Dimensional Effects on Magnetic Properties of Fe–Si Steels Due to Laser and Mechanical Cutting

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Introduction

Different cutting techniques affect the cutting zone in a different way. At mechanical cutting plastic deformation appear in the zone near the cutting line. At laser cutting a thermal shock wave appear, which result in thermal stresses. The changes in the microstructure at the cutting edge have been intensively investigated by measurements of microhardness, changes in the grain structure, variation of the texture and of misorientation by using EBSD. Much less deterioration in the microstructure was found at laser cutting compared to mechanical cutting. There are not so much results on the deterioration effects oo the resulting magnetic properties: magnetization behavior and specific magnetic losses by the different cutting techniques as function of the size of the samples.

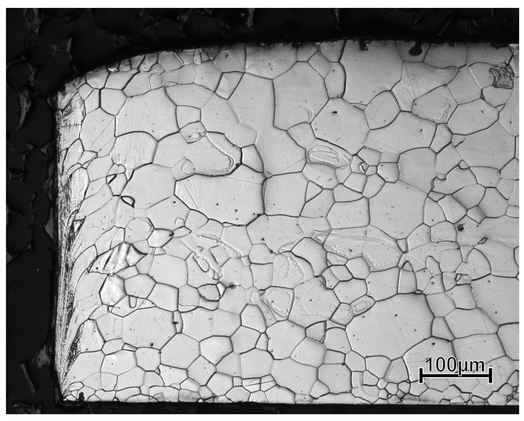
Experimental

The experimental investigated samples comprise conventional FeSi steels with different composition and different grain size as well as FeSi6.5 samples. Strips of different width (5mm to 30mm) as well as rings with different values of the inner diameter Ri and fixed outer radius Ra (Ra – Ri = 15, 10, 5 mm) were prepared by mechanical cutting and by laser cutting. The differences by the different cutting techniques on the microstructure was studied by metallographic investigations and by EBSD. In addition the microhardness as function of the distance from the cutting edge was measured using a Zwick machine with a load of 0.2kg. The effects of the sample size on the magnetization behavior was studied by measuring the hysteresis loops using a Brockhaus magnetic measurement unit.

Results & Discussion

Microstructure

(A)



(B)

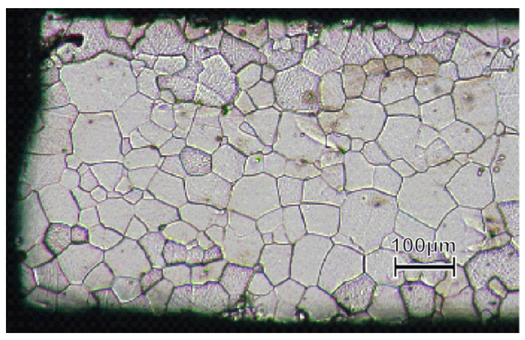


Fig. 1: Optical micrographs FeSi samples with medium Si-content: sample (A) – mechanical cutting sample (B) – laser cutting

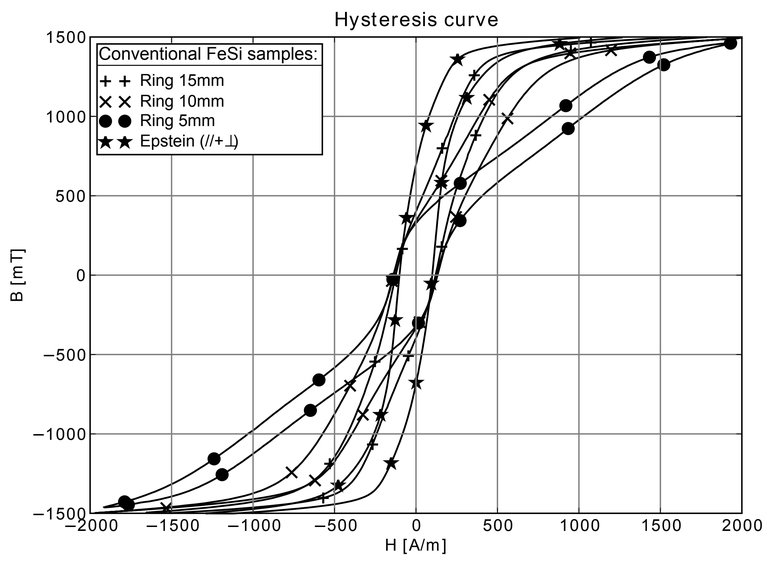


Fig. 2: Hysteresis loops laser cut rings, conv. FeSi.

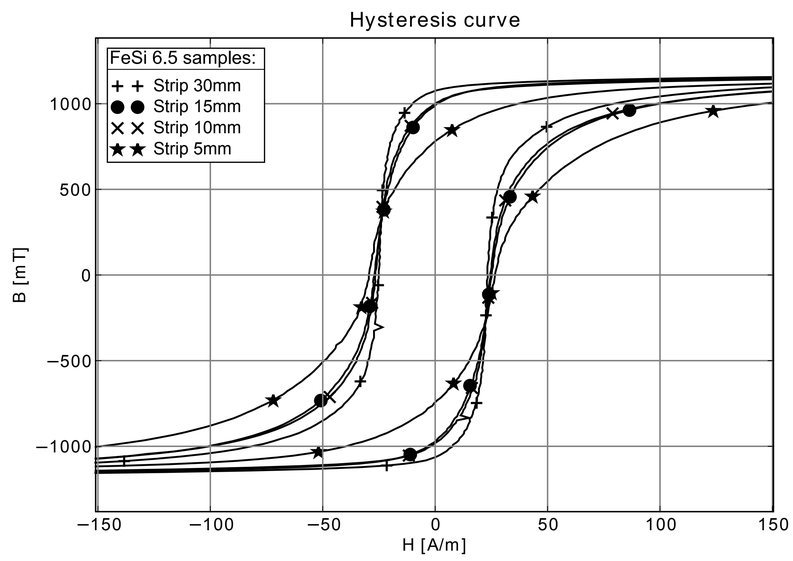


Fig. 3: Hysteresis loops laser cut strips, FeSi6.5.

