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ASYMMETRICAL EDDY CURRENTS AND CONCENTRATION EFFECT OF MAGNETIC FLUX IN A HIGH-SPEED ROTATION DISC

K.Bessho, T.Morisue, S.Yamada, N.Sakai and H.Nishino

Abstract - A new method of generating a high magnetic field is described. The fundamental principle is that the flux induced by an electromagnet is concentrated in the hole surrounded with four high-speed rotating conductive discs and is compressed to a high magnetic flux density. This method requires a relatively small electric source compared with those of previously published or tested because of using the kinetic energy of the rotating discs for concentrating a magnetic flux. The high magnetic field produced in this method has long pulse duration and this method has the feature that it is easy to generate AC high magnetic field by AC excitation

INTRODUCTION

Recently, the progress of material science has required the technical developments of producing extreme physical condition. The high magnetic field, one of the extreme conditions, is very important and attracts much attention because it is closely related with nuclear fusion and plasma physics.

There have been various high magnetic generators such as superconducting magnet and various kinds of pulse magnets with normal conductor. These generators, however, is not so easy to handle and need a large power source. The new generator proposed by the authors can be operated at room temperature and uses a relatively small scale electric power. Therefore, our generator is convenient for various engineering demands.

ASYMMETRICAL EDDY CURRENTS AND CONCENTRATION EFFECT

Let us consider the conductive plate between magnetic pole as shown in Fig.1. It is well known in Fig.2(a) that the distribution of eddy currents induced in a conductive plate is nearly symmetrical. But when a conductive plate moves at high speed, the distribution of eddy currents becomes asymmetrical and the eddy currents which induce the flux against the direction of applied flux occupy the most part of the distribution. Figure 2(b) shows the distribution in this case. It is found from these figures that the distribution of eddy currents for velocity $V=80\text{m/s}$ becomes completely asymmetric. Therefore, the flux passing through a plate decreases in

