Exercise: Study of an induction motor

We consider a squirrel cage induction motor powered by a network with a frequency of **50 Hz** and voltages **between phases** equal to **380 V**.
It was subjected to the following tests:

At no-load:

- **No-load absorbed power :** $P_{a0} = 360\ W$
- **No-load current :** $I_0 = 3.6\ A$
- **Rotation speed :** $N_0 = 2995\ rpm$

With load:

- **Absorbed power :** $P_a = 4560\ W$
- **Current :** $I = 8.1\ A$
- **Rotation speed :** $N = 2880\ rpm$

The windings of the stator are **coupled in star**; The resistance of **each of them** is $r = 0.75\Omega$.
Iron losses in the stator P_{fs} are estimated at **130 W**.

1- What is the synchronism speed **Ns** ? Deduce the slip **g** under load.

2- **For no-load operation:**

a) Calculate the Joule losses P_{j0s} at the stator.
b) Justify that in addition to rotor iron losses, the Joule losses in the rotor are negligible.
c) Deduce the mechanical losses p_{mec}.

3- **Under load operation :**

a) Calculate the stator joule losses P_{js} and the joule losses in the rotor P_{jr}
b) Calculate the useful power P_u and torque C_u of the motor
c) Calculate the efficiency of the motor η

4- The motor now drives a pump whose moment of the resistive torque **Cr** is Proportional to the rotation speed and is **18 Nm** at **3000 rpm**.

In its useful part, the mechanical characteristic **Cu (N)** of the motor can be assimilated to a **straight line**.
Determine the rotation speed ***N*** of the motor-pump unit.

Correction

1) $\text{Ns} = 3000\ \text{tr/min}$

$$g = \frac{3000 - 2880}{3000} = 4\%$$

2) For no-load operation:

a) $P_{j0s} = 3 \times R \times I_0^2 = 3 \times 0.75 \times 3.6^2 = 29W$

b) At no-load, the slip g is negligible.

$P_{jr} = g \times P_{tr}$

Therefore, the Joule losses in the rotor are negligible.

c) $p_{mec} = P_{a0} - P_{j0s} - P_{fs} = 201\ W$

3) Under load operation:

a) $P_{js} = 3 \times R \times I^2 = 3 \times 0.75 \times 8.1^2 = 148\ W$

b) $P_{jr} = g \times P_{tr} = g \times (Pa - P_{js} - \text{Pfs}) = 0.04 \times (4560 - 148 - 130) =$

$$P_{jr} = 0.04 \times 4282 = 171W$$

$P_u = 4282 - 171 - 201 = 3910\ W$

$C_u = \frac{P_u}{\Omega} = \frac{3910}{2880 \times \frac{\pi}{30}} = 13\ Nm$

c) $\eta = \frac{P_u}{Pa} = \frac{3910}{4560} = 85{,}7\%$

4) Cr (Nm) = 0,006 N (tr/min)

$C_u = 0\ Nm$ à 3000 tr/min

$C_u = 13{,}0\ Nm$ à 2880 tr/min

So $C_u(Nm) = 324 - 0.108\ N$ (tr/min)

Operation point:

$C_u = C_r$

324-0.108 N = 0.006 N

N =2842 tr/min