TECHNOLOGY FOR PRODUCTION OF AMORPHOUS ALLOYS LARGE SCALE CORES

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Abstract

High average power pulsed accelerators are enabling the potential use of high peak power technology in a number of different industrial application areas such as material processing, food processing, stack gas cleanup and the destruction of organic contaminants etc.

The development and commercial availability of amorphous alloys allowed the development of new class of short pulse duration, high peak current, high average power accelerator that is capable of efficient repetitive operation up to 10^4 pps (pulses per second) using semiconductors, thyratrons and saturable core magnetic switches. The saturable switches are now employed in high current, high average power systems, such as CLIA, TBA and COBRA accelerators and others. It is known, that optimum magnetic properties of amorphous alloys for use with high dB/dt applications are achieved only with core annealing. With increasing magnetization rates there are increase interlaminar voltage and core loss (cause by interlaminar eddy currents). Ribbon for such cores have to be coated with interlaminar insulation coating. As a rule, manufacturers of large scale cores use amorphous alloys (2605SC, 2605CO or 2705 METGLAS™) without annealing, but with interlaminar insulation (mylar or special paper). With such technology core has high interlaminar break voltage, but nonoptimal magnetic properties: - induction Bm, squareness ratio B_r/B_s (SR), pack factor (PF) and increased losses.

The paper addresses the spesialists associated with development and manufacturing efficient (low loss), most compact, inexpensive and reliable cores with inorganic insulation coating, for magnetic pulse compression circuit (MPC), magnetic switches (MS), inductors for linear accelerators (ILA), high voltage pulse transformers (HVPT), pulse power transformer (PPT) etc.

1 INTRODUCTION

With creation of pulse high-power accelerators the rather important role is connected with technological aspects of cores manufacturing. The magnetic cores of powerful accelerators can have the rather large sizes and weight. High induction B_s, squareness ratio B_r/B_s, high pack factor, insulation coating with the high electrical characteristics, low losses - there are the main requirements for cores manufacturing technology. The important influence have also other reasons: cost efficiency, availability of simple in maintenance equipment for cores manufacturing with high output, possibility of automation, low power consumption, ecological safety etc.

At present, [1,2,3,4] toroidal configuration cores with size range from 130×50 mm to 1500×800 mm (OD×ID), wounded with an insulating layer of mylar or special paper and are exclusively used **without annealing or thermomagnetic treatment** (TMT). There are also data in [2] about annealing ribbon (obviously below 300°C) before wounding. For the technology of core manufacturing with TMT and insulation coating there are severe restrictions for materials, which can be used as insulation - a high heat distortion of arround 450°C, high heat conductivity, possibility to change coating thickness, high electrical characteristics of insulation coating, strong adhesion, thermal expansion (TE) of coating must be the same or closed to TE of amorphous alloys under winding. These restrictions badly complicate the design of such technology, especially for large-sized cores. By the literature [1... 7] in high average power systems are mainly used the magnetic cores with the characteristics, appropriate to magnetic properties a ribbon of amorphous alloys "as cast", i.e. B_{max}=1.2-1.3 T (with H=80A/m), squareness ratio SR= 0.5-0.7. Obviously, that squareness ratio and losses of ready cores are far from those values, which can be obtained with TMT (for a longitudinal magnetic field).

2 SHORT TECHNOLOGY DESCRIPTION

Technological prosesses of winding large scale cores from amorphous alloys with applying insulation coating and computer aided TMT have been developed in Moscow radiotechnical institute (MRTI) of Russian Academy of Sciences. The equipment for manufacturing cores from amorphous Fe-base alloys (with high Curie temperature) with a minimum ID from 25 mm, maximum OD up to 600 mm and width of a ribbon up to 50 mm was made. The main features of the developed technology are following: - additional ribbon cleaning, applying insulation coating in special bath with insulation solution (modified Na liquid glass), preliminary drying in special vertical tunnel, check quality of coating and finally - winding. The winding is carried out with tension beforehand given and supported with high accuracy by the special servosystem. All this processes are carried out on special mashine, developed in ÌRTI and shown on Figure 1. The mashine for core winding works, as a rule, act in a semi-automatic mode, the interference of an operator is necessary only in case of ribbon breakaway or abnormal disconnecting (bad quality of insulation etc.). After winding and preliminary control of insulation quality the cores are located in special furnace for annealing (TMT).