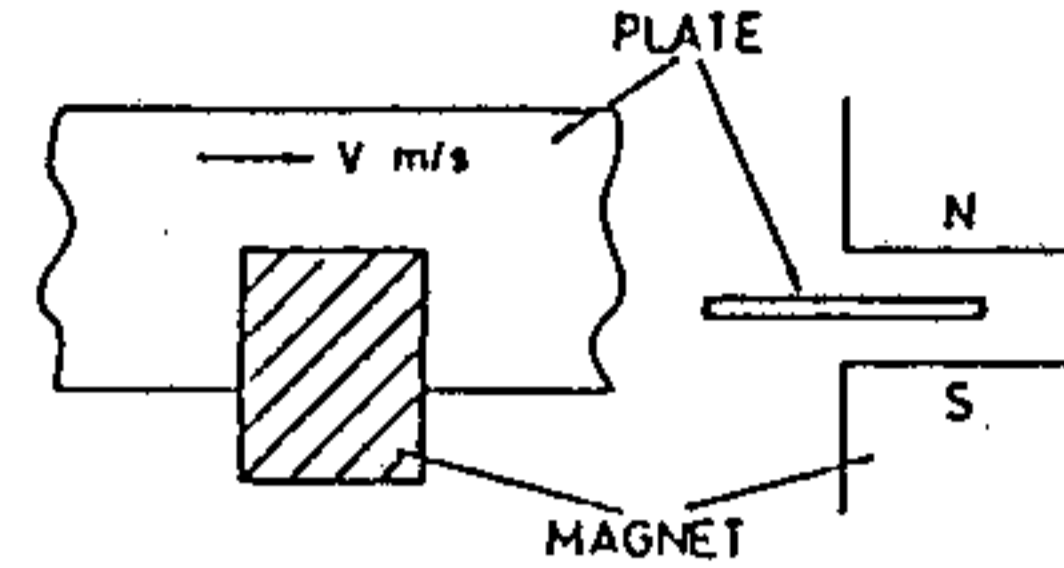
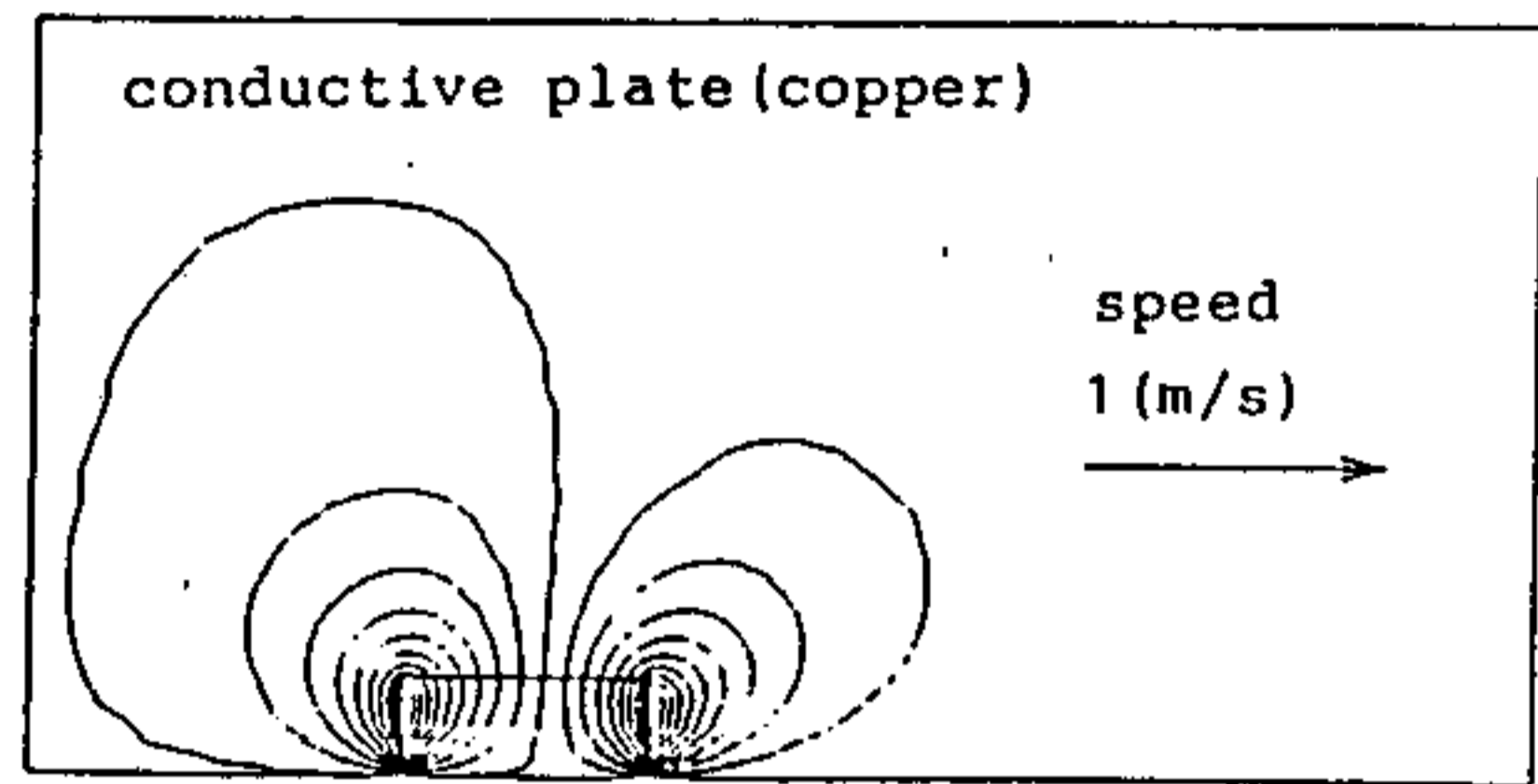
