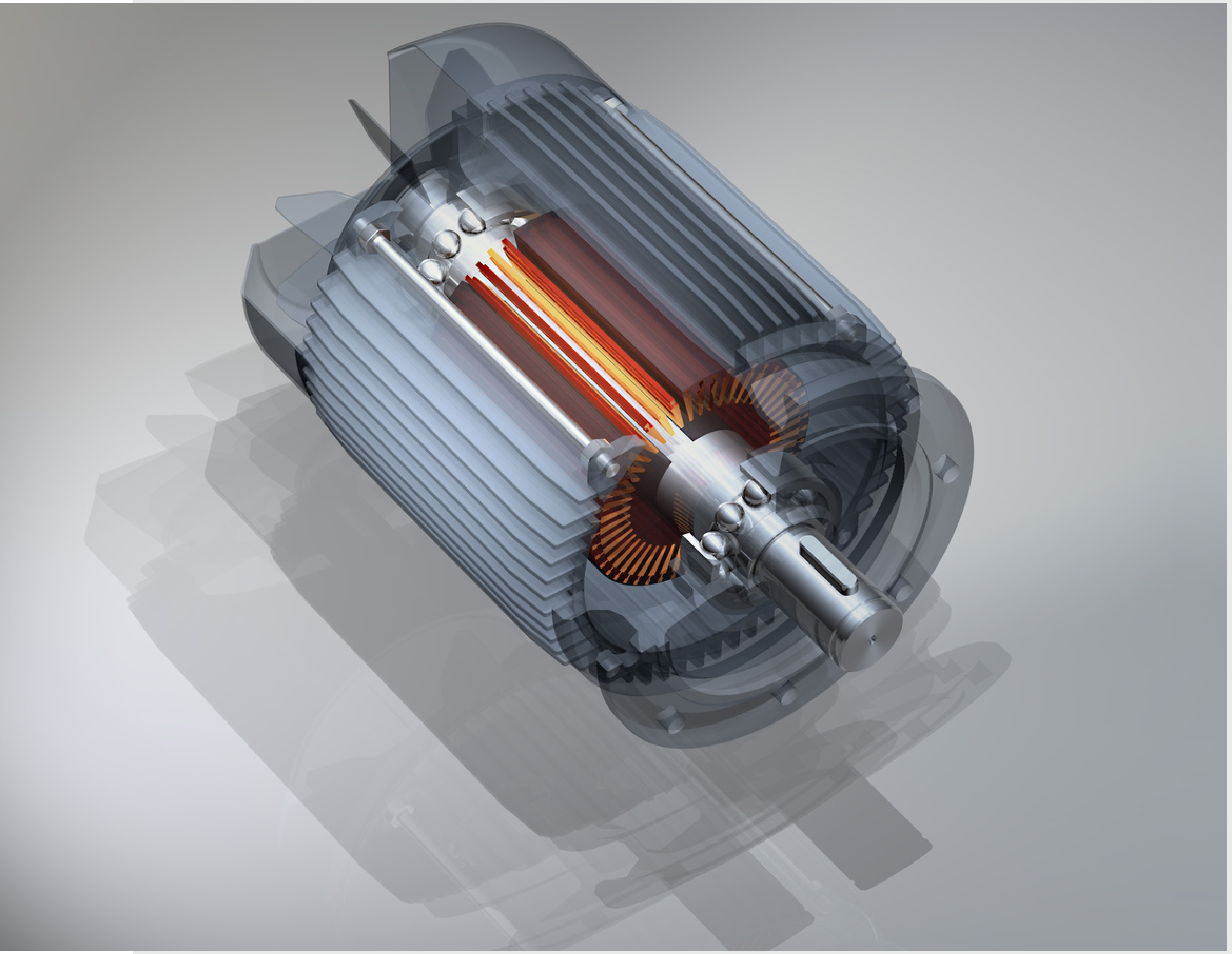
COOLING AND VENTILATION (IC) OF THE THREE-PHASE INDUCTION MOTOR

EPE3020 - GROUP 8



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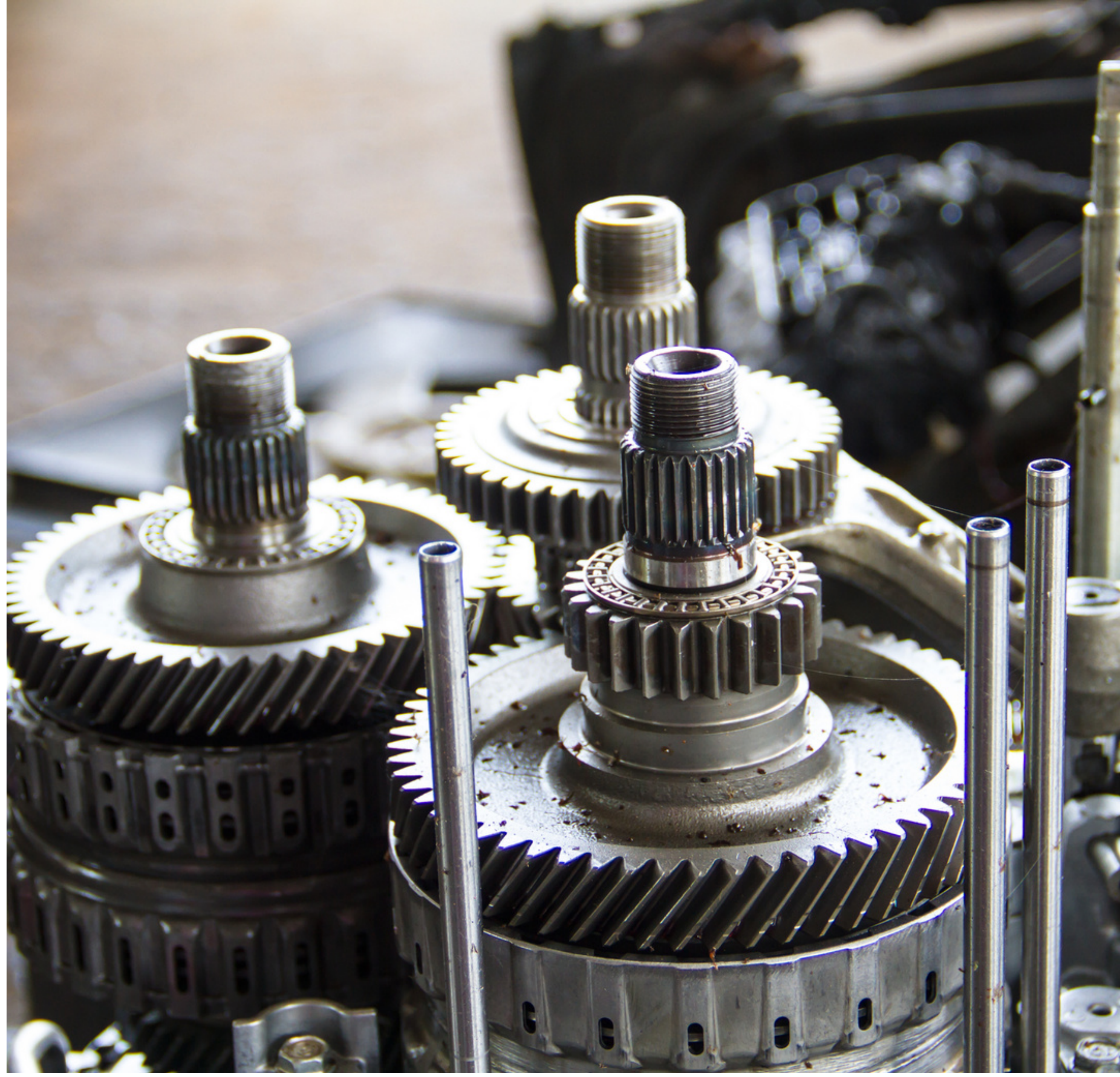
INTRODUCTION

It is known that the effect of electric resistance and magnetic losses (either hysteresis or eddy currents) or the friction losses from rotation takes the form of heat losses. All these losses decrease the efficiency and lifespan of any electric machine. Thus, several efforts were made to dissipate these heat loss.
There are various methods to cool or ventitalate a machine from self cooling fans to more complex methods using special cooling medium.



OVERVIEW

WHY IS COOLING NEEDED?

- When an electric motor is in operation, the rotor and stator losses generate heat.
- Efficient cooling has a significant impact on the lifetime of motor.
- The most vulnerable components to overheating are the isolation system and the bearings.

Isolation system	Bearings
Every 10°C over T_r, lifetime is divided by 2. Every 10°C below T_r,lifetime is multiplied by 2.	Every 15°C over T_r, lifetime is divided by 2. Every 15°C below T_r,lifetime is multiplied by 2.

OVERVIEW

WHAT ARE THE BENEFITS OF APPROPRIATE COOLING?

- Efficient cooling has a significant impact on the lifetime of motor.
- The most vulnerable components to overheating are the isolation system and the bearings.

OVERVIEW

HOW TO CHOOSE THE BEST COOLING METHOD?

THE APPLICATION

The type of use with which the motor will be used critically defines the loading conditions as well as the rated values.

OVERVIEW

HOW TO CHOOSE THE BEST COOLING METHOD?

THE APPLICATION

Not only does the motor's cooling method depend on the voltage level and the protection type (IP number), but also, the application in which the machine will be used at.

