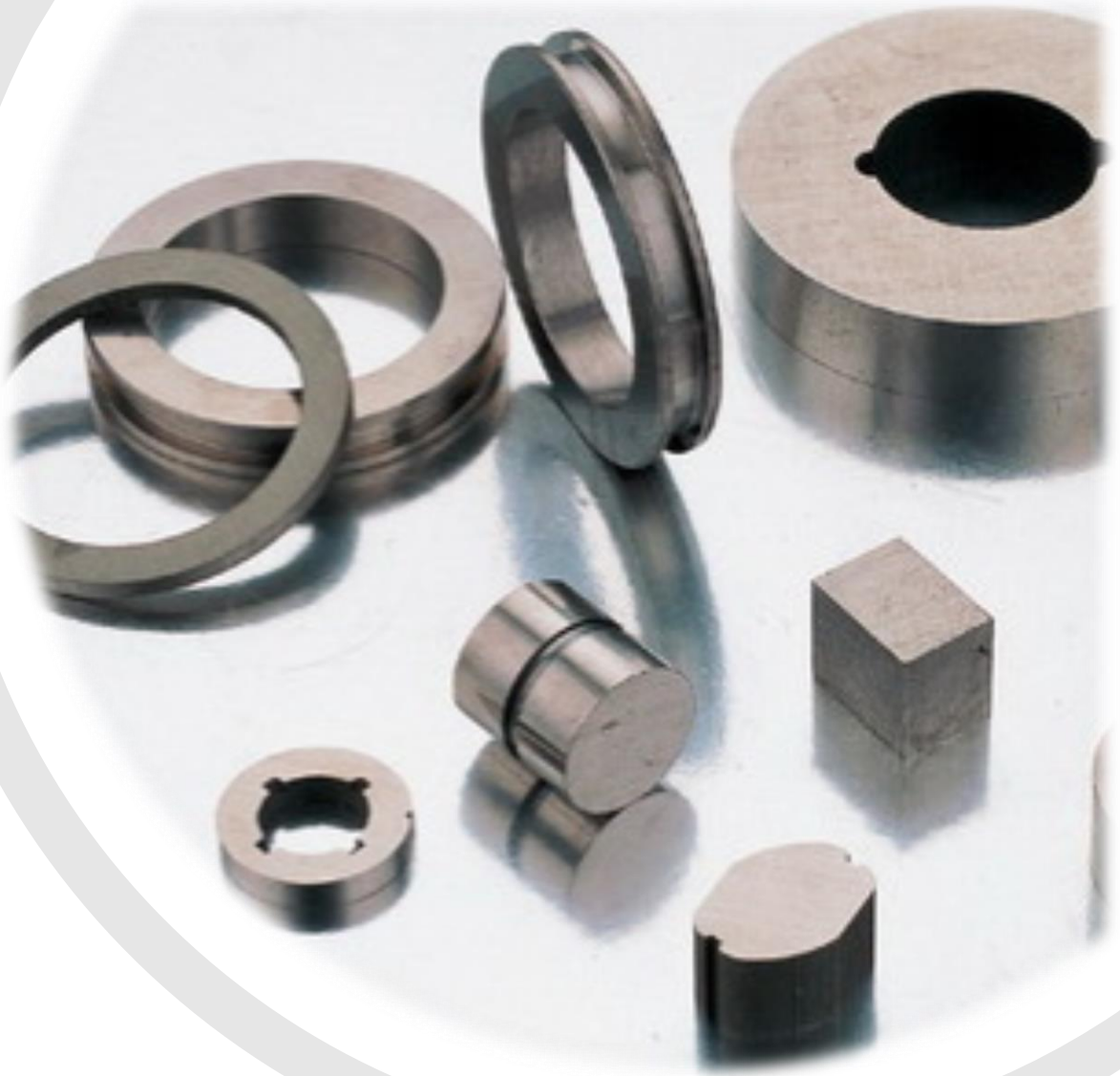
eit RawMaterials
Connecting matters

VALOMAG

2nd Seminar – Delft, the 6th December 2022

Dismantling and extraction of permanent magnets

N. Menad



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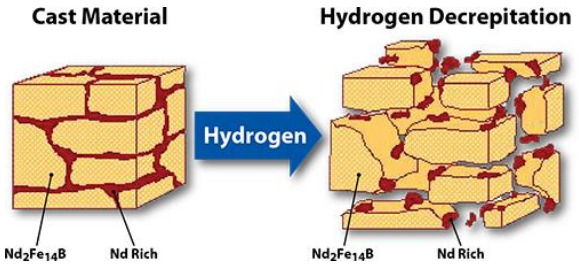
SUMMARY

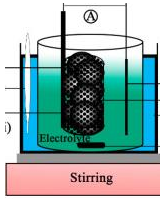
1. Introduction
2. Materials
3. Methodology
4. Characterisation of NdFeB magnets
5. Mechanical sorting (fragmentation and classification)
6. Smart size reduction test of permanent magnets recovered from HDDs
7. Masse balance
8. Conclusions

INTRODUCTION

Recycling methods of magnets

- Hydrogen decrepitation
- Pyrometallurgy
- Hydrometallurgy



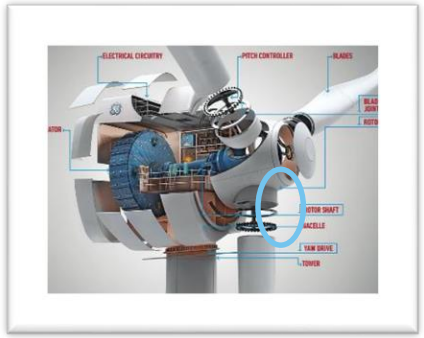


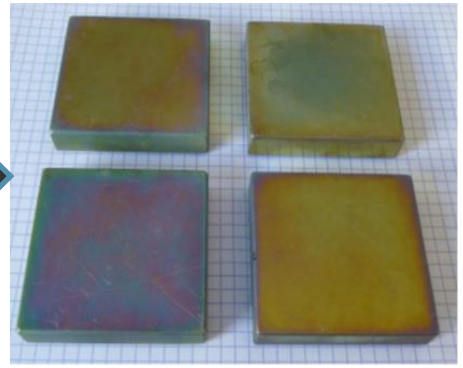
Magnet recycling barriers

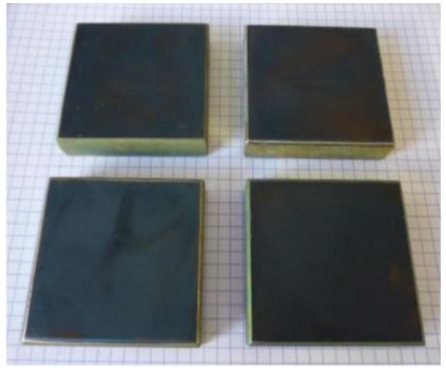
- Difficulties related to the dismantling of products due to their often compact and complex design
- Variation in chemical composition, even within the same application
- Strict requirement of the REEs market in terms of degree of purity
- Difficulties related to the separation between REEs due to their similar physico-chemical properties
- Presence of other undesirable metals, in particular Fe

Materials

Wind Turbine Magnets