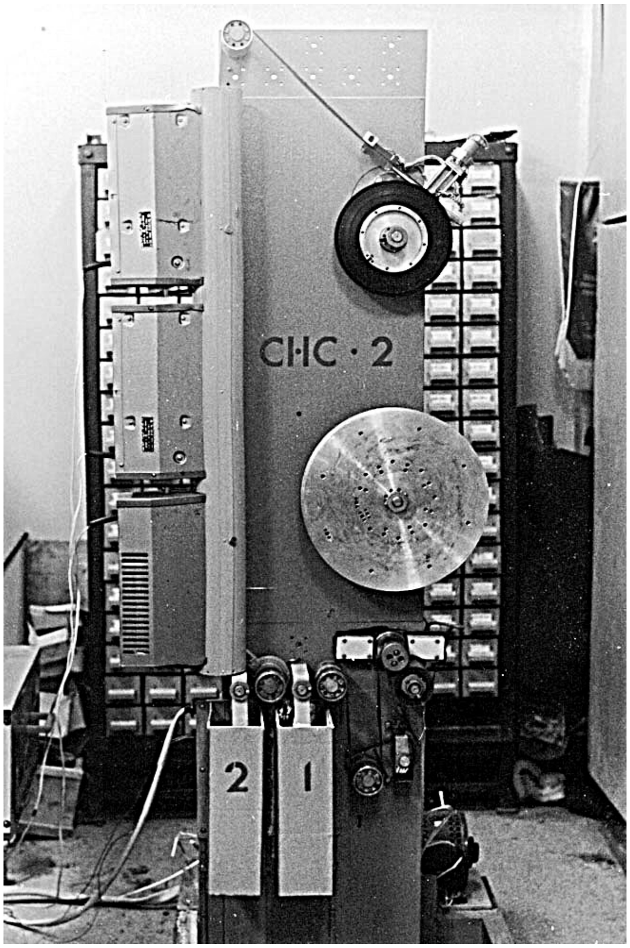

Figure: 1 The mashine for core winding works.

The main features of furnace, that is shown on Figure 2, are following: amount of cores for contemporary annealing up to 4, automatic loading and unloading mode, computer control modes of TMT, possibility of

Figure: 2 The furnace for cores with OD up to 700mm.

annealing (and cooling) with longitudinal field (up to 2500 A/m for cores with OD up to 500 mm).

With PC aid operator, through the special interface chooses a mode of TMT and a program of the measurements of current values, the main magnetic and other core characteristics. Some factors are taken into account for speed of heating and finite temperature: brand of alloy, presence or absence of insulation coating, amount of contemporary anneling cores, size or weight of core(s). Intermediate temperature platform with temporary hold-up are availability. Uninterrupted, during the TMT process mesurement core′s magnetic characteristics and the speed and sign of their changes, allow (using specially developed algorithm) to reach optimal magnetic core properties for power pulse applications.

3 THE REACHED RESULTS

Computer aided TMT and insulation coating make possibility to provide minimum of H_c, maximum of B_m, high SR B_r/B_s (0.9-0.95) and rather high μ_{eff} (for dB/dt up to 30T/mksec), low loss. The technology allows also to use inexpensive amorphous Fe base alloys with small Co contents (about 9 %) and to reach parameters compared to parameters of cores, made from more expensive alloys.