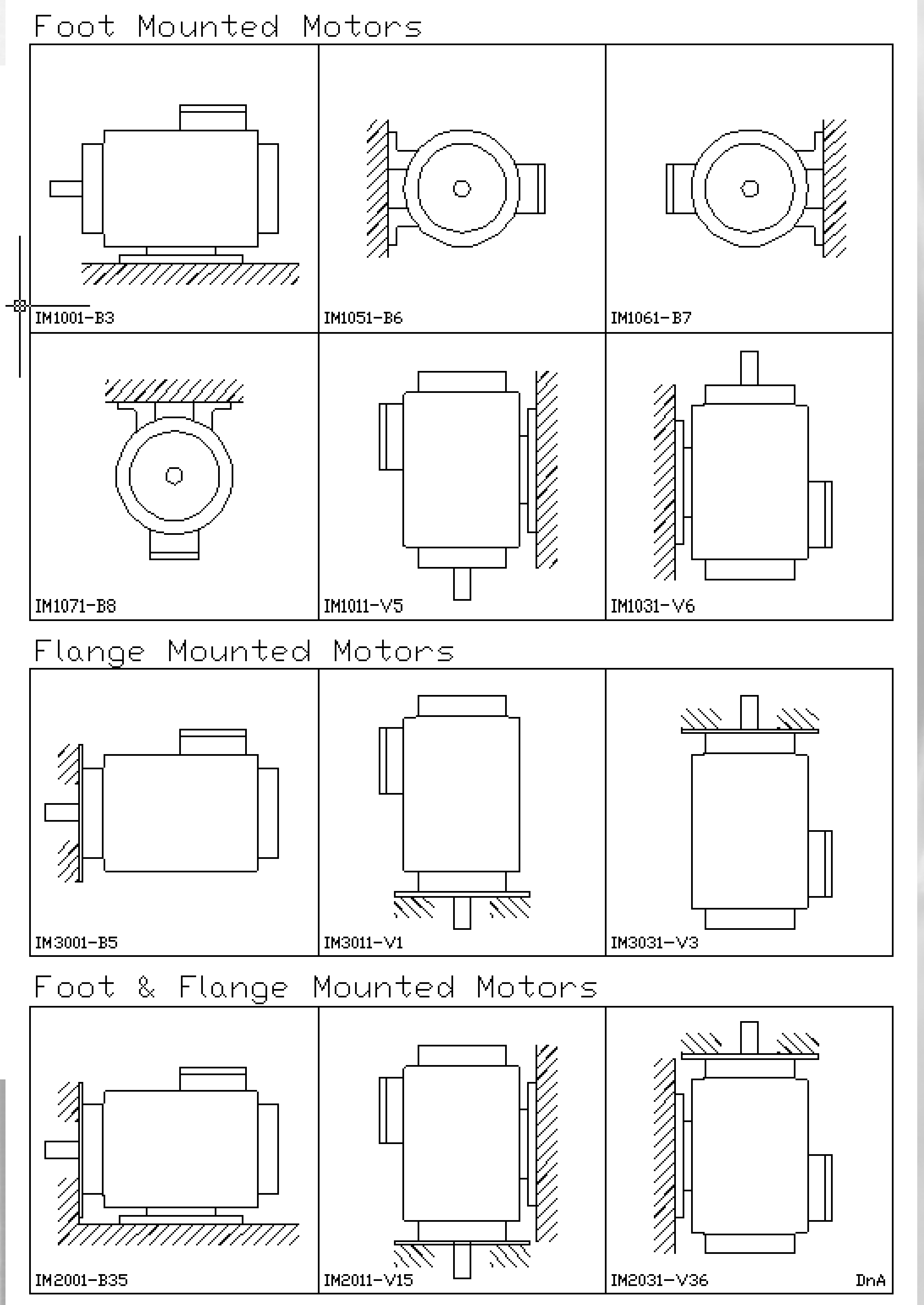
OVERVIEW

HOW TO CHOOSE THE BEST COOLING METHOD?

WHERE THE MOTOR IS MOUNTED?

The mounting code (IM code according to IEC standard 60034-7) takes into account:

- The position of the motor shaft
- The type of bearing shield
- Fastening of the machine
- Method of installation
- Nature of the shaft end



OVERVIEW

HOW TO CHOOSE THE BEST COOLING METHOD?

