Professional Grade Soft Ferrites For Welding Power Sources (Inverter Type)

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Why we need soft Ferrities for welding Inverters ?

A welding power source (rectifier type) accomplishes conversion of input power to output power through a transformer and output inductor. This transformers and inductors comprises of heavy wire / strip windings around metal core, the heaviest component of the power source.

Transformer Equation

A = V / f x k

Where

A = Crossectional Area of Transformer core, V = Magnitude of AC Voltage to be transformed, f = frequency of the AC Voltage to be transformed, k = varios design constants

Inductor Equation

A = V / f x i x k

Where

A = Crossectional Area of Inductor core, V = Magnitude of AC Voltage applied to the inductor, f = frequency of the AC Voltage applied to the inductor, i = change in current in inductor, k = various design constants.

From the above it is obvious that the area inturn the size of the transformer and the inductor varies inversely to input frequency. An inverter based machine create their own operating frequency, tens of thousands cycles. This enables lowering of the size of the transformer and inductor to operate at tens of thousands of cycles. Hence, it is essential to use professional grade soft ferrites.

HISTORY

National Physical Laboratory took up systematic studies on the processing of high permeability Manganese, Zinc, ferrous, Ferrites of the Professional Grades in 1966.

Many of the raw materials and equipments needed for processing such as the highly pure raw materials. Ferric Oxide and Manganese Oxide controlled atmosphere box furnaces, highly intricate three tier press tools for core pressing, the double action presses, air gap adjusting machines with an accuracy of one part in 10,000 of an inch were designed and fabricated in the workshop attached to the component unit. Process parameters such as particle size distribution to get optimum green density, standardisatian of calcining conditians to attain the required ferrous content and finally the temperature atmosphere profile and the rate of law of the inert gas were stabilised by a series of experiment on a large number of batches. The studies included the very difficult balancing of the firing conditions to achieve the required end characteristics which very difficult balancing of the firing conditions to achieve the required end characteristics which very aften were conflicting. Detailed studies of the microstructures of the sintered ferrites provided a rapid method of checking whether the treatment of the material composition has been accordinalv ta laid down procedures. It has now been possible to standardise all the parameters to produce pot cores af acceptable quality with very reasonable yields.

INTRODUCTION

Ferrites are a class of ceramic materials which exhibit magnetic properties. They are solid solutions of inorganic Oxides mainly of Iron. Manganese, Nickel, Barium and Zinc with additions of other elements such as Cobalt, Lead, Strontium, Calcium, Manganese etc. in appropriate proportions. Compounds of some of these oxides are prepared and sintered at high temperature. Broadly there are two classes, one having a cubic crystailine structure analagous to that of the spinels and the other hexagonal. The first class Ferrites, in the spinels are designed as 'soft' ferrites and the other `hard' ferrites.

ADVANTAGES OVER METALLIC MAGNETIC MATERIALS

Magnetic Ceramics have some unique properties which has significantly contributed to the whole field af high frequency telecommunications in the frequency range of 1 KHz to 10 GHz. One salient feature is that the specific resistivity of ferrites is many orders of magnitude higher than that of metallic magnitude materials such as silicon steels, mu metals, radio metals etc. Consequently, the eddy current and hysteresis losses are very low and ferrites can be moulded into different shapes and sizes instead af being laminated.

SOFT FERRITES

Unlike 'hard' ferrites which retain its magnetism, soft ferrites, though magnetic, do not retain its magnetism once the influencing field is removed. It however, tend to concentrate the flux lines and thereby the inductance of the coil wound around a core is increased manifoid. They are also termed as linear ferrites.

Torroids, U & I Cores, E & I Or, E & E Cores, Deflection Yokes

These are also Manganese, Zinc, Ferrites processed under similar conditions as for pot cores. For E-Cores high permeability is important if it has to substitute for silicon steel, mu metal etc. Soft ferrites in general, can be used, apart from antenna rods and inductor cores, for applications such as wide band pulse transformers. HF Power transformers DC to DC converter transformers. deflection vokes and line output transformers in TV etc.

Ferrite EE & EI Cores of different sizes are an addition to the growing family of ferrite components. The Pot Cores which form an essentiai part of present day filters and loading coils are ideal for critical applications. The E-Cores come next with many advantages as compared to the laminated cores that are used in pulse transformers, inverters, filter chokes etc.

The specific resistivity of ferrites are a few orders af magnitude more than metal alloy cores and hence the cores can be manufactured in just two pieces (two E's or E & I) with the result that the assembly of the transformer or choke become easier. This is so because the eddy current and hysteresis losses are very much less than grain oriented silicon or mu-metal alloy laminations.

In comparison with conventional laminated iron cores a much higher frequency can be chosen without increasing eddy current losses.

Since the materiai losses are quite low at high frequencies they are ideally suited to operate from audio frequency to about 200 KHz.

However, while choosing a ferrite core the modest saturation flux densities of the ferrite material should be kept in mind.

The hysteresis losses and consequently the third harmonic distortion of ferrite cores are lower than that of other materials.

