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INVESTIGATE THE ASYNCHRONOUS MOTOR

Measurement practice IV.

FOR VEHICLE ENGINEER STUDENTS

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1. Introduction

The aim of the laboratory exercise is to learn how an asynchronous motor works.

1.1 Objectives

- Asynchronous motor structure, working principle;
- Investigation of the motor nameplate and parameters;
- Understanding and calculating slip.

2. Literature review

Asynchronous or induction machines are widely used in various fields, where it is for domestic or industrial use, because of their characteristics of simple structure, low cost and easy maintenance. For the sake of completeness, the grouping of asynchronous machines is shown in the first figure.

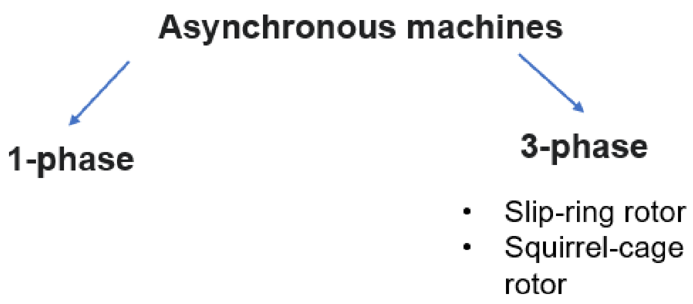


Fig.1. Grouping of asynchronous machines

2.1 Structural design of asynchronous machines (3-ph)

2.2.1 Stator

Asynchronous machines can be structurally divided into two major parts: the stator and the rotor. The stator of an asynchronous machine is structurally identical to the stator of a synchronous machine, so it will not be discussed in detail.

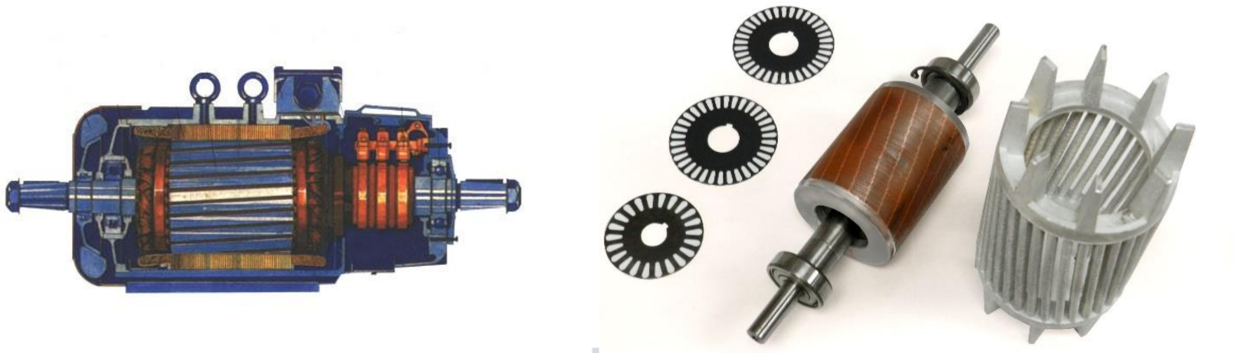
2.2.2 Rotor

Two types of rotors are distinguished:

- slip-ring (also referred to as wound rotor in some literature);
- and asynchronous motor with a squirrel-cage rotor.

In operation, the rotor is always short-circuited, regardless of its design. The structural design of each type of rotor is shown in Fig. 2. The slip-ring design has a rotor winding similar to the stator winding and is connected to external resistors or controllers via slip rings. This configuration allows for better control of starting torque and speed, making it suitable for

applications requiring variable speed and high starting torque. However, it is more expensive and requires more maintenance (due the brushes).
In the case of the squirrel-cage rotor, the winding is not of classical design. This type of induction motor has a rotor made of conductive bars shorted at both ends by end rings, forming a cage-like structure. It is the most common type due to its simple and rugged construction, low cost, and reliable operation. However, it has limited starting torque and speed control capabilities.



a) Wound rotor   b) Squirrel-cage rotor

Fig. 2. Rotor configuration possibilities for asynchronous motors

2.2 Working principle

The stator is connected to the AC power source. Alternating flux is produced around the stator winding due to AC supply. This alternating flux revolves with synchronous speed. The revolving flux is called as "Rotating Magnetic Field" (RMF).
The relative speed between stator RMF and rotor conductors causes an induced emf in the rotor conductors, according to Faraday’s law of electromagnetic induction. The rotor conductors are short circuited, and hence rotor current is produced due to induced emf. That is why such motors are called as induction motors.
(This action is the same as that occurs in transformers, hence induction motors can be called as rotating transformers.)
Now, induced current in rotor will also produce alternating flux around it. This rotor flux lags behind the stator flux. The direction of the induced rotor current, according to Lenz's law, is such that it will tend to oppose the cause of its production.
As the cause of production of rotor current is the relative velocity between rotating stator flux and the rotor, the rotor will try to catch up with the stator RMF. Thus, the rotor rotates in the same direction as that of stator flux to minimize the relative velocity. However, the rotor never succeeds in catching up the synchronous speed. This phenomenon can be seen in Fig. 3. It is the basic working principle of induction motor of either type, single phase of 3 phase.