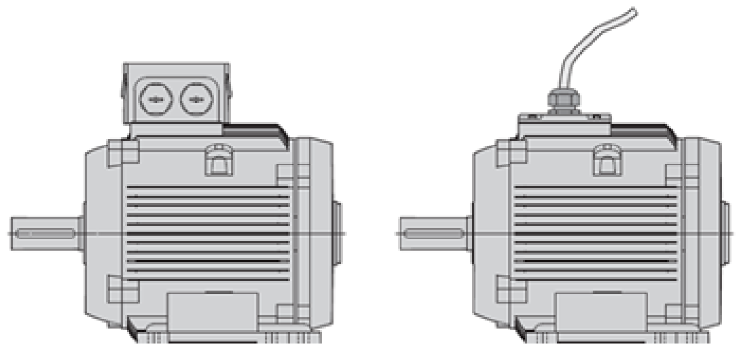
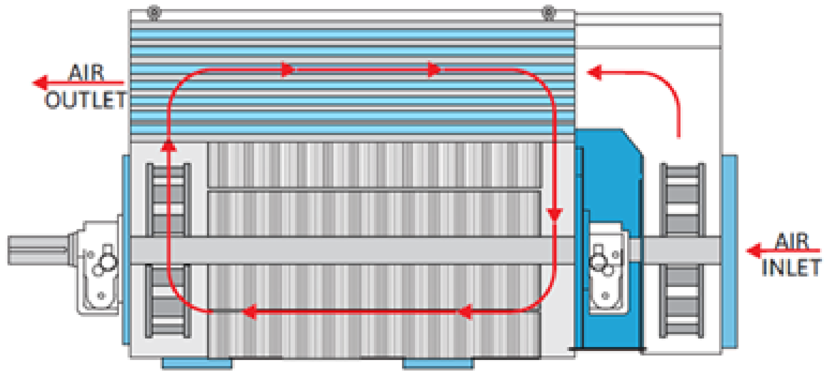
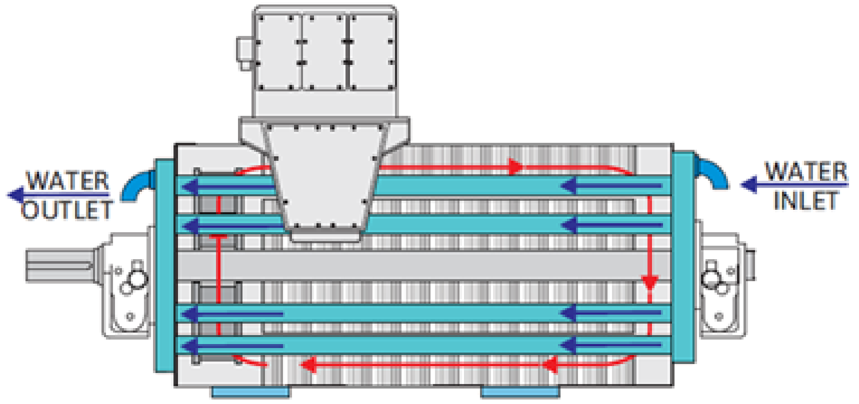
OPERATING ENVIRONMENT

Most industrial motors are used in well ventilated areas to provide sufficient cooling. However, some may require a higher protection against the environment (higher IP) and thus a higher IC cooling code.

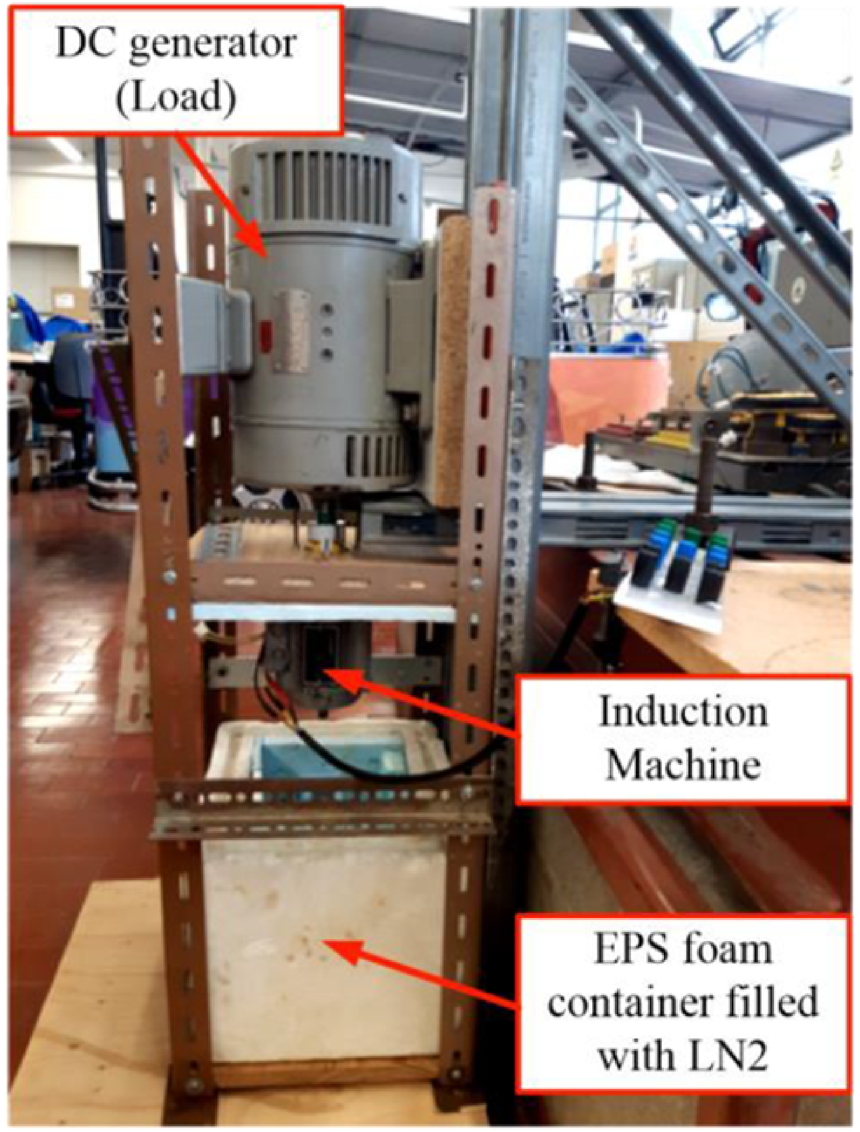
COOLING MEANS FOR INDUCTION MOTORS

Common cooling medium markings: "air" is A; "water" is W. In case, the cooling medium air mark A, it can be omitted.