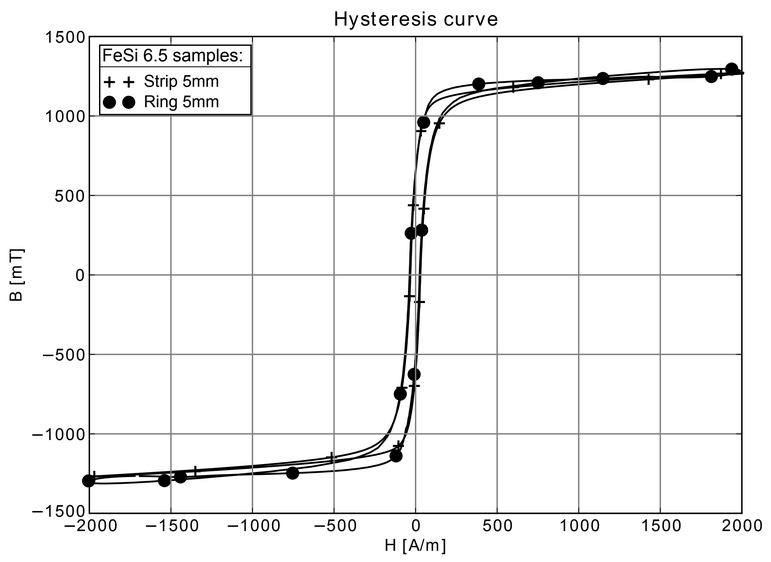


Fig. 4: Hysteresis loops laser cut rings and strips, FeSi6.5.

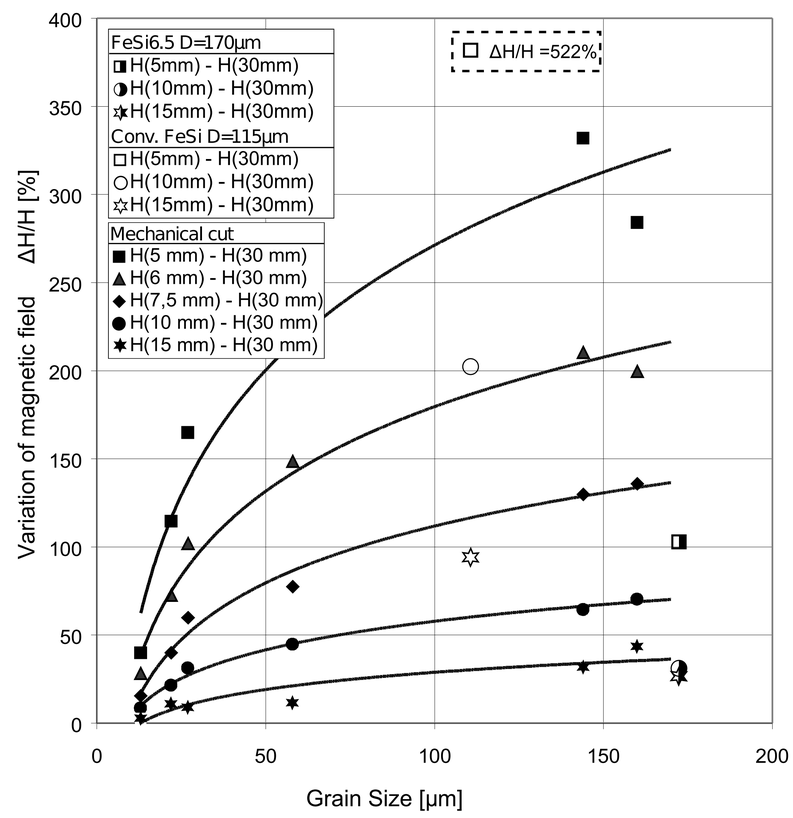


Fig. 5: Increase of magnetizing field at B = 1T as fct. of grain size and of the width at mechanical cutting (A. Schoppa, PhD 2001) and laser cutting.

Summary and Conclusions

The observed effects point to different underlying mechanism of the deterioration of the magnetic properties for these two cutting techniques. In the case of mechanical cutting there is a clear region of changes in the grain structure near the cutting edge due to elastic and plastic deformation. On the other hand there is no clear indication of a change of the grain size and texture for samples obtained by laser cutting. At laser treatment biaxial stresses: tensile stress as well as compressive stress appears]. Residual stress due to the thermal shock wave at laser cutting may be therefore the origin of the observed changes of the remanent induction, respectively the decrease of the permeability at higher magnetic fields.
The remarkable “size effect” (influence of the width of the samples) with respect to the deterioration of the magnetic properties demands for a different optimum choice of the material grade to reach a minimum of deterioration of the magnetic properties due to the different mechanism of deterioration of the magnetization behavior at mechanical cutting and laser cutting.