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Keywords of the Tutorial:
Ferromagnetism, electrical steels, magnetic alloys, iron losses, permeability, electrical machines

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Abstract:
Soft crystalline magnetic materials

Ferromagnetic materials play a key role in electrical machines: their presence in the cores of these machines can greatly influence the torque / power developed, as well as their efficiency. This works via the mechanism of flux concentration: if a current carrying conductor coil is placed around a ferromagnetic material, much more magnetic flux can be generated for a given current; and this flux is important for the torque developed by a motor or the energy transferred in a transformer.
The tutorial starts with the principles of ferromagnetism and develops further into what happens during magnetisation processes, within the structure of typical ferromagnetic materials such as FeSi (electrical steels), FeCo and FeNi. Phenomena such as hysteresis, eddy currents, magnetic domains, Curie temperature, soft versus hard materials, are explained.
The parameters that influence the level of flux concentration, as well as the level of energy losses within the ferromagnetic material are shown.
The target of the tutorial is to clarify what are the differences between magnetic materials on the market, to show their key advantages and weaknesses. The different classes of magnetic materials will be explained: soft vs. hard, crystalline vs. amorphous, ferrites vs. composites vs. laminations, non-oriented vs. oriented, fully processed vs. semi-processed. The most suitable magnetic material for different types of electric applications will be explained, with examples on their influence of machine performance.
The aim is to assist in a cost/performance choice when going into machine design and having a ferromagnetic material choice to make. This will be done in most detail for soft crystalline magnetic materials.

Outline

- The role of ferromagnetic materials in electrical machines, sensors, actuators
- Ferromagnetism:
  - what is happening inside the material on an atomic scale
  - which elements are ferromagnetic
  - how is this state effected by external fields, temperature (Curie temperature)
  - why do magnetic domains exist
  - which energy types affect the internal state of the material
- the primary role of ferromagnetic materials: flux concentration
- the side effect of ferromagnetic materials: losses
  - hysteresis losses
    - magnetic domain evolution in an AC cycle
    - parameters affecting the level of hysteresis losses
    - soft and hard magnetic materials
  - eddy current losses
    - the use of laminations
    - parameters affecting the level of eddy current losses
  - excess losses
    - relevance depending on application frequency
    - parameters affecting the level of excess losses
- comparison of the performance flux concentration – losses of different ferromagnetic materials
  - Fe, Ni, Co based
  - crystalline vs. amorphous
  - ferrites vs. composites vs. laminations
  - non-oriented vs. oriented
  - fully processed vs. semi-processed
- specific applications' needs in term of ferromagnetic material
  - different transformers types
  - selfs
  - sensors
  - actuators
  - relays
  - micro motors
  - household appliance motors
  - automotive auxiliary and traction machines
  - industry motors
  - hydro, wind and turbo generators
- future evolution

Sigrid Jacobs graduated in electro technical engineering at Ghent University in '88 and obtained an MBA at the Vlerick School for management in '91. After developing electrical steels at the metallurgy

lab of Ghent University, she joined the ArcelorMittal group. She first was involved in engineering projects for steel production. Then she continued the development of electrical steels in different plants from the group, in an international know-how exchange context. She is now the Portfolio Director for the group's activities in Electrical Steels. Scientific publications range from general metallurgy, to texture developments, as well as application oriented work such as magnetic or mechanical machine design. Sigrid is board member of the Belgian Electrotechnical Committee (IEC) and active participant to TC68 in the international standardisation of magnetic materials and measurement techniques.

Scientific work (limited extract over the last 5 years, reflecting different work aspects)

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