Examples on cooling IC codes are:

IC410 - TENV - Totally Enclosed Naturally Ventilated (No fan)	
IC611 - (formerly IC 0161) - CACA - Air-Air cooling with integral fan on motor's shaft inside stator and heat exchanger with open external circuit with fan on motor's shaft.	
IC31W - Air-Water cooling with inlet and outlet pipe or duct for cooling water circulation.	

INDUCTION MOTORS USING CRYOGENIC COOLING



The apparatus setup of the experiment.

MACHINE CHARACTERISTICS

TABLE I
NOMINAL VALUES AND DESCRIPTION OF THE TESTED MACHINE

Induction machine	**Rated Values**
Voltage, (V)	40
Current, (A)	3.6
Power, (W)	90
Speed, (rpm)	1350
Frequency, (Hz)	50
cos(φ)	0.61
Materials	
Rotor cage	Aluminum die-cast
Stator windings	Copper distributed
Iron core	FeSi Alloy

TABLE II
EQUIVALENT CIRCUIT PARAMETERS AND MECHANICAL LOSSES FOR THE TESTED IM AT AMBIENT AND CRYOGENIC TEMPERATURES

Parameter	Amb. Temp. (20°C)	Cryo. Temp. (77K)	Difference
R_{fe}, (Ω)	116.4	104.3	-10.4%
X_m, (Ω)	7.33	7.24	-1.2%
R_S, (Ω)	1.10	0.175	-84.1%
R'_R, (Ω)	0.914	0.240	-73.4%
X_S, (Ω)	0.532	0.532	+0.0%
X'_R, (Ω)	0.532	0.532	+0.0%
P_{losses_mec}, (W)	1.96	3.83	+95.4%

TEMPERATURE MEASUREMENT

In order to measure the temperature change according to the current level during the no load test, three separae temperature sensors were use, two of which are in cotact with the rotor (Tbot and Ttop) and the other was installed in the air gap (Tgap)

