OPTIMISATION OF D.C. REACTOR USED IN WELDING MACHINES (WELDING RECTIFIERS)

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INTRODUCTION

A Reactor placed in series with the output circuit of Welding Machines (welding Rectifiers) improve the performance of welding with following effects.

- Reduces spatter in welding and thereby makes the welding smooth and increase weld metal recovery.
- Allows control Heat input variable D.C. Reactor

For these above features, the D.C. Reactors are connected in output circuit of Welding Rectifiers which improves the welding quality of the Welding Rectifier power sources and become a very important component in Welding Rectifiers. So the importance of optimization becomes very vital. Again the place and use of the D.C. Reactors play an important role in the design of D.C. Reactors. Now as the specified condition vary according to the place of use of the D.C. Reactors, the preparation or determination of the design data also vary accordingly. The variation may be grouped under the following broad headings :-

- In most of the cases optimum material involvement is the deciding factor.
- In some other cases minimum weight is also required.

Here we will analyse the above mentioned cases to achieve an approximate solution. For simplification we will assume the following :

- Core section is square ie. Limb width = stack of length of core
- Limb section and Yoke section of the core to be the same
- The core limb center distance is equal to the maximum winding diameter

Now by the reasoning as mentioned above we can replace the D.C. Reactor as shown in Fig.1 below.

We will analyse the cases as mentioned earlier as per the construction shown in Fig 1.

OPTIMUM INVOLVEMENT

In this case the copper volume is

$$2 \times 4 \frac{(a + d).n.q}{2} \qquad \text{..........1}$$

Where

n = no. of turns
q = Conductor section
d = Limb width = stack length
L = window height
a = outside dimension of coil

Also from Fig.1 we get copper volume is : 2L(a – d) 2

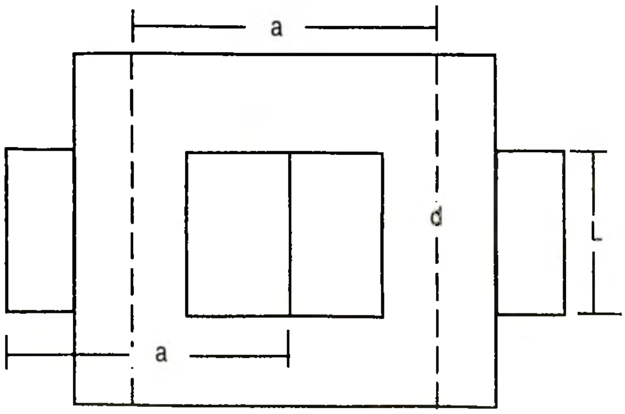

Fig. 1

Now for economical design we know that core price should be equal to copper price. Let the copper price per Kg be u and core price per kg be v. Then for an economical design :

u x copper weight = v x core weight
So cu volume x δ 2 x u =
core-volume x δ 1 x v
where $\delta 1$ & $\delta 2$ are the densities of core and copper.
Therefore Copper volume

$$= \frac{\delta 1 \times v}{\delta 2 \times u} \text{ core volume}$$

= c.core volume

$$\text{where } c = \frac{\delta 1 \times v}{\delta 2 \times u}$$

Where Q = Core Section = d^2
Now core volume = Q(2a+2d+2L)
So Copper Vol. = c.Q(2a+2d+2L) 3
Now from equations (1) & (3)
4(a+d) n. q. = $2d^2$ c(a+d+L)

$$\text{or, } \frac{2n.q\ (a+d)}{d^2c} - (a+d) = L$$

Therefore,

$$L = (a+d)\left(\frac{2n.q}{d^2c}\right) - 1 = (a+d)K \quad \text{....4}$$

$$\text{Where } K = \frac{2n.q}{d^2c} - 1$$

Now putting the volume of L in (2) and comparing it with (1) we get :
4(a+d).n.q. = 2(a+d). k.(a^2-d^2)

$$\text{or } \frac{2n.q}{K} = a^2 - d^2$$

$$\text{Therefore } a = \sqrt{\frac{2nq}{K} + d^2}$$

Now determinimg a from the above relation we can also determine L from equation no. (4) and by that all necessary data of design.

MINIMUM WEIGHT CONSIDERATION

In this case also we will consider the Fig. 1 and as such the equations (1) (2) & (3) are also valid. Now here from (1) & (2).

4(a+d).n.q = 2L(a^2–d^2)

$$\text{or, } n.q. = \frac{L}{2}(a\text{-}d)$$

So, L = 2nq / (a–d) 5

Now copper weight is :

$$4(a+d)n.q.\delta 2 = (a+d).4q\delta 2\ \frac{c}{d^2} \text{ .....6}$$

(n-c/d^2, as Q = d^2)

So copper weight from (6) is

$$K1\ \frac{(a+d)}{d} \text{ ....6a}$$

Now, from equation No. 3 core weight may be written as :

2Q (L+a+d) $\delta 1$

$$= 2d^2 \left\{ \frac{2nq}{(a\text{-}d)} + (a+d) \right\} \delta 1$$

$$= 2d^2 \left\{ \frac{2cq}{d^2(a\text{-}d)} + (a+d) \right\} \delta 1$$

$$= \frac{4cq\ \delta 1.1}{(a-d)} + 2\ \delta 1.d^2\ (a+d)$$

$$= K2\ \frac{1}{(a-d)} + K_3d^2\ (a+d) \text{ ....7}$$

Where $\delta 1$ = density of core
K2 = 4cq$\delta 1$ & K_3 = 2$\delta 1$

Therefore Total weight

$$Wt = \frac{K_1(a+d)}{d} + K_2\frac{1}{(a-d)} + K_3d\ (a+d) \text{ ..8}$$

Now this expression (8) will have a minimum value if and only if the following conditions are fulfilled :-

- The first derivative of the expression w.r.t. "a" should be zero
- The second derivative should be positive.

Now differentiating the expression No. (8) with respect to "a" We get

$$\frac{d\ wt}{da} = \frac{K1}{d} - K2\frac{1}{(a-d)} + K3d$$

To fulfill first condition $\frac{dwt}{da} = 0$

$$\text{so, } \frac{K_1(a-d) - K_2d + K_3d\ (a-d)}{d\ (a-d)} = 0$$

so K_1(a–d) – K_2d +K_3d (a–d) = 0

K_1(a–2ad+d)K_2d + K_3d(a–2ad+d) = 0

Or, a(K_1+K_3d) – a(2dK_1+2dK_3)
+ (K_1d – K_2d + K_3d) = 0 9

Now by differentiatting $\frac{dwt}{da}$

once again fulfilling Second Condition we get :

$$\frac{d^2\ wt}{d\ a^2} = \frac{2K2}{(a-d)3} \quad \text{.................. 10}$$

From the above it is obvious that if minimum weight is the main consideration then a must be greater than d and a will be root of the quadratic equation (9) and by that the design data will be fixed.

So in conclusion we can add that for different considerations design data are to be fixed in separate manner as described with simplification above. This is a guideline for fixation of design parameters with different conditions and requirements of applications of D.C. Reactors.

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