MAGNETIC COMPRESSIVE GENERATORS USING GASEOUS EXPLOSIVE

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ABSTRACT

We present a preliminary experimental compression generator for which the normal solid explosive is replaced by mixture $2\text{H}_2 + \text{O}_2$ at a pressure of 60 bars. A coaxial, conducting structure is formed by an aluminium tube of 92 mm external diameter, 6 mm thick, holding the mixture and placed in a conducting carcase (internal diameter 140 mm). An exploding wire placed axially in the tube initiates the explosion which accelerates the tube radially outwards. The magnetic field initially created by the discharge of a capacitor bank through the coaxial structure is thus compressed by the tube. With an initial current of 0.8 MA, we have obtained 4.75 MA, the energy increasing from 10 to 30 kJ. In this structure, which has the minimum possible dimensions for a conclusive result, flux losses of 50 % have been observed corresponding to theoretical predictions. For larger units a more complex tube structure could be chosen, considerably reducing the losses. With this type of generator, only the tube is destroyed and energies greater than 10 MJ can readily be delivered for a minimum of total cost at a good chemical efficiency. The mixture $2\text{H}_2 + \text{O}_2$ is produced by electrolysis, avoiding the storage of high energy explosives.

INTRODUCTION

At the present time, production of high magnetic energies (a few MJ in a few $10^{-4}$s) is easily done by means of magnetic field compression generators. They all employ solid explosives and they can be used to realise plasma experiments as well as the high energy capacitor banks with short delivery times, but their cost is much lower. Unfortunately, because of its destructive nature, the use of classical explosive driven devices is limited to laboratories having their own explosive facilities.

In this paper, we propose a new type of generator of particularly low cost which can work in a conventional laboratory and we show its feasibility. It uses a gaseous explosive $2\text{H}_2 + \text{O}_2$ which, for the same chemical energy density, is much less destructive than the solid explosives because the exerted pressure is lower but lasts longer.$^{2,3}$

DESCRIPTION OF THE GENERATOR

Figure 1 gives the scheme of the generator.

The liner, a thin cylindrical aluminium tube 1, is coaxial to a cylindrical casing 2. This last one is made of steel and is covered on its inner part by bronze. A gaseous mixture $2\text{H}_2 + \text{O}_2$ under a pressure of 60 bars is contained in the liner closed by 3. The detonation of the explosive is initiated along the axis of the system. The liner is then accelerated by the high pressure exerted by the explosion products and is plastically deformed. If an initial magnetic field exists between the inner and the outer conductors, it will be compressed by the...
exploding liner until the magnetic pressure stops it (when flux losses are limited). The chemical energy of the explosive is thus transformed into kinetic energy of the liner and next into magnetic energy.

The initial magnetic field was chosen to be azimuthal because it is easier to create an axial current in the generator. Furthermore, for a given magnetic energy amplification, the liner stops at a greater distance from the casing when the current is axial; so in that case, the defects in the symmetry of its deformation are of less importance.

MECHANICAL BEHAVIOUR OF THE LINER

In order to achieve the best chemical into kinetic energy transformation, it is obvious that the liner must exhibit a final over initial radius ratio as large as possible, in particular because the polytropic exponent of water vapour is low, about 1.15. Besides, the highest kinetic energy is obtained when the initial pressure of the explosive gas mixture equals to the yield pressure of the liner. In this last condition, the radial velocity does not depend on the dimension of the liner but only on its mechanical characteristics: mass density, stress-strain relation, ductility. For these reasons, we have chosen aluminium liners and have studied experimentally their free radial expansion under explosive loading.

The main results concern the strain at rupture and the marked increase of the hoop stress with strain and strain rate. Fractures appear for a strain $\epsilon / \epsilon_0 \approx 1.5$; for $\dot{\epsilon} = v/r = 5 \times 10^3 \text{s}^{-1}$, the work of plastic deformation is important, it corresponds to a mean stress of about four times the initial hoop stress.

FLUX LOSSES

The conversion of kinetic into magnetic energy is connected to the diffusion of the magnetic field into the conductors.

Due to the symmetry of our coaxial generator, a simple estimation of flux losses is obtained if we assume that the current varies during compression as: $I(r) = I_0 \exp \left( \frac{t}{\tau} \right)$ where the characteristic time $\tau$ can be approximated from the liner velocity. This approach is motivated by the approximatively exponential current increase observed in flux compression devices.

With this approximation, we can replace the classical field-diffusion equations by the formal equations of a L.R. circuit which we can easily solve. So we obtain literal expressions for the flux coefficient $\psi / \psi_0 = \exp \left( t / \tau \right)$ and for the magnetic energy amplification $W / W_0$.

The dimensions of the system are parameters of these expressions, so they are very useful for the design of a generator. They give the increase of $\psi / \psi_0$ and $W / W_0$ with dimensions and show the existence of a smallest dimension to attain an effective magnetic energy amplification.

SIZE OF THE GENERATOR

For the realisation of a first generator we have chosen a sufficiently large system in order to achieve a magnetic energy amplification of three which proves the feasibility of a gaseous explosive driven device, and sufficiently small to be cheap and relatively easy to handle.

This compromise leads to the following dimensions:
- casing: Inner radius: 7 cm
- liner: Inner radius: 4 cm
- Thickness: 6 mm
- Length: 43 cm

PRODUCTION OF THE GASEOUS EXPLOSIVE $\text{H}_2 + \text{O}_2$

The mixture $\text{H}_2 + \text{O}_2$ was produced in place by electrolysis of a solution of potash in a special device made of stainless steel. This device can bear a static pressure of 1200 bars so that it can resist an eventual explosion with an initial pressure of 60 bars; it can be isolated from the volume of the liner by high pressure valves.

In our experiment, the electrical current was furnished by a DC power supply ($2000 \text{A} ; 0-15 \text{V}$). With a 100 Amp current, the volume of the liner was filled in approximately 15 min to the pressure of 60 bars.

This process has revealed to be sure and simple. It needs no storage and manipulation of hydrogen and oxygen under pressure. No untimely explosion has ever been observed.

IGNITION SYSTEM

To initiate the explosion of the mixture $\text{H}_2 + \text{O}_2$ along the axis of the liner, the most convenient device is an exploding wire operated by a condensor bank. However,