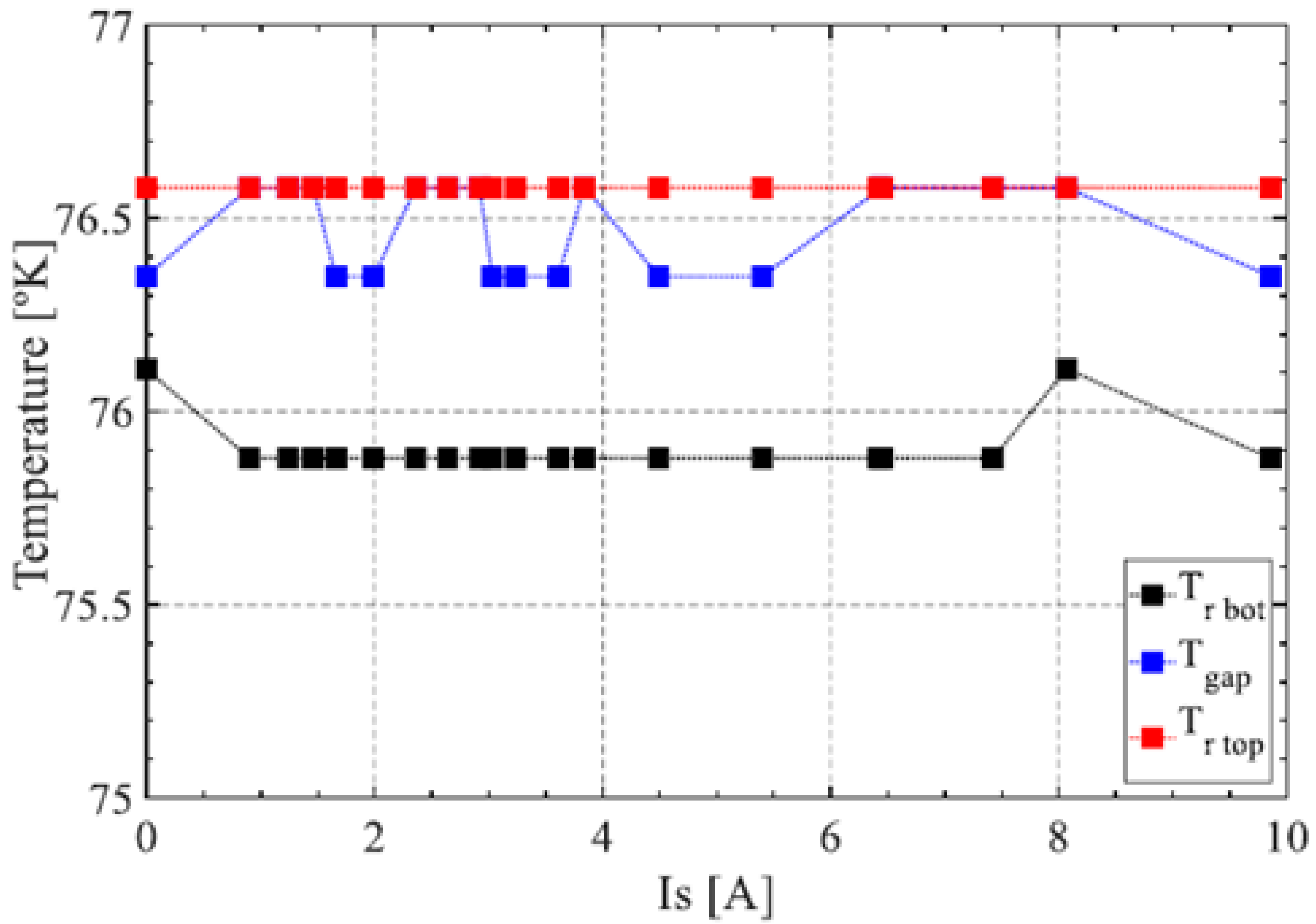


Fig. 8. No-load test. Temperature of cryogenic sensors at the airgap (T_{gap}) and at the top (T_{r_top}) and bottom (T_{r_bot}) of the rotor.

When measuring the temperature of different parts of the rotor being immersed in LN2, it was found that all the parts did not exceed the boiling point of LN2 (i.e. 77K) but there was quite a small gradient in temperature.

EXPERIMENTAL SETUP

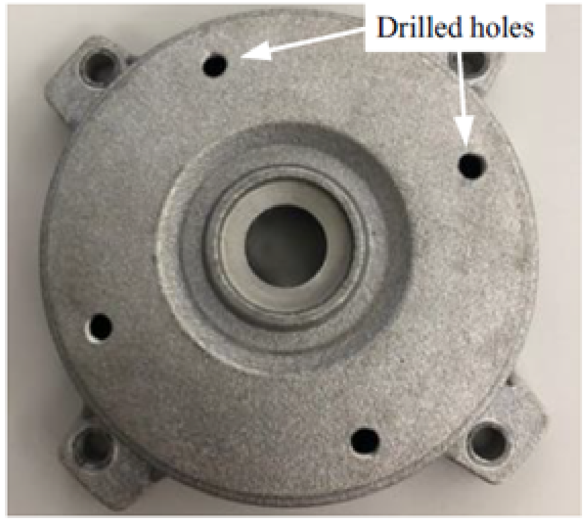


Fig. 6. Drilled holes in the IM cover to allow liquid nitrogen inside.

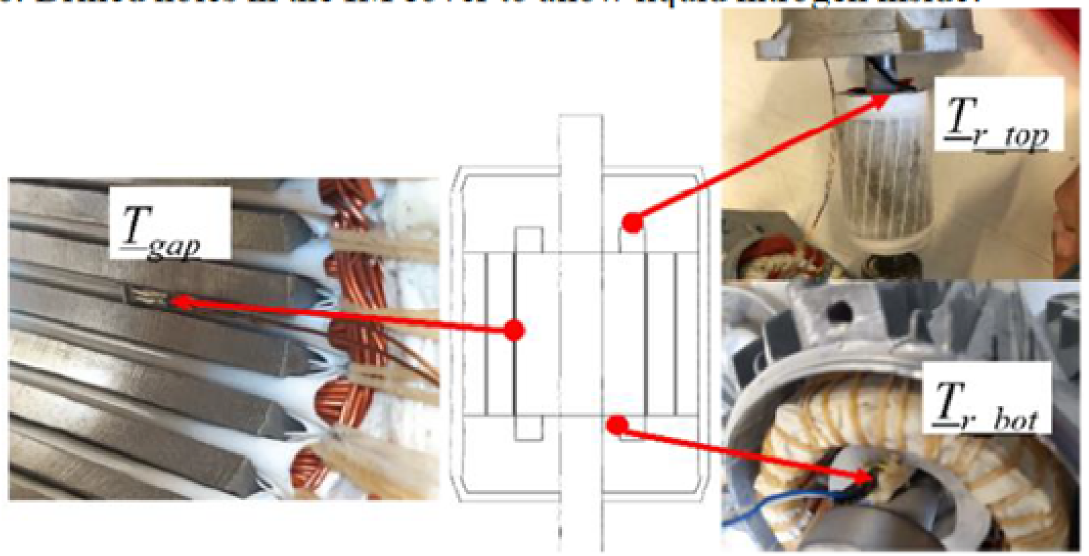


Fig. 7. Position of cryogenic temperature sensors.