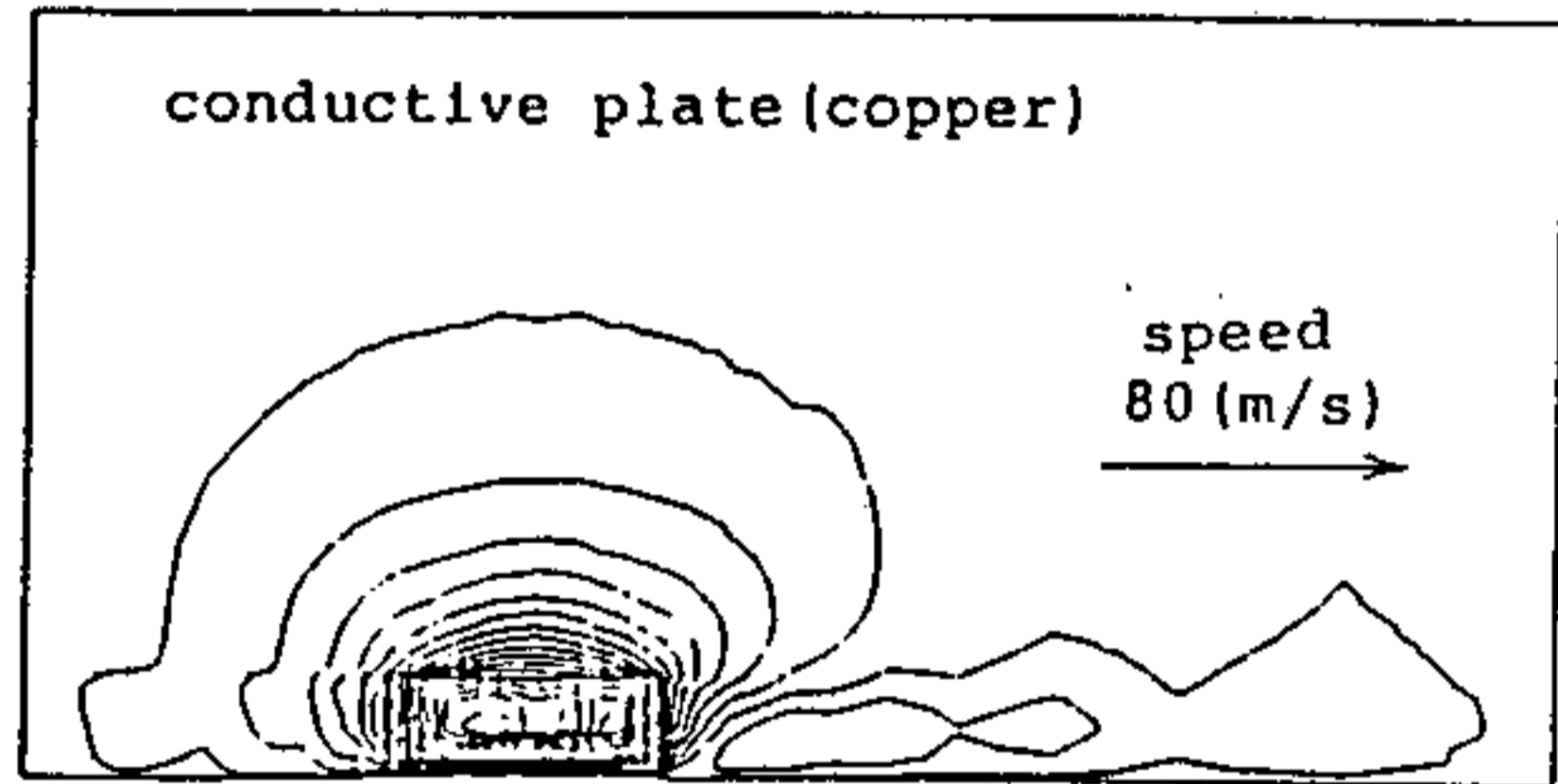