Ferrite EE & EI cores are ideal for low power applications, due to the additional advantage of ferrite E & I cores of their constant initial permeability over a very large frequency range. Same typical sizes of cores and their characteristics that are currently available are given below.

Applications

For transformers, inverters, converters, fiulter-chokes

Type and size :

1. E 20/10/5

Approximate weight = 8 gms. / set

Magnetic Data

Core factor I_e/A_e = 1.37 mm^{-1}
Effective Length I_e = 42.8 mm
Effective Area A_e = 31.2 mm^2
Effective Volume V_e = 1340 mm^2

Transformer cores can be built up by containing an even no. of E-Cores, a shape that is often used in the shell type transformer E 20.20/5 is composed of two cores type E 20/10/5

Electrical Properties at 25 + 10°C (for shell type transformers E 20/20/5)

2. E 42/21/15

Approximate weight = 84 gms./ set

Magnetic Data

Core factor I_e/A_e = .534 mm^{-1}
Effective Length I_e = 97 mm
Effective Area A_e = 182 mm^2
Effective Volume V_e = 17600 mm^3

Electrical Properties at 25 + 10°C (for shell type transformers E 42/42/15)

Without air gap (Δ_o)	μ_e = 1380 - 2500 A_L = 1270 - 2300	1830 - 3000 1680 - 2700
Hysteresis Coefficient at (1.5 & 3.0 mT)	2.0 at 10 KHz	2.5 at 10 KHz
Relative Dissipation factor	3.0 at 1.0 KHz	2.5 at 10 KHz
($\tan\delta_i$ μ_i) x 10^6	15.0 at 100 KHz	7.5 at 100 KHz

1

Without air gap (Δ_o)	μ_e = 1500 - 2900 A_L = 3465 - 6700	2100 - 3400 4870 - 8000
Hysteresis Coefficient at (1.5 & 3.0 mT)	2.0 at 10 KHz	2.5 at 10 KHz
Relative Dissipation factor	3.0 at 1.0 KHz	2.5 at 10 KHz
($\tan\delta_i$ μ_i) x 10^6	15.0 at 100 KHz	7.5 at 100 KHz

2

Without air gap (Δ_o)	μ_e = 1520 - 2800 A_L = 6950 - 12800	2040 - 3390 9338 - 15500
Hysteresis Coefficient at (1.5 & 3.0 mT) μ_e		

3

Transformers cores can be built up by combining an even no. of cores, a shape that is often used in the shell type transformer E 42/42/15 is composed of two cores type e 42/21/15

3. E 65/32/13

Approximate weight = 76gms./ piece

Magnetic Data

Core factor I_e/A_e = .275 mm^{-1}
Effective Length I_e = 147 mm
Effective Area A_e = 532 mm^2
Effective Volume V_e = 78200 mm^3

Electrical properties at 25+10°C

The Transformer Core can be built up by combining an E Core with I Core.

Notes :

1. The inductance can be calculated with either of the two formula

$L = \mu_e \mu_o N^2 / Ie/Ae$ (All units in MKS system).

$L = A_L N^2$ (10^{-9}-H)

SYMBOLS AND DEFINITIQNS

I. Initial Permeability (μ_i)

The limiting value of permeabiiity of a ferromagnetic body at the origin of the curve of first magnetisation

$\mu_i = 1 / \mu_o \text{ limit}_{H \rightarrow 0} B/H$

where

μ_i = relative initial permeability
μ_o = absolute perrneability of vacuum in Vs / Am
H = amplitude of the alternating field strength in A/m
B = Flux density in Wb/m^2

The table of material characteristics shows initial permeability measured on toroidal cores at negligible field strength (≥ 0,25 ml).

2. Effective Permeability (μ_e)

If an air gap is introduced in a magnetically closed core e.g. a pot core with air gap, the permeability is lower than that of the same core without air gap. The smaller permeability is due to higher reluctance of the air gap and is calleo effective permeabiaity. Its value depends not only on the core material but also on the shape and dimensions of the core. Measurements are carried out at low flux densities

$\mu_e = L \Sigma V_4 / \mu 0 \times N^2$

where

ΣV_4 = Core factor in m^{-1}

μ_0 = Magnetic field constant 1.257 X 10^{-6}

L = Inductance in hennes

N = Number of turns

3. Amplitude Permeability (μ_a)

Under stated conditions, the permeability at a stated value of the field strength, the field strength varying periodically with time and no static magnetic field being present

$\mu_a = 1/\mu_0$ B/H

4. Incremental Permeability (μ_Δ)

The permeability at alternating magnetic field and in the presence of a static magnetic field.

$m_D = 1/m_0$ DB / DH

where

μ_Δ = relative incremental permeability

μ_0 = absolute permeability of vacuum in Vs / Am

ΔH = peak to peak value of the incremental field strength in A/m

ΔB = corresponding induction in wb,m^2

5. Eddy Current Losses

The losses caused by the eddy currents in a ferromagnetic part.

6. Hysteresis losses

The losses caused by magnetic hysteresis in a ferromagnetic part, when the magnetic field varies with time.

7. Residual losses

The difference between the total losses of the ferromagnetic part and the sum of the eddy current and hysteresis losses.