OUTPUT VALUES

Comparison between ambient temperature and cryogenic conditions (each at maximum efficiency)

TABLE III
SUMMARIZED PERFORMANCE FOR THE TESTED IM AT MAXIMUM EFFICIENCY POINT AND AT SAME TORQUE FOR AMBIENT AND CRYOGENIC OPERATIONS (% VARIATIONS WITH RESPECT TO AMBIENT CONDITIONS)

	Ambient temperature.	Cryogenic temperature			
		@ max. efficiency		@ same torque	
Maximum efficiency, (%)	63.0 (s=10.9%)	85.2 (s=4%)	+35%	79.7 (s=1.5%)	+16.7%
Stator current, (A)	3.3	6.7	+103%	4.0	+21%
Torque, (Nm)	0.72	1.95	+171%	0.72	
Rotor speed, (rpm)	1353	1441	+7%	1477	+9%
Mechanical output Power, (W)	102.0	294.3	+189%	111.4	+9%
Mechanical losses, (W)	1.96	3.83	+95%	3.7	+89%
Iron losses, (W)	12.5	14.5	+16%	14.4	+15%
Stator Joule losses, (W)	35.9	23.3	-35%	8.4	-77%
Rotor Joule losses, (W)	9.6	9.5	-1%	1.8	-81%

OUTPUT VALUES

Comparison between ambient temperature and cryogenic conditions

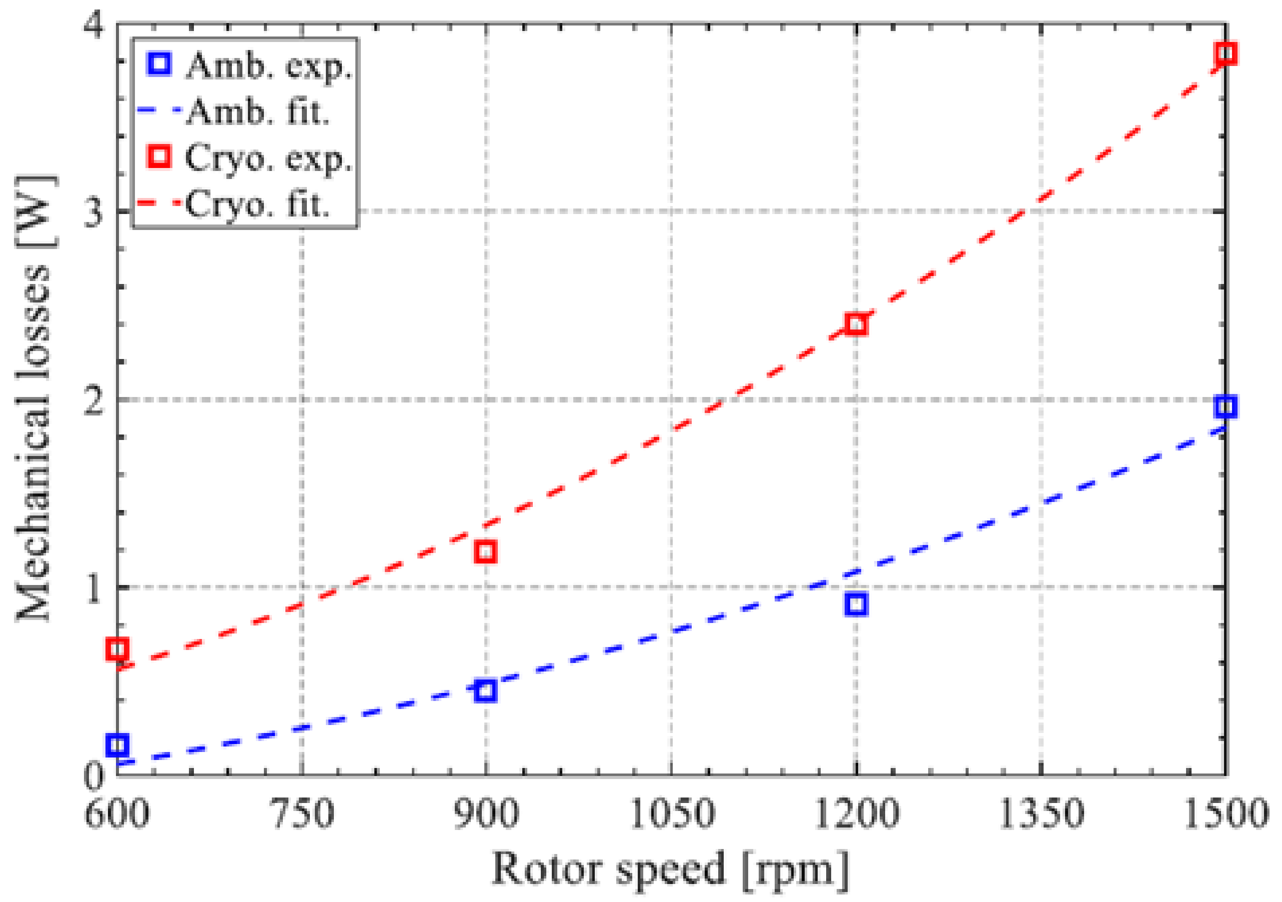


Fig. 11. Comparison between ambient temperature and cryogenic mechanical losses for different frequencies.