Fig.1 Conductive plate moving between magnetic poles



(a) Velocity $V=1.0\text{ m/s}$



(b) $V=80\text{ m/s}$

Fig.2 Eddy currents in moving plate

proportional to velocity. The conductive plate is apparently shielded from the magnetic field and forces the magnetic flux to flow outside the plate. As a result, the conductive plate acts as a diamagnetic material. The increase of a magnetic storage energy with the change of a flux path is supplied by the kinetic energy of the moving plate.

By arranging the conductive discs as shown in Fig.3 and rotating the discs at high speed, the flux applied by the electromagnet can be concentrated in the air hole composed of four discs and the high magnetic field can be resulted. It should be noticed that the induced eddy current produces a considerable braking force. While the flux is compressed by the discs, the reacting force on the rotating discs acts as a braking force. Therefore, it is necessary to make large discs to keep enough moment of inertia.

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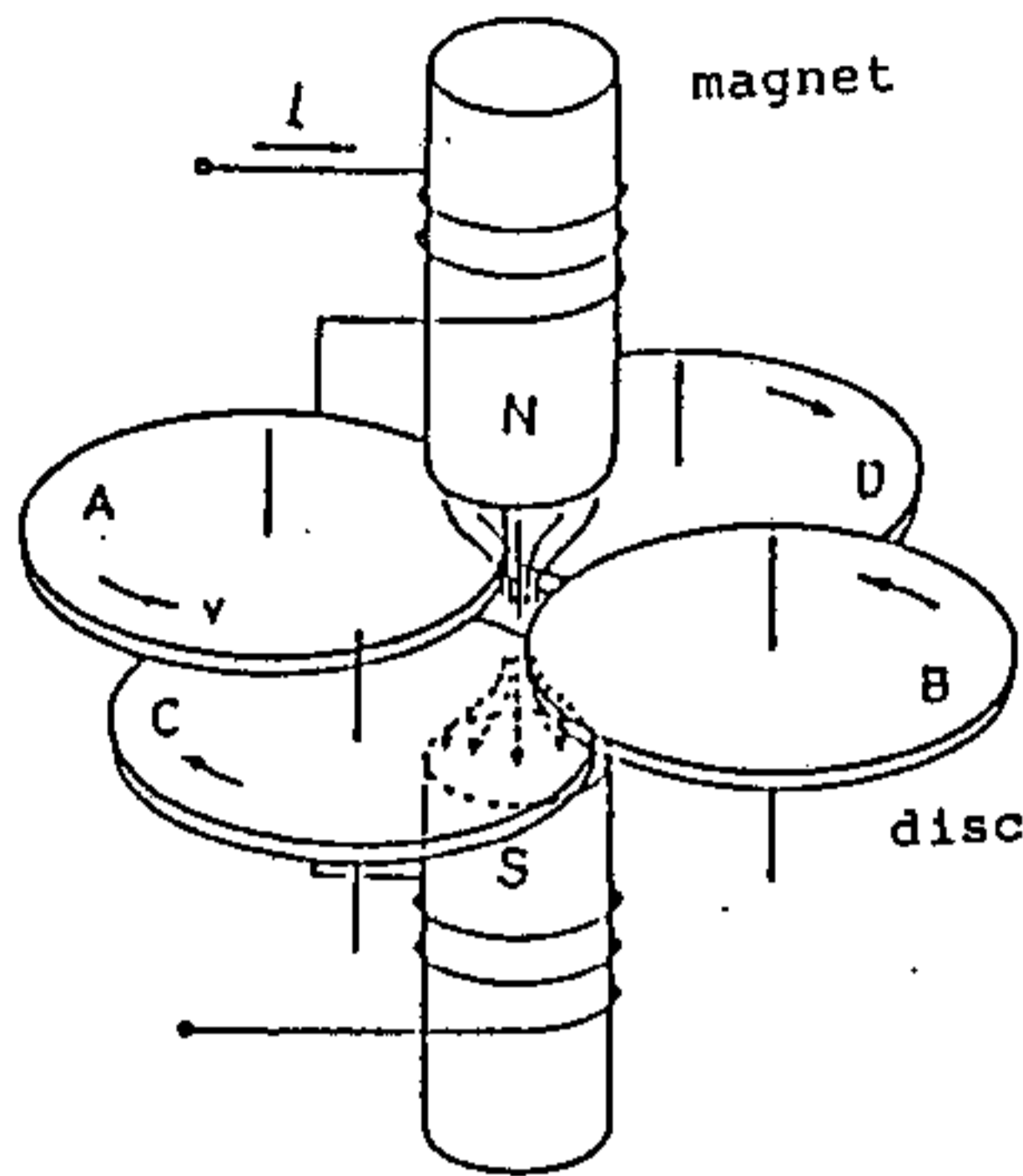