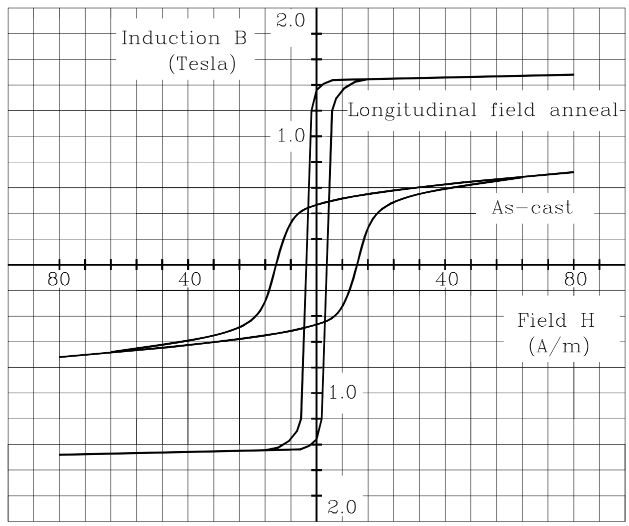

Figure: 3 Typical quasistatic (50 Hz) hysteresis loops for alloy 9KCP.

The method of applying of insulation coating provides thickness of coating layer from approximately 0.2mkm up to 3mkm and its value depends on smoothing of ribbon surface and magnetization rate dB/dt (pulse duration). Electrical characteristics of insulation after core annealing (up to 450°C): $\rho=10^{7}-10^{15}$Ohm$\times$m, break-down voltage =15-30V/mkm. Correlation coefficients between B_r, winding tension, PF and between break-down voltage, coating thickness, PF has been founded. It allows to achieve high output suitable cores with given properties and dispersion not exceeding 10%. Such technology is espesially suitable for researche and optimization of TMT modes for cores with different sizes and weights, with or without insulation coating.

With the purpose of saving high values of the core magnetic characteristics and also for elimination or weakening of influence on the annealed core mechanical stresses and/or climatic conditions, at once after TMT and preliminary test measurements the core covers over special silicon compound with temporary and thermal shrinkage closed to zero. This process can be carry out under vacuum. After full hardening (within 72 hours) the check cycle of measurements of ready core are carried out (50Hz and pulse). The results of this measurements are write to computer′s memory in form of label, with the indication of core number, dimensions, weight, brand of alloy, conditions of measurements and all main characteristics (including view of a hysteresys loop with different values of a field). The characteristics of cores from different alloys are formed in Table 1.

	30KCP after TMT	9KCP after TMT	2605SC as cast	2605CO as cast
B, T 80A/m	>1.5	>1.45	<0.7	<1.2
SR 80A/m	>0.95	>0.92	<0.6	<0.9
B, T 800A/m	>1.56	>1.56	<1.3	<1.3
SR 800A/m	>0.92	>0.9	<0.5	<0.7-0.8
PF	>0.7	>0.7	<0.7	<0.7

Table 1: The static core characteristics from differrent alloys.

The data of alloys 2605SC, 2605CO are taken from [1,2,5,6].

The measurement of the pulse characteristics of cores was carried out in 1-cosine voltage saturation mode on the specially developed device with the following parameters: U_{max} = 40 kV, f = 800 kHz, r = 2 Ohm.

4 CONCLUSION

About 1500 kg cores with different weights (ID×OD from 25×50 up to 460×220 mm) was manufactured during 1994-1996. The export order on cores for the accelerator similar to the CLIA was executed. Also cores for the pulse modulator (report is represented on this conference) was manufactured. The assemblage of the accelerator for delivery on export comes to an end, the cores was produced after described technology. In the whole technology has shown the reliability, stability and rather high output of suitable products (cores). The economic index of technology also are rather high. Unfortunately a thickness of a ribbon and its quality (stability of properties, geometry and especially quality of a surface) do not allow to realize all advantages of considered technology.

In the further it is planned:

- to carry out experiments on additional processing of a ribbon (polishing and purge off a thin surface defect layer) and use thin ribbon (13-18 mkm), that will allow to use cores from such ribbon with pulse duration up to 50 nsec;
- to use for core manufacture nanocrystalline alloys with low saturation magnetostriction and low μ_{sat}.

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