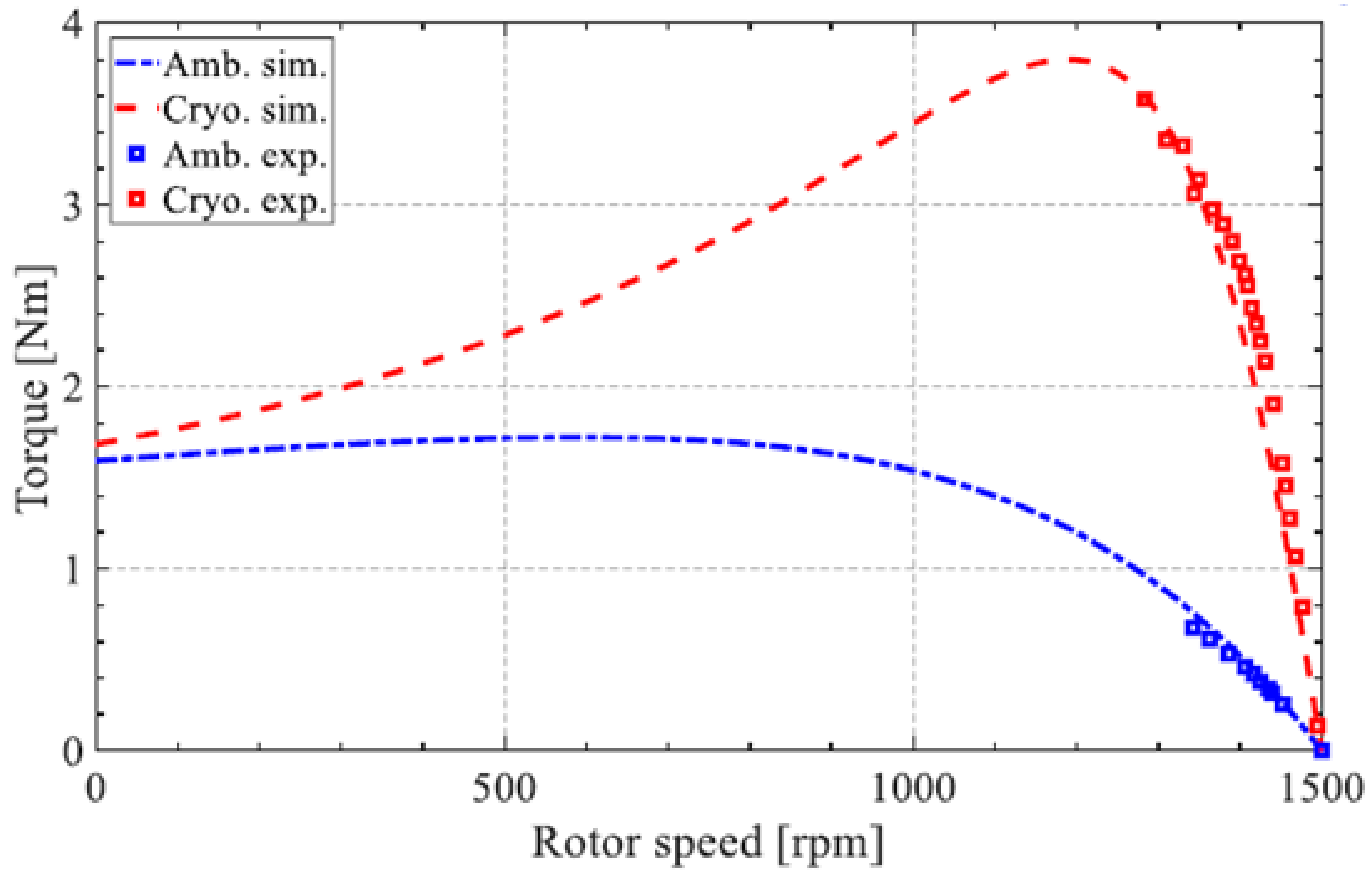


Fig. 12. Toque as a function of the rotor speed for the investigated IM.

CONCLUSION

Several efforts have been made to deal with the heat losses during machine operation. The IEC standard specifies the cooling mode, that is, the medium to be used and the type of external cooling installations (e.g., external cooling fan, water pump, etc.).
There are other cooling methods such as cooling using liquid nitrogen LN2 to circulate inside the machine parts (i.e. rotor, stator and air gap) to ensure maximum possible efficiency.

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