4\pi} d\vec{I}_2 \times \left(d\vec{I}_1 \times \frac{\vec{r}}{r^3} \right)$$

So, the expression for the Lorentz torque is:

$$\vec{T}_{Lorentz} = \int_{Coil} \int_{magnet} \vec{L} \times \left(\frac{\mu_0}{4\pi} d\vec{I}_2 \times \left(d\vec{I}_1 \times \frac{\vec{r}}{r^3} \right) \right)$$

The expression for the parallel action torque is the integration of the differential Ampere's force given by equation (1):

$$\vec{T}_{parallel} = \int_{coil} \int_{magnet} -\frac{\mu_0}{4\pi} \left(d\vec{I}_1 \cdot d\vec{I}_2 \right) \frac{\vec{r}}{r^3}$$

The computation was done for the following case:

Magnet size	Coil size	Distance between the magnet and coil	Height of the magnet
5×1	2×1	0.5	0.2

The resulting torques are:

Lorentz torque	Ampère torque
0.1416 10^{-7} N.m	-0.2924 10^{-7} N.m

Figure 4 shows the mathematical model of the magnet and the coil. The arrows indicate the direction of the currents; the red circle is the axel of rotation.

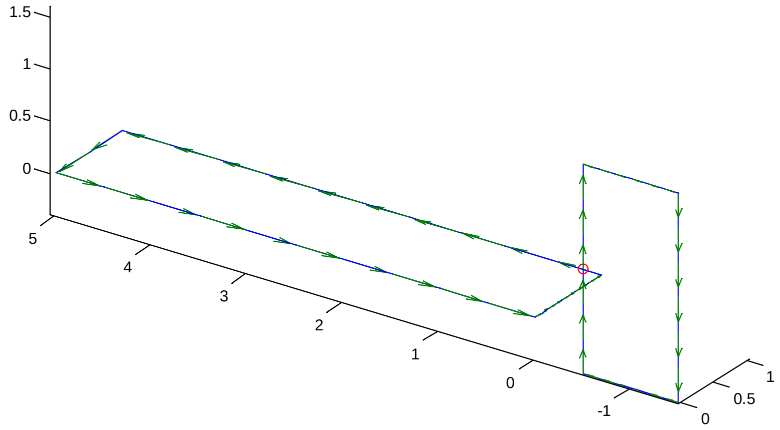

Figure 4

Program of computation executable in Matlab

```
%  parallel action
a=1; % mu/4pi, 100 A et 1 A
crn=[[0;0;0],[1;0;0],[1;1;0],[0;1;0],[0;0;0]];%rect nu
xt=1;yt=5;%taille coil 1
crn(1,:)=xt*crn(1,:);crn(2,:)=yt*crn(2,:);crn(3,:)=0;%position

mp=10;tf1=0:1/mp:1;%i:indice x, f:fix
mp2=2;tf2=0:1/mp2:1;%i:indice x, f:fix
k=1;
s=tf1;sl=crn(:,k+1)*s-crn(:,k)*(s-1);lc=sl;%
s=tf1;k=k+1;sl=crn(:,k+1)*s-crn(:,k)*(s-1);lc=[lc(:,1:length(lc)-1),sl];%
s=tf2;k=k+1;sl=crn(:,k+1)*s-crn(:,k)*(s-1);lc=[lc(:,1:length(lc)-1),sl];%
s=tf1;k=k+1;sl=crn(:,k+1)*s-crn(:,k)*(s-1);lc=[lc(:,1:length(lc)-1),sl];%
m=length(lc)-1;
x1=(lc(:,2:m+1)+lc(:,1:m))/2;dI1=lc(:,2:m+1)-lc(:,1:m);%discret coil 1 rectgl
plot3(lc(1,:),lc(2,:),lc(3,:),'-');hold on
quiver3(lc(1,1:m),lc(2,1:m),lc(3,1:m),dI1(1,:),dI1(2,:),dI1(3,:),0.5)

crn=[[0;0;0],[0;1;0],[0;1;1],[0;0;1],[0;0;0]];%2nd square
xt=0;yt=1;zt=2; %taille coil 2
cx=0;cy=yt*1.5;cz=zt*0.2;%zt/2;%centrer le zero a ce point

centre=[-cx;yt*1.-cy;zt*0.5-cz];c=centre;%centre du couple
crn(1,:)=xt*crn(1,:)-cx;crn(2,:)=yt*crn(2,:)-cy;crn(3,:)=zt*crn(3,:)-cz;%position
k=1;
mp=6;tf1=0:1/mp:1;%i:indice x, f:fix
```

```
s=tf1;sl=crn(:,k+1)*s-crn(:,k)*(s-1);lc=sl;%
k=k+1;sl=crn(:,k+1)*s-crn(:,k)*(s-1);lc=[lc(:,1:length(lc)-1),sl];%
k=k+1;sl=crn(:,k+1)*s-crn(:,k)*(s-1);lc=[lc(:,1:length(lc)-1),sl];%
k=k+1;sl=crn(:,k+1)*s-crn(:,k)*(s-1);lc=[lc(:,1:length(lc)-1),sl];%
n=length(lc)-1;

x2=(lc(:,2:n+1)+lc(:,1:n))/2;dI2=lc(:,2:n+1)-lc(:,1:n);%
plot3(lc(1,:),lc(2,:),lc(3,:),'-',c(1),c(2),c(3),'ro');
quiver3(lc(1,1:n),lc(2,1:n),lc(3,1:n),dI2(1,:),dI2(2,:),dI2(3,:),0.5)
hold off;axis equal;

na=1;%a1=0;a2=0.05;va=(a1:(a2-a1)/na:a2*1.001);%variation

xdisp=zeros(na,3);ddfamp=zeros(3,m,n);ddffic=ddfamp;
dfamp=zeros(3,n);dffic=dfamp;dcplamp=dfamp;dcplfic=dfamp;
for ia=1:na %Variation
%Calcul de force et moment differential
for j=1:n
for i=1:m
r12=x2(:,j)-x1(:,i);vr=r12/norm(r12)^3; %coef rayon
ddfamp(:,i,j)=-dot(dI2(:,j),dI1(:,i))*vr; %diff force ampere
ddffic(:,i,j)=dot(dI2(:,j),vr)*dI1(:,i); %diff force fictive en 2
end
end
% integrals sur le coil 1 pour 1 point du coil 2
for j=1:n
dfamp(:,j)=sum(ddfamp(:,:,j),2);
dffic(:,j)=sum(ddffic(:,:,j),2);
dcplamp(:,j)=cross(x2(:,j)-centre,dfamp(:,j));
dcplfic(:,j)=cross(x2(:,j)-centre,dffic(:,j));
end
% integrals sur tous les points du coil 2
famp=sum(dfamp,2)*a; %force ampere
ffic=sum(dffic,2)*a; %force fictive
cplfamp=sum(dcplamp,2)*a; %couple dampere
cplffic=sum(dcplfic,2)*a; %couple fictive
florentz=famp+ffic; %force de lorentz
cpllorentz=cplfamp+cplffic; %couple de lorentz
end
fcpl=[florentz,famp,cpllorentz,cplfamp]
return
```