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Method of D^2L Separation Chart in Asynchronous Machine

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Abstract

This paper present the generalized electrical machines design problem, with a review of induction machines.
The presentation of the machines characteristics, such as the explanation of a new chart for separating the bore diameter (D) and axial length (L) from their D^2L is fully presented, and its role in the general electrical machines design problems. The chart for separating the main dimensions bore diameter (D) and axial length (L) from their D^2L product, idea thus unified all existing methods of separation of D and L from their D^2L and it also gives a clearer understanding of the problem and allows for the easy imagination of the physical structure of a machine. Furthermore, in computer aided design it simplifies and economizes computer usage in optimal design of main dimensions.

Keyword: AC Machine, modeling, Computation

Introduction

In order to obtain the main dimensions of the stator bore diameter (D_1) and the axial Length (L) of a machine, the D^2L product is first established and then separated into its components, D_1 and L_1. Thus this product, which is actually a measure of the physical volume of a machine, is a function of two variables, D_1 and L. Therefore, their evaluation requires one or more independent equation, which must also be a function of D_1 and L, such as to set up two equations which are to be solved simultaneously for these two unknowns. However, this requirement may not be necessary if one of the unknowns can be determined independently.
Several literatures [1]-[3] show that there appear to be no fixed method for either setting up the independent equation or having the knowledge of one of the variables, such that the separation will give the best machine. This, of course, is because the best at minimum cost must have its main dimensions satisfy all necessary constraints. Despite the different methods of approach suggested by various designers, the trial and error design roughly method prove to be most satisfactory which involves the assumption of different sets of values, working out the for each case, and thus picking out that which will give good operation at reasonable cost in order to successfully carry out the execution of this method with ease and within a relatively short time, with the use of computer is obvious. One of these other different methods is the idea of using equations in place of storing data of selected points into the memory of the computer and using interpolation formula to obtain values of a point in-between two selected points, as a means of representing a graph in computer Aided Design of Machine among others which can be found in [4],[8],[19] - [22].

Thus in computerized design, this is easily done by the process of iteration, as suggested in figure 1.

Existing Methods

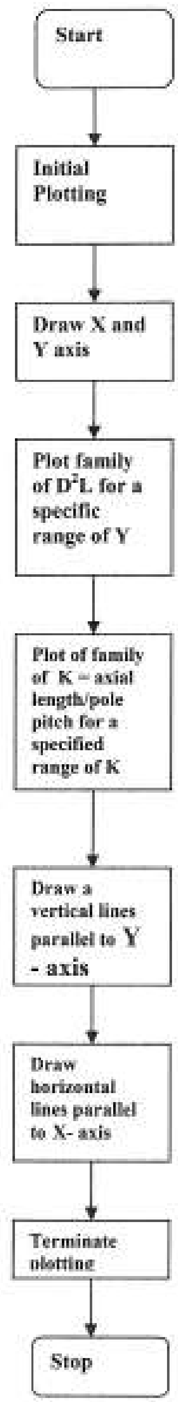

Figure 1: Flow diagram for the plotting of the D^2L separating charts

These methods help to establish the extra independent equation, and referred to above, by finding the most favorable proportion of D_1 and L for any specific case[1]-[10]. The various factors involved in establishing this proportion are power factor, economical considerations in terms of labor cost, cost of materials, ventilation, peripheral velocity, existence of frame size with accessories, and other performance factors.

The pole pitch-Axial length Relationship.

Vickers [2-3], made an analytical study and concluded that, for best power factor

$L/Y = 2PL/\pi D$ -------- (1)

Where Y is the pole – pitch in cm and

$Y = \pi D/2P$ (2)

The D^2L product equation has volume dimensions. Hence we have,

$V = D^2L$ (3)

With V known and by substituting "(2)" in "(1)" and solving "(1)" and "(3)" simultaneously, it will result to the respective values of D_1 and L. The problem associated with this method is that it does not take into consideration other factors mentioned above.The pole shape is often taken as the basis for a significant establishment of a relationship between D_1 and L. Thus this is achieved in terms of the ratio of axial length (L) to pole pitch (Y), and for a square pole face, $L/Y \cong 1.0$. Kullman5 suggests that L/Y = 2.0 for minimum cost integral – kilowatt motors and 0.6 for small motors. With equation 3 and the knowledge of the most suitable ratio, the respective values of the main dimensions can be found. The peculiar problem in this case is that the ratio that satisfies one factor may not satisfy the other, hence it is difficult to find the ratio that satisfies all the factors, for a particular case.

The KW/Pole Pitch Relationship.

Pole pitch (Y) will obviously depend some what upon the kilowatt per pole and will be considerably larger in machines of larger output with fewer poles than those of smaller output with many poles. The basis of equal output per pole is such that the area of the air gap (Y x L) must be large for a low frequency machine because of the slower rate of cutting of the flux by the conductors in the slot. This method is rather preferable in obtaining dimensions for cost of machine.

The Rotor Speed Relation Minimum

Where the peripheral velocity plays a leading role, equation

$U = N_{s\pi}D_1$ ……………….. (4)

is used. U is velocity in meters/second and N_s is synchronous speed in radians per second. With U and N_s known, D_1 obtained from "equation (4)" is used in "equation (3)" to obtain L. This method satisfies only the peripheral velocity but not the other factors. But this relation is important when strength of materials is considered.

D and L Relation

Different designers suggested various ratios between D_1 and L based on their experiences. For example Trickey [1] suggested making L = 0.3D. More of these can be found in [4]-[10].

Chart for Separating D and L from D^2L

The chart for separating D^2L figure 2.2 is developed from the fact that for a D^2L product there exist infinite kinds of sets of values of D_1 and L. And of these only one set will be used in the final construction of the machine. Usually that which gives the best machine at minimum cost and hence the solution is to choose this set.