8. Relative Dissipation Factor

Measured on a core of homogenous magnetic materiai at low flux density (≤ 0.25mT) the ratio of the tangent of loss angle to the relative initial permeability of the material and is equal to: .~

$\tan\delta/\mu_1 = R_s\mu_1\omega L_s = 1/\mu_1 \times 1/Q$

where

$\tan\delta$ = tangent of loss angle

μ_1 = relative initial permeability taken as equai to the toroidal permeability

R_s = resistance of the measuring coil in ohms, calculated as series resistance, due to the losses in the core only.

$\omega = 2\eta$ x measuring frequency in hertz

L_s = self-inductance of the measuring coil on the core in henrys
Q = Quality Factor

9. Effective Dissipation Factor ($\tan\delta_e$)

Due ta an air gap the dissipation factar $\tan\delta$ of the coil appears only in the ratio μ_e/μ_1

The effective dissipatian factor for a core with air gap

$\tan\delta_e = \tan\delta/\mu_i \Xi \mu_e$

10. Q Factor of coil

The ratio of the reactance to the total resistance of a coil is called the Q factor.

$Q = \omega L/R_s = 1/\tan\delta_L$ = reactance / total real resistance

where = resistance in series with the inductance L

$\tan\delta_L$, = dissipation factor of camplete coil

'The measurenlent of Q factor is carried out at low flux density (≤0.25mT).

11. Hysteresis Coefficient (μ_B)

Under stated conditions and in the Rayleigh region, the quotient of the tangent of loss angle due to hysteresis and product of effective permeability and the peak value of the flux density -

$\mu_B = \tan\delta_h / \mu_e B$

where

μ_B = hysteresis material constant (in T^{-1})

$\tan\delta_h$ = tangent of loss angle due to hysteresis only

μ_e = relative effective permeability and

B = peak value of flux density in tesla in the core during measurement

in accordance with IEC recommendation, η_B is measured at B = 1.2 and 3mT and f = 10 KHz. When comparing η_B figures, the different measurement conditions of the individual manufacturers must be taken into account.

When an air gap is introduced into a magnetic circuit, the hysteresis losses are reduced by the square of the ration (μ_e/μ_i).

12. Saturation magnetisation B_S

This is the vaiue reached by the fiux density B at high field strength. The flux densities shown in the table of material characteristics are already close to the saturation point. They were measured at a field strength of 3000 A/m.

13. Inductance Factor (A_L)

It is the self inductance that a coil of specified shape and dimensions placed on the core in a given position should have, if it consisted one turn

$A_L \sim L/N^2$

where

AL = inductance factor

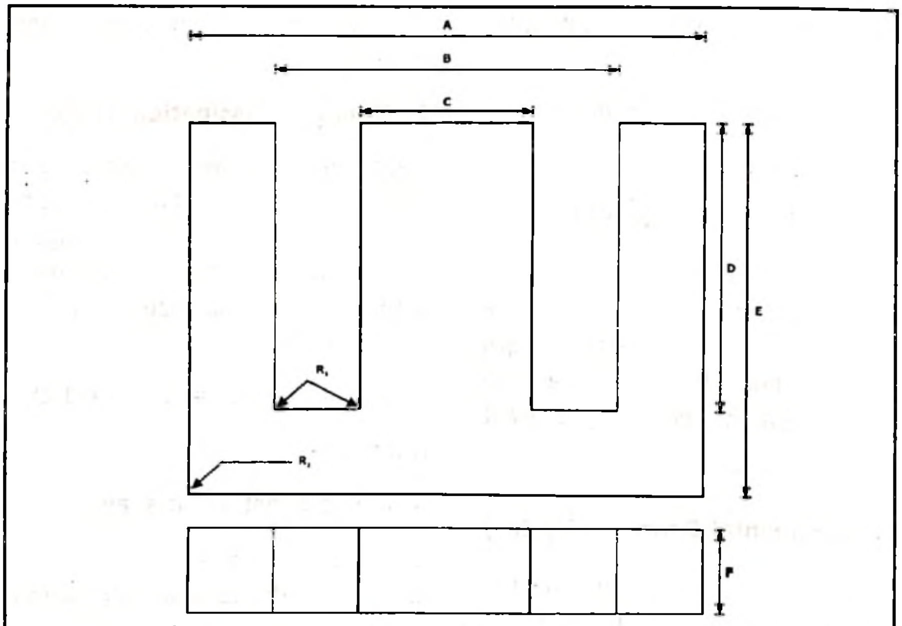
L = self inductance of the coil in nano henries

N = number of turns in the coil

Occasionally, turns factor (α) is used to determine the number of turns in accordance with the formula

$N = \alpha \sqrt{L}$

where L is expressed in mH.



TYPE	A	B	C	D	E	F	R_1	R_2
E 20/10/15	20.7	12.8	5.2	6.3	10.0	5.8	0.5	1.0
E 42/21/15	43.0	29.5	12.8	14.6	21.0	15.2	0.8	2.0
E 65/32/13	66.5	44.2	20.0	22.2	32.0	13.7	1.0	2.0