Fig.3 Configuration of the generator

EXPERIMENTAL EQUIPMENT AND RESULTS

Figure 4 shows the tested equipment and this high magnetic field generator under consideration is based on the above theory. An air hole is constructed with four discs between the magnetic poles. The flux applied by the electromagnet is concentrated in the hole and the high magnetic field is generated in it.

The specification of the equipment are;

Electromagnet

Cross section of yoke : $10 \times 10 \text{ cm}^2$
 Number of turns : 300×2 turns
 Exciting current : DC 660 A

Discs

Material : copper
 (15cm width ring)
 Diameter : 51 cm
 Thickness : 2 cm
 Moment of inertia : 1.3 kgm^2
 Maximum rotational speed : 4000 rpm

After the discs are driven to the speed of 4000rpm by induction motors, the motors are disconnected from the discs and an exciting current is applied to an electromagnet. The magnetic flux density in the hole increases and the braking force by eddy currents acts on the discs then the rotating speed of the discs decreases rapidly.

The characteristics of this equipment are shown in Fig.5. When the discs rotate at 4000rpm ($V=107\text{m/s}$ at the edge of the disc) and the exciting current of 660A is applied, the magnetic flux density in the hole rises to 5.8T and then decreases to 2.4T as the discs stop within 0.6s by the braking force. The concentration ratio (the ratio of the concentrated magnetic flux density to the steady magnetic flux density) is 2.4. The flux on the magnetic pole is reduced to 60 percent in quantity for period of the concentration, because a part of the magnetic flux induced by eddy currents flows reversely into the magnetic core. Therefore, we experimented with an air-gaped coil as the

