

General Theory of Multiple-Cage Induction Motors

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POWER COMPANIES are usually particular about the starting current and running power factor of an induction motor. However, induction-motor manufacturers cannot possibly supply a motor much better in these respects than the present National Electrical Manufacturers' Association Design C standards, even though ideal materials should be discovered in the future.

Both the primary resistance and the saturation effect on leakage reactance are neglected in this analysis. While the first assumption can be fulfilled only with idealized material, it is a close enough approximation in motors of 20 horsepower or above. Under the assumptions, the motor can be analyzed with the help of a well-known theorem which states that as soon as the imaginary component of a physical network function is known for all values of frequency, the real component is totally determined up to an additive constant. In this case, the input reactive volt-amperes is the real component; the torque in synchronous watts the imaginary component; the slip corresponds to frequency; and the magnetizing current is the additive constant.

Figure 1 shows the assumed torque as a function of slip. Figures 2 and 3 show the full-load power factor and starting kilovolt-amperes per horsepower as functions of full-load slip and $k_{r\infty}$. The basic leakage factor $k_{r\infty}$ is defined as $1 - X_a/X_b$ where X_a is the leakage reactance not including the slot leakage of inner cages and X_b is the total reactance. Since no special configuration or multiplicity of rotor slots is assumed, the result indicates that the best obtainable start-

ing current and full-load power factor are fixed as soon as the full-load slip is chosen. Since the value of $k_{r\infty}$ is not influenced by the selection of inner cage dimensions, altering the inner cage design would not improve the starting current and power factor without lowering the torque curve in general or in part. Real improvements can be accom-

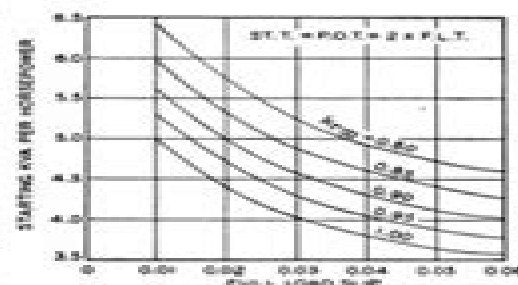


Figure 3. Starting kilovolt-amperes per horsepower of a constant-torque motor as a function of full-load slip and $k_{r\infty}$.



Figure 1. The speed-torque curve of a constant-torque motor.

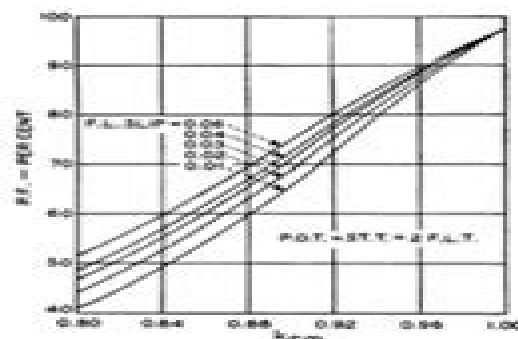


Figure 2. Power factor of a constant-torque motor as a function of full-load slip and $k_{r\infty}$.

plished only by measures which increase $k_{r\infty}$, such as reducing the air gap, increasing the number of stator slots, and so forth. All of these measures have practical limitations.

The theory also provides a guide for designing rotor laminations. Let X_a be the total leakage reactance at no load, R_a be the rotor resistance of the outermost cage only, and R_b be the rotor resistance with all cages in parallel. X_a , R_a , and R_b are determined by equations 1, 2, and 3.

$$\frac{X_a}{X_b} = \frac{1}{s} \left(2.57 + \ln \frac{s}{s_m} \right) \quad (1)$$

$$\frac{R_a}{X_b} = \frac{X_a}{X_b} \frac{s}{2} \quad (2)$$

$$\frac{R_b}{X_b} = \frac{X_a}{X_b} \frac{s_m}{s} \quad (3)$$

In these equations, s_m is the slip at maximum torque point and is about equal to 3.73 times the full-load slip; s_1 is the slip at which the torque tapers off. The value of s_1 is usually in the range of 1.5 to 2.5. The value of s_1 is chosen to compromise the full-load power factor and starting current. Both are lower for higher value of s_1 and conversely.

The values of R_a and R_b determine the total slot area and the slot area of the outermost cage, respectively. X_a determines the combined slot constant of the inner cages. Though all these conditions do not completely determine the slot shape, they are more than a starting point.

Digest of paper 49-238, "General Theory of Multiple-Cage Induction Motors," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17-23, 1949. Published in AIEE Transactions, volume 68, 1949, part 2, pages 1139-43.

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Electrical Eng Volume 8 A General Reference

Walter Richard Crane



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Electrical Engineering - Volume I Kit Po Wong, 2009-11-30 Electricity is an integral part of life in modern society. It is one form of energy and can be transported and converted into other forms. Throughout the world, electricity is used to light homes and streets, cook meals, power computers, and run industrial plants. Electricity is so integrated with our way of living that electricity consumption per person is used to measure the levels of economic development of countries. Any disruptions to electricity supply or blackouts will lead to huge financial loss and threats to lives and well-being in the community. Electrical engineering is the profession and study of generating, transmitting, controlling, and using electrical energy. It offers a wide range of exciting opportunities to those looking for a fulfilling, challenging, and professional career. Electrical engineers are the designers of modern electrical machinery, power systems, transportation, and communication systems. They work in various sectors of the community as well, including the building industry, the manufacturing industry, the construction industry, consultancy services, technology development, education services, as well as government. In these volumes, the essential aspects and fundamentals of electrical engineering are presented. In-depth knowledge of various areas of electrical engineering are disseminated by learned scholars in their fields. It is hoped that readers will find all the writings comprehensive, informative, and interesting. It is further hoped that these fundamentals will assist the readers to study advanced topics in electrical engineering. If the readers are electrical engineers themselves, it is hoped that the articles will broaden their horizon in electrical engineering and provide them with the necessary knowledge to further their profession as electrical engineers.

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