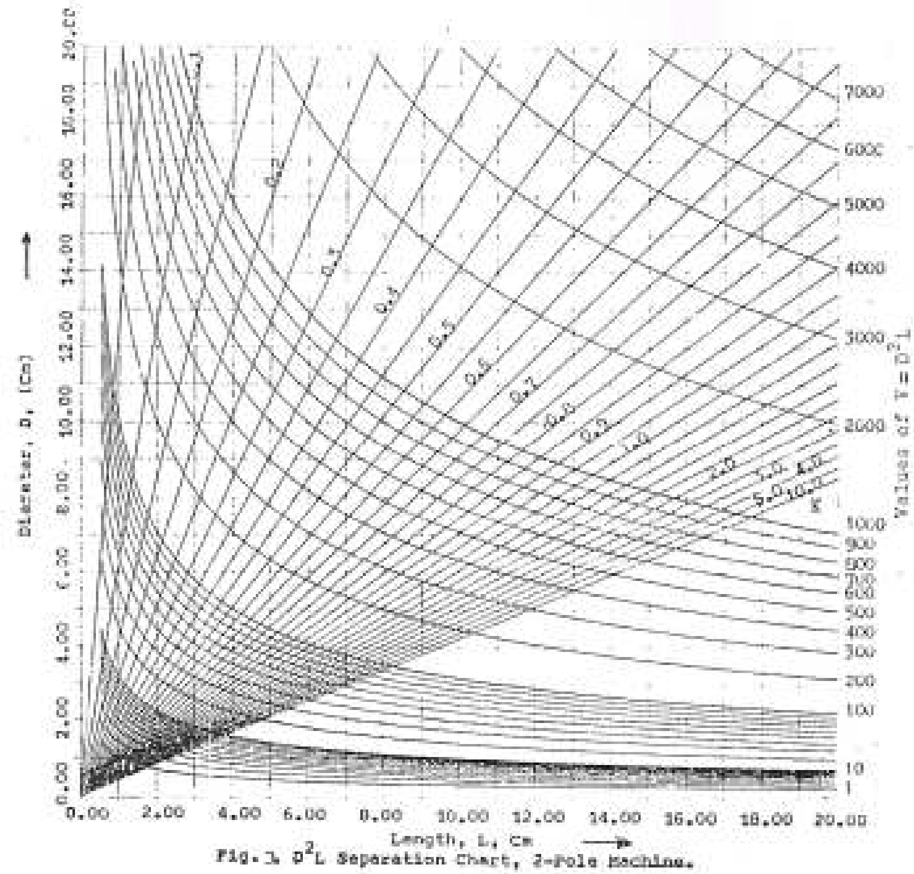

Figure 2: D^2L Separation Chart; 2 - Pole Machine

However, the problem is not totally solved by this chart, but it simplifies the problem, by presenting a diagrammatic view of the infinite sets. Thus by observation of the chart the best set or a range of possible best sets may be established. From a range of possible best sets, the best can be obtained by using, with the aid of a computer, the trial and error method, as mentioned in the introduction of this paper.

Thus in establishing this chart the following two equations were employed:

$V = D^2L$ (5)

$K = L/Y = 2pL/\pi D_1$ (6)

where K is the ratio of the axial length to the pole pitch.

“Equation (5)” which is from section 1.1 above, is rather preferred for use to the others because it has a similar problem as that of separating D_1 and L from D^2L. Since these two equations are independent. Certainly, there will always be solution for D_1 and L for any positive values of V and K aside from zero, which is not of any practical importance. The major reason for preference of “(5)” to others is that the pole face of any machine is a function of both the performance and cost factors, as listed in "(1)". There must always exist a pole face, thus K that satisfies all these factors and thus gives the best machine at the minimum cost as well.

Observations of these two equations show that for given V and K "equation (5)" gives an inverse square curve while "(6)" gives a straight line curve. Both equations are plotted on the same axis as they will always intersect at only one point. This point of intersection is what we are interested in, and hence the charts of figure 2 was formed by taking the diameter D_1 and axial length L as the ordinate and abscissa respectively and drawing families of curves for equations (5) and (6). The units of all the variables are chosen to include all the dimensions of the existing machines for a particular number of poles (2p). A different chart is however established for different number of pole-pairs for a given machine. These charts were drawn with the aid of the computer, and the programs used are shown in references [8] [4]. The flow chart for their easy understanding is also shown in figure 1.

Any point on the chart is a function of the four variables V, K, D and L. Hence, the chart can be employed to establish values of two of these variables if the remaining two are known [3] – [5] and [18] – [21]. It is worth mentioning here that tremendous work has been done on this aspect by Prof. P.A. Kuale and A. A. Jimoh [6] - [9]

Conclusion

In conclusion, In order to obtain the main dimensions of the stator bore diameter (D_1) and the axial Length (L) of a machine, the D^2L product is first established and then separated into its components, D_1 and L_1. Thus this product, therefore which is actually a measure of the Physical volume of a machine is a function of two variables, D_1 and L. Therefore, their evaluation requires one or more independent equation, which must also be a function of D_1 and L, such as to set up two equations which are to be solved simultaneously for these two unknowns.

The new chart for separating the bore diameter (D) and axial length (L) from their D^2L was fully presented. This chart idea unified all the existing methods of separation of D and L from D^2L. Any point on the chart is a function of the four variables V, K, D and L. Hence, the chart can be employed to establish values of two of these variables if the remaining two are known [3-5]. It is worth mentioning here that tremendous work has been done on this aspect by Prof. P.A. Kuale and A. A. Jimoh [1] – [8].

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