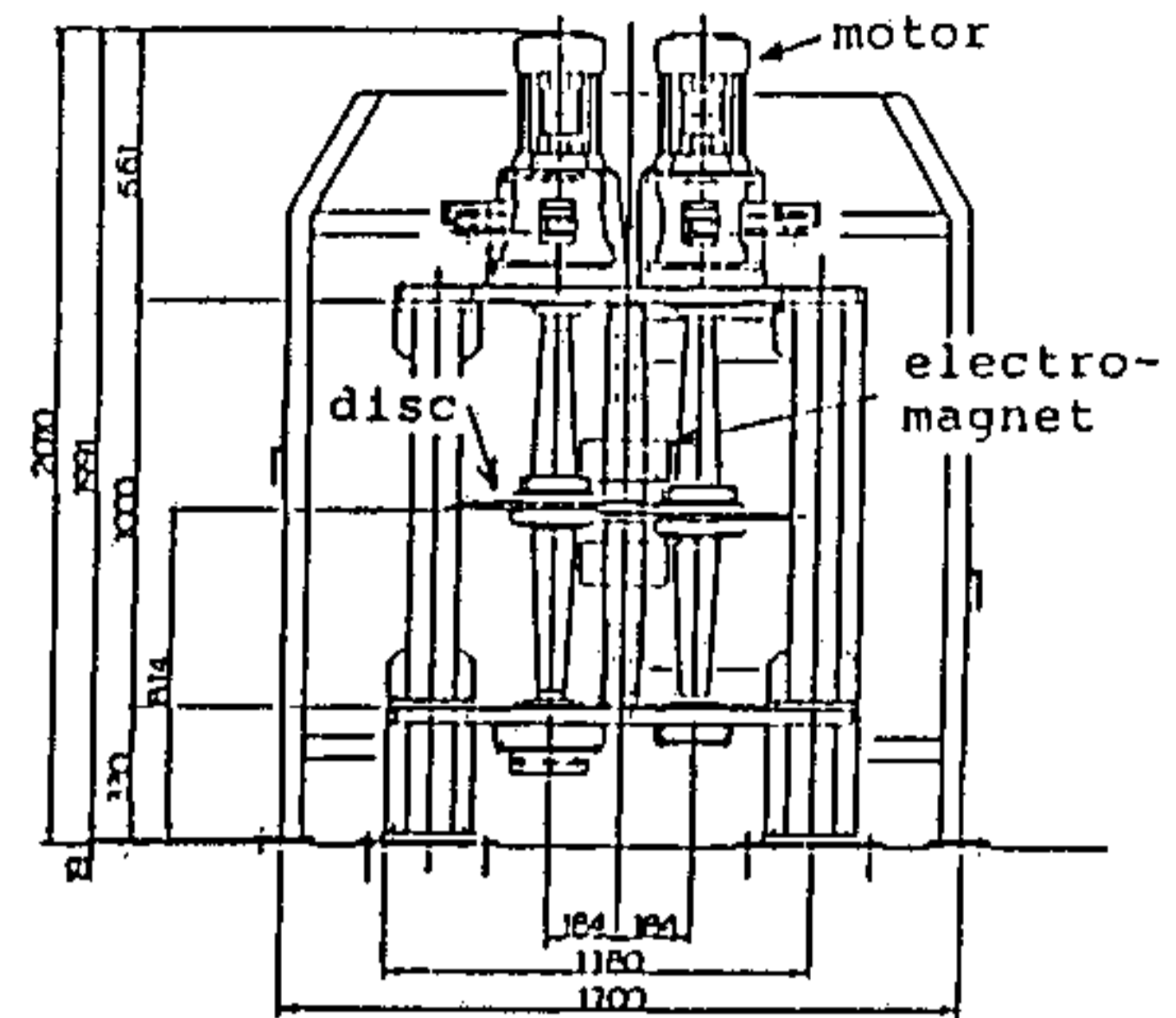


Fig.4 Experimental apparatus

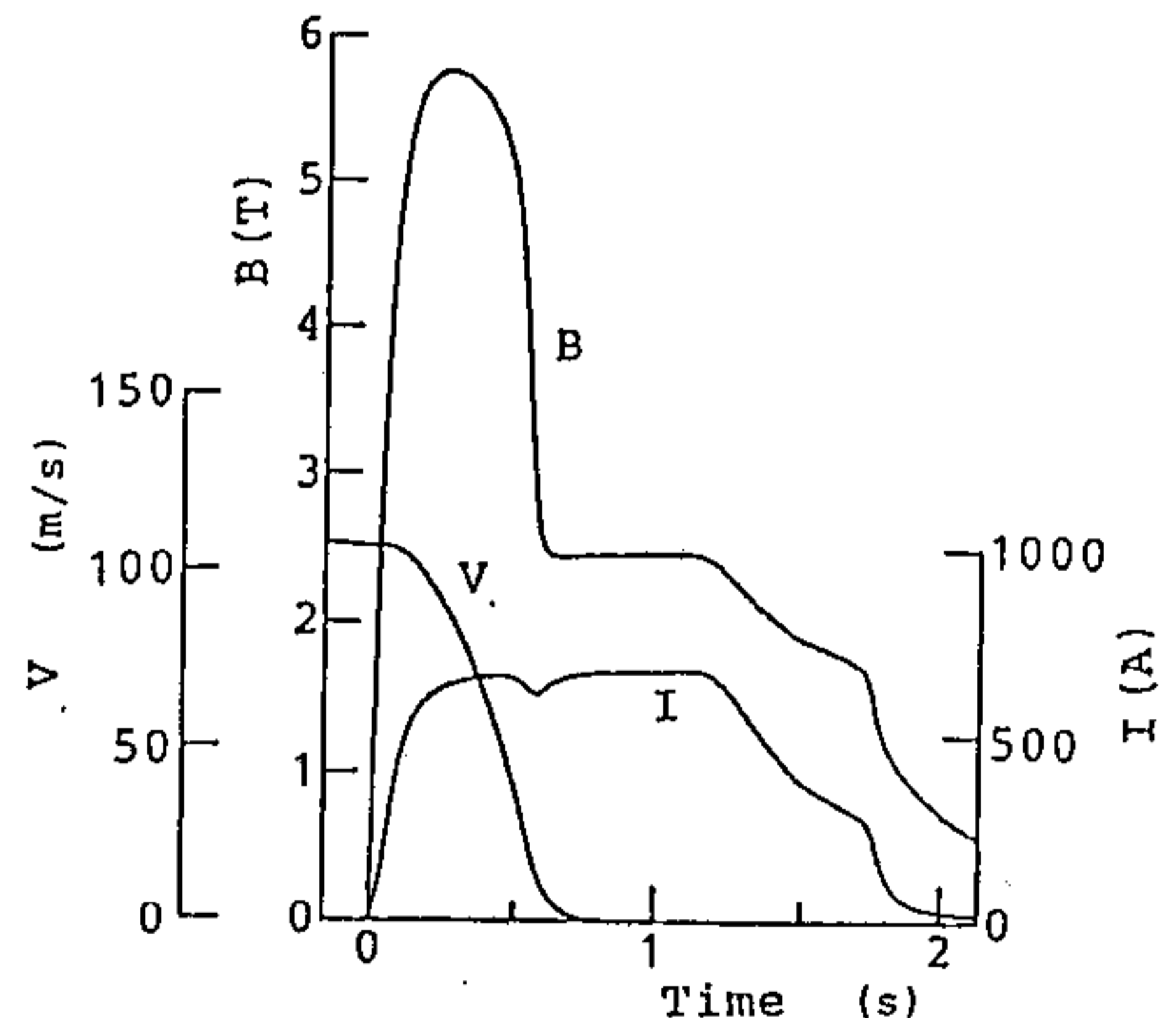


Fig.5 Waveforms of flux density B, speed of disc V and exciting current I in the process of concentration (with iron core)

electromagnet for the purpose of excluding the influence of the magnetic core and improving the concentration ratio.

The results of this experiment is shown in Fig.6. Although the steady magnetic flux density decreases to 0.82T because of using an air-gaped coil, the concentrated magnetic flux density increases to 2.8T and the concentration ratio rose to 3.4.

EXPERIMENTS WITH AC EXCITATION

Figure 7 shows the waveforms of the AC excitation at 3Hz. The electromagnet of the tested equipment has an iron core and the exciting current is supplied by a cycloconverter. The cycloconverter supplies the exciting current with 1-6 Hz to the electromagnet. Figure 8 shows the comparison of the concentration effect as a function of an exciting frequency. The maximum magnetic flux density for each frequency at the period