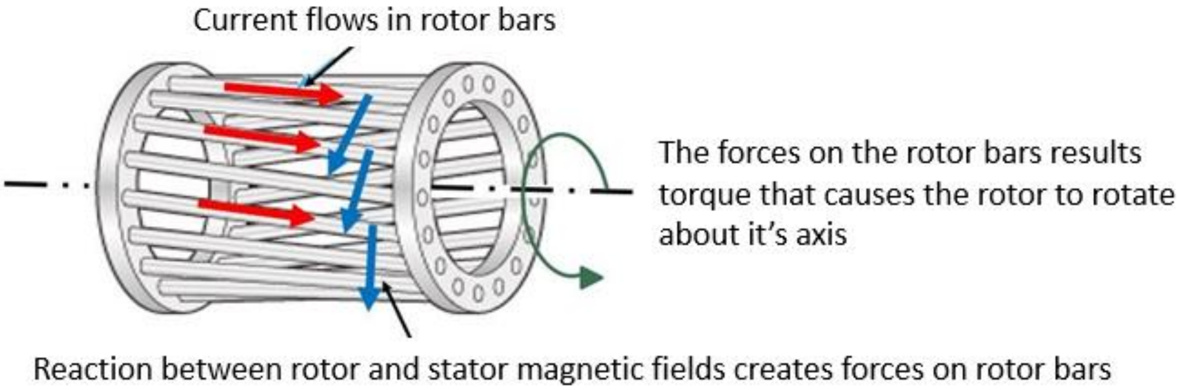


Fig. 3. A 'Squirrel Cage' rotor working principle

The synchronous speed of the stator (n_s) depends on the excitation frequency (f_s) and the number of poles (p):

$$n_s = \frac{60 \cdot f_s}{p} \quad (1)$$

And the speed of the rotor lags behind the rotating field of the synchronous (hence the name asynchronous). This is called a slip:

$$s = \frac{n_s - n}{n_s} \cdot 100\ [\%] \quad (2)$$

Importantly, the asynchronous machine is not capable of synchronous operation. If the slip were reduced to 0, the torque of the machine would be zero.

For example, the speed of a 2-pole asynchronous machine with 50Hz supply and 2% slip will be 2940 rpm.

The currents induced in the rotor also create a rotating field, but the two fields (stator and rotor field) are combined into one field in the air gap. Constant torque can only be achieved if the stator and rotor have the same number of poles.

3. Experiments

3.1 Test bench start-up

1. Turn the main switch to energise the inverters of the machines.
2. Select the language (English / Hungarian) via the HMI and click on the next button to get the control panel for the machines.
3. Turning a key safety switch without the permission of the instructor or the person supervising the measurement is forbidden!
4. It is IMPORTANT to reset the torque meter and clear any error codes before measuring!
5. Switch on the DC system rail, the test (BENCH - asynchronous servo motor - black machine) and the tested (UUT - synchronous motor with cylindrical rotor - blue

machine) machine according to the operating instructions. It is important that both machines are started before starting the measurement!

Note: Take into account the HMI response time before saving the measured data! The software manual will help you to analyse the data structure.

3.2 First measurement: investigate the operation of the asynchronous machine!

Steps of the measurement:

1. Determine the number of the motor pole pair! Help: pole pair must be a whole number!
2. Set the RPM limit to 3500 rpm (you can do it on the left HMI)!
3. Set the load side torque to 0% (you can do it on the left HMI)!
4. Set the nominal motor speed on the HMI (You can do it on the right HMI)! You can read this from the data table!
5. Read the inverter frequency for the rated speed!
6. Calculate the slip of the motor! To calculate it, use the following equation:

$$s = \frac{f_{nominal} - f_{inverter}}{f_{nominal}} \cdot 100\ [\%] \qquad (3)$$

Type of motor:

Pole pair of motor:

Nominal speed:

Measured frequency at nominal speed:

Slip of the motor:

3.3 Second measurement: Investigation of asynchronous motor slip as a function of load

Steps of measurement:

1. Set the load side torque to 0% (you can do it on the left HMI)!
2. Set the RPM limit to 3500 rpm (you can do it on the left HMI)!
3. Set the nominal motor speed on the HMI (You can do it on the right HMI)! You can read this from the data table!
4. Read the inverter frequency for the rated speed!
5. Calculate the slip of the motor!
6. Repeat the measurements by varying only the load torque according to the given table! (the speed should remain unchanged!)
7. Calculate the slip value for the new load torques. What do you experience?

Load torque* [%]	**Rotating speed [rpm]**	**Nominal frequency [Hz]**	**Inverter frequency [Hz]**	**Slip [%]**
0				
-15				
-25				
-35				
-45				

* Negative torque means braking the engine in practice.

5. Conclusions

What is a slip in asynchronous motor?
How does slip value vary as a function of load?
What happens if the value of the slip decreases to 0?
What happens if the slip becomes negative?

6. Homework

7. References

[1] Electrical Engineering for Technical Secondary Schools, Student's book, Form Three.

[2] https://www.flaktgroup.com/nl-be/news/news-archive/2020/july/basic-principles-of-ac-induction-motors/