IMPROVEMENT OF THE PELLET CHAINS IN THE TANDEM ACCELERATOR LABORATORY OF KYUSHU UNIVERSITY

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ABSTRACT

We wish to report the recent imporvement of our pellet chain system, which has been originally developed in the electrostatic accelerator labolatory of Kyushu University.

INTRODUCTION

An original charging device named pellet-chain has been developed in the electrostatic accelerator laboratory of Kyushu University since 1962. This pellet chain and electrostatic charge induction system had been expected to attain more stable operation for high voltage generation compared to ordinary insulator and belts and corona spray charging systems.

In the pellet chain of the Kyushu University, stainless steel pellets of cylindrical shape are fixed on a long flexible insulator cord with equal spacing. This structure is of an ideal form for the protection of inner insulator materials from electric surges in the case of breakdown of the high voltage generator.

This chain system was first used in the Van de Graaff Accelerator of Kyushu University for the test purpose. After many trials for the pellet chain and its operation system, an excellent performance of generation 8.9MV had been obtained at 1970[1].

This is the first accelerator using the pellet chain in the world.

At this stage, the pellet chain used neoplane rubber coated polyester string as an insulation cord, and 10mmϕ×6mm stainless steel pellets were arranged on the cord using spacers of the polyurethan sleeves.

Construction of 10MV tandem accelerator has been made in this laboratory in the years of 1972-1980.

This accelerator was designed to be a very high field gradient machine, and hence the pellet chain system was used as a charging device.

The performance of our pellet chain is due to the excellent property of polyurethan which is used as the constituent material of insulator portion.

The pellet chain, shown in Fig.1, had achieved a stable operation under the voltage gradient of 1MV/30cm in a compact 1MV test generator, and finally it became possible to generate 11MV in the tandem accelerator with an insulation stack of the length of 5m at 1981[3].

PELLET CHAIN

The sizes of our stainless steel pellets have been gradually enlarged from 8mmϕ to 20 mmϕ, with an improved technique of fabrication from the very beginning to the present time. The center fiber string cord of 3mm in width is coated by the thermo-plastic polyurethan. This insulator cord is fabricated in this laboratory with a special extrusion molding machine.

The dielectric strength of this urethan-cord had been tested for various conditions. It was confirmed that the urethan-cord had a sufficient insulating strength for the use in the tandem accelerator, so far as it is kept in a completely dryed condition before being mounted on the accelerator, otherwise the insulation of the center cord apt to breakdown in the high field of the tandem accelerator. This breakdown found to occur along the boundary layer between of the center polyester string and the urethan sheath.

For fixing of pellets on the cord, melted polyurethan is injected into the inside of each pellet, and fuses with the surface of the center cord as shown in Fig.1.

About three years ago, design change of the pellet chain had been performed for improving the former model of Fig.1. This presently working model is shown in Fig.2. The main improvements are as follows.

1. Size of the pellet is enlarged to 20mmϕ×20 mm. By this larger pellet size, fusing area of the injected urethan to the center cord can be substantially increased.
2. The connector of the chain is designed to attain the more strong structure, see Fig.2. This connector section was the most troublesome portion of the past chain structure.
3. The metal partitions which form the cavity for injection of melted polyurethan (cf. Fig.1) are replaced with those made of the same polyurethan materials as injected one. The pellet chain becomes very simple in the structure and has attained both the machanical and the electrical strengths. This change brings about a great profit of reducing the weight of the pellet chain, which is very important to get a stable operation of the chain.
4. The charge-carrying capability is increased by about 40% due to the enlargement of the pellet size. By this increase only two chains are needed for generating 10MV on the tandem accelerator.

Table 1. shows the main feature of both the 15mmϕ and 20mmϕ chains.

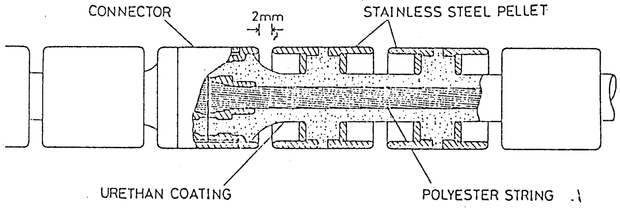


Fig.1. 15mmϕ pellet chain

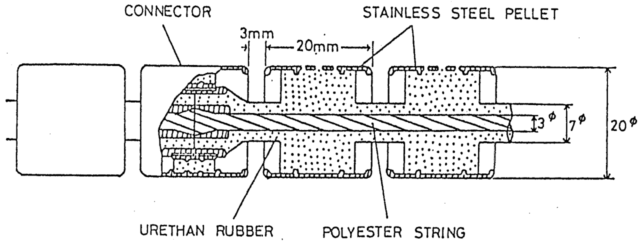


Fig.2. 20mmϕ pellet chain

CHAIN DRIVING SYSTEM

The driving of the pellet chain is greatly simplified owing to the strong damping of lateral vibration in the atomosphere of the high pressure SF_6 gas. Usually the amplitude of vibration is reduced down to a few mm. The situation is not largely changed in the horizontal tandem compared to that of the vertical machine. However, the construction of the pellet chain and the driving wheel mechamism should be well designed and machined in order to avoid unnecessary shocks to the moving chain. Uniformity of the weight along the chain and centering of the position of the fiber string in the center cord are fairly important. For the driving system the accuracy of centering of each wheel and the alignment of various pulleys placed at different portions in the system are essentially important. Some provisions for damping of vibration and also the tension adjusting mechanism are necessary. The running speed of the chain has to be finely adjust so as to avoid the resonance points of the lateral vibration, since the speed of the chain give a considerable influence on the vibrational frequency.