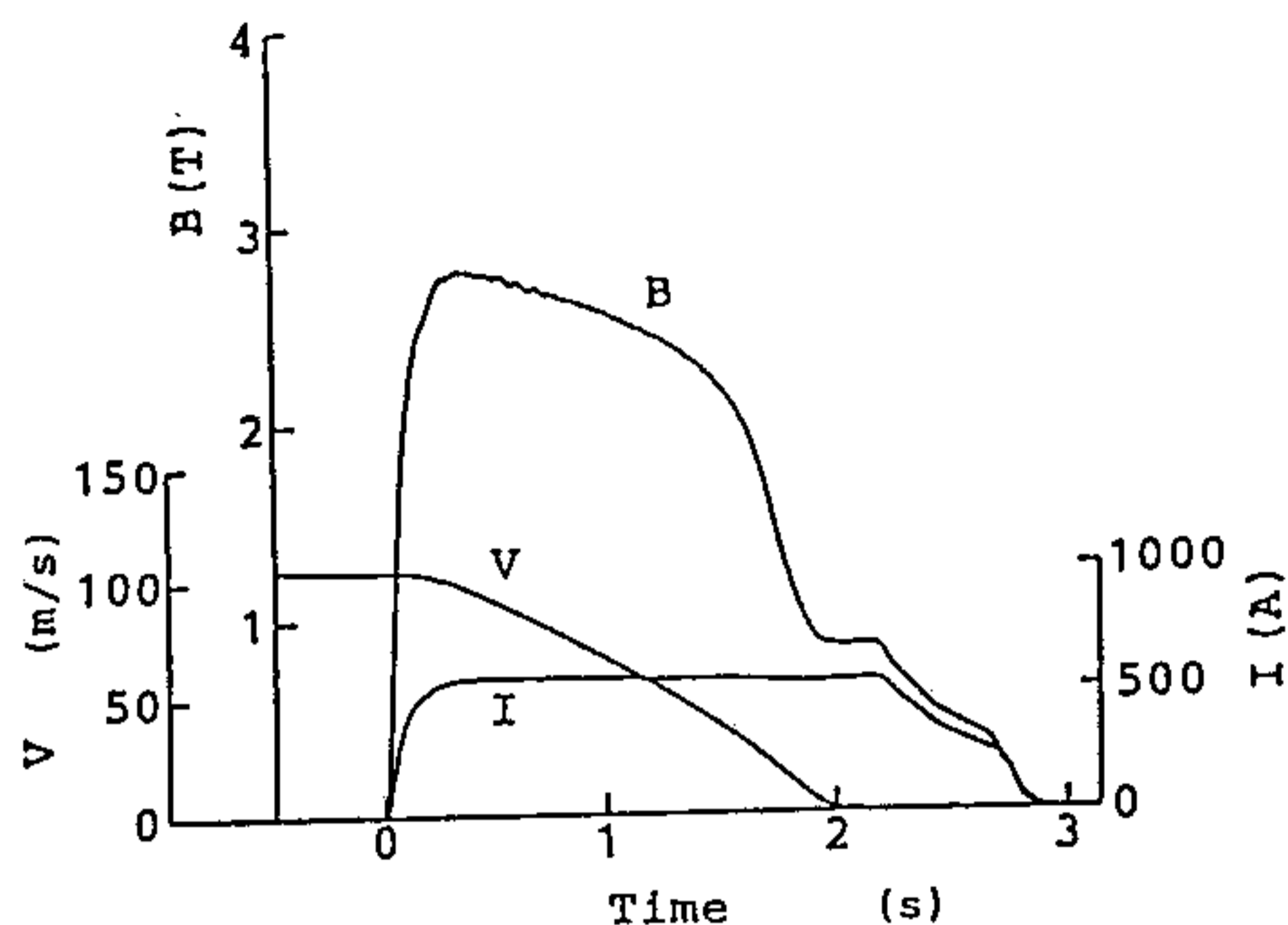


Fig. 6 Waveforms (without iron core)

of concentration is the same but the magnitude changes when the discs stop. Since eddy current effects occur with the AC excitation even at a standstill.

CONCLUSIONS

It has been shown that the magnetic concentration effect exists as a result of eddy currents induced in the conductive disc. Furthermore, the concentration ratio is greater on the excitation of air-gaped coil than that of electromagnet with magnetic core. The experimental results suggest that the magnetic pole must be kept apart from the conductive disc so that the magnetic flux induced by eddy currents does not reversely flow through the yoke of an electromagnet.

The realization of more high magnetic field arises the problem of strength of material. In the advanced equipment, the conductive disc is considered to be made of beryllium-copper which has the high conductivity and the good strength.

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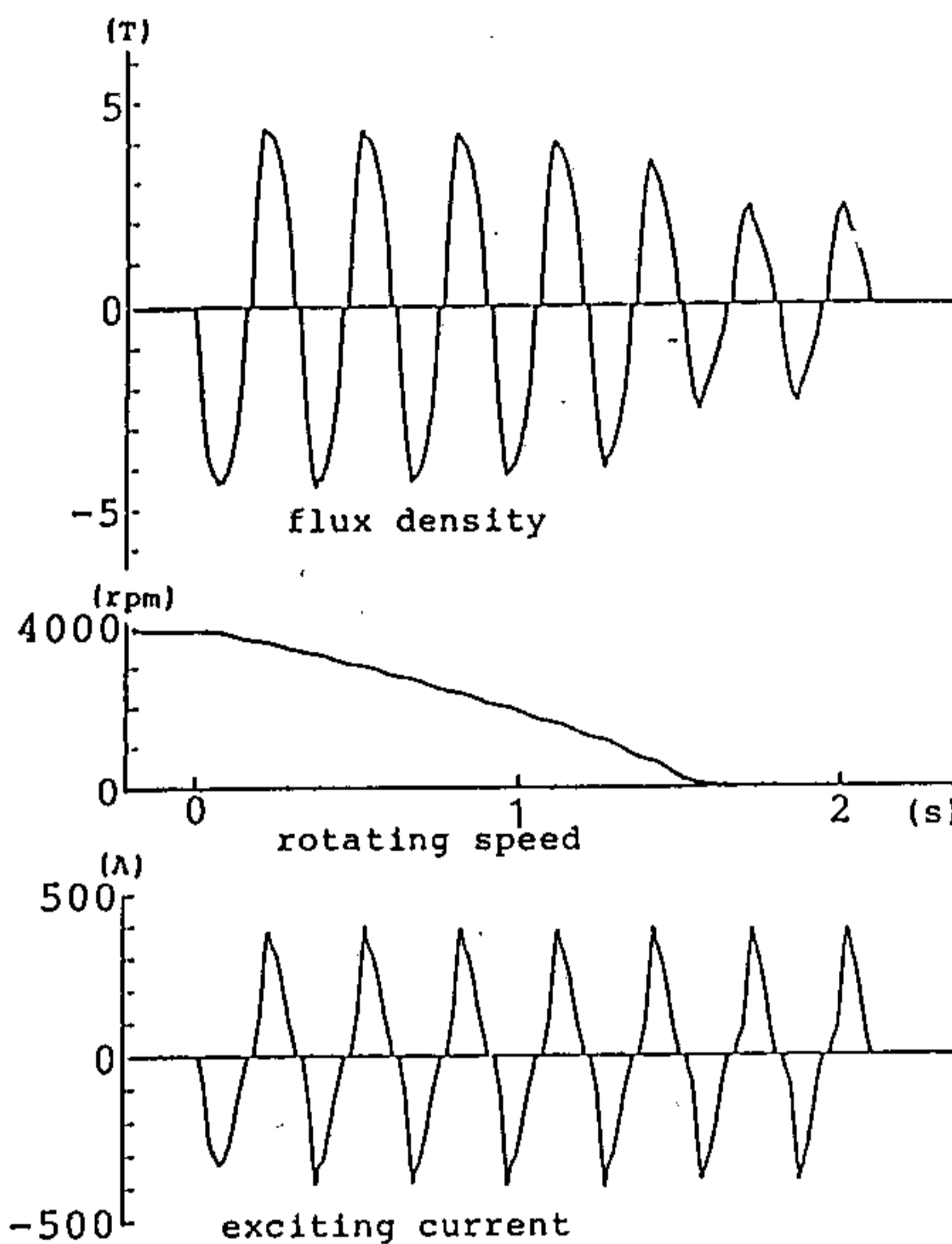


Fig. 7 Concentrated flux at frequency 3 Hz

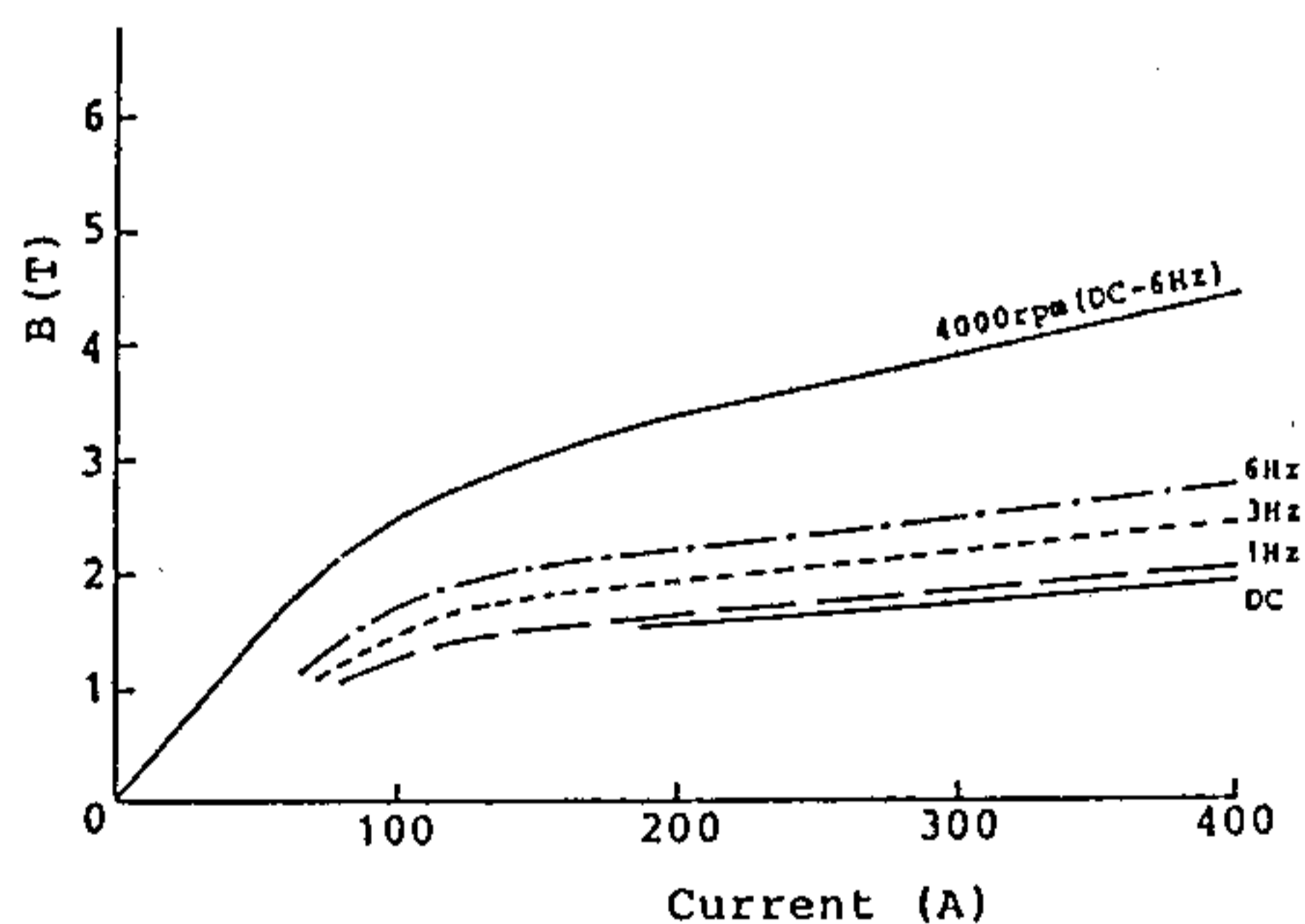


Fig. 8 Relations between concentrated flux and frequency

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