Fig.3 indicates the chain driving system which is presently used in the tandem of Kyushu University. The driving system consist of five 250mmϕ pulleys, six 100mmϕ guide rollers, two inductor electrodes, two corona suppressor electrodes and a tension adjusting device.

The charge inductors are set one at the base and another at the cebter terminal, and the electric charge with a proportional value to the voltage of the inductor electrode is induced to the pellets through the inductor pulley, and is carryed to the opposit electrodes of the tandem and then it trasfered to the earthing pulley without corona discharge due to the guiding field by the corona suppressor electrode.

The terminal voltage of the tandem accelerator has quick response to a change of the charge density on the chain , which is just leaving the terminal electrode. This fact is used for the feedback control system of the terminal voltage stabilizer (down charge control). For minimizing the time delay of this control system, the terminal inductor is placed near to the exit point of the down-chain as close as possible, and the potential of the inductor pulley is modulated by the feedback error signal.

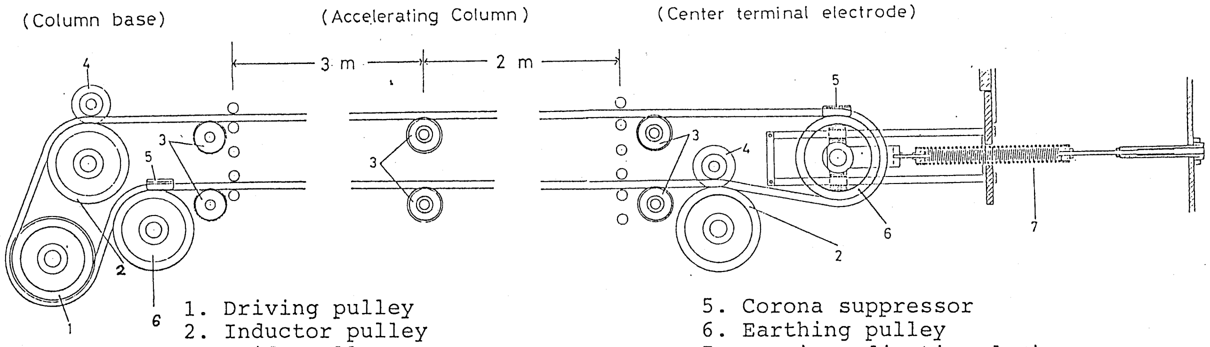
The all pulleys except for the driving pulley have the attachment of the conductive polyurethan wheels. The wheel of the driving pulley and the guide rollers are made of the normal insulator polyurethan rubber. The conductive polyurethan makes from a thermosetting type polyurethan and a graphite powder. Its electric resistivity can take a value for a wide range by charging the mixing ratio of the graphite. In the present purpose, mixing of the 15% graphite gives enough conductivity for the time constant of the charge transfer. This conductive rubber has rather better durability for wearing by the metal friction compared with the normal polyurethan. The chain mounted on the driving system is toughing only these polyurethan materials, so that this system has been operated with no production of a metalic dust. The tension pulley is placed in the center terminal electrode and tension to each pellet chain can be adjusted independently.

Normally the pellet chain is operated with a tension of the strength of 20kg.w. Originally the tension pulley is placed at the tank base, but it was found that with the large size pellet chain (20mmϕ) the unbalance of the tension was generated between the up chain and down chain in the SF_6 gas. So that it became difficult to find driving speed with which both the up- and down-chains are stable.

The charging current per one chain, including up- and down-chains is limited about 120μA at this moment. This limitation is produced by the instability of the chain vibration whence the amount of charge approaches to a some level, depending on the running speed and the magnitude of the tension, where the vibrational frequency goes to zero.

NEXT PLAN OF THE PELLET CHAIN

Although our current chain seems to have a long enough working life, we presume that after the operation of several thousand hours, the 3ϕ polyester string may be getting weakened by the continuated mutual rubbing of the polyester fiber during the driving operation and finally the chain will be cut off. If a thinner string can be used for the center cord, the damage by rubbing motion should be reduced and the more longlife will be attained.



1. Driving pulley
2. Inductor pulley
3. Guide roller
4. Inductor electrode
5. Corona suppressor
6. Earthing pulley
7. Tension adjusting device

Fig.3. Chain driving system

Recently an excellent string material called "PHILLYSTRAN"* becomes available, which is a polyurethan impregnated strand of "KEVLAR" fiber. KEVLAR is a famous DuPont's aramid synthetic fiber, which has a very high strength (about three times of polgester fiber), a low elongation and a high insulation strength etc. The PHILLYSTRAN string seems very suitable for the use of the chain-cord, because it is strengthened for bending by the urethan impregnation, and the string can be thinned to about one third of the present string by its intrinsic high strength for tension. Presently we have been started to fabricate the pellet-chains using KEVLAR (PHILLYSTRAN) string.

* Philadelphia Resins Corporation (USA)

REFERENCES

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Table 1

Size of pellet	15mmϕ×15mmϕ	20mmϕ×20mmϕ
Linear density of the chain	480g/m	500g/m
Total length of the chain loop	14.6m	14.2m
Tension on the chain	15Kg	20Kg
Driving speed of the chain	15.7m/sec	16m/sec
Diameter of the driving pulley	25cm	25cm
Charging efficiency of the inductor (per inductor)	1.2μA/KV	1.5μA/KV
Maximum inductor voltage	~40KV	~45KV
Charging current capacity (per chain)	~80 A	120 A
Ripple of the terminal voltage (peal to peak/terminal voltage)	$\sim 10^{-5}$	$\sim 10^{-5}$
Amplitude of vibration of the chain in the middle portion	a few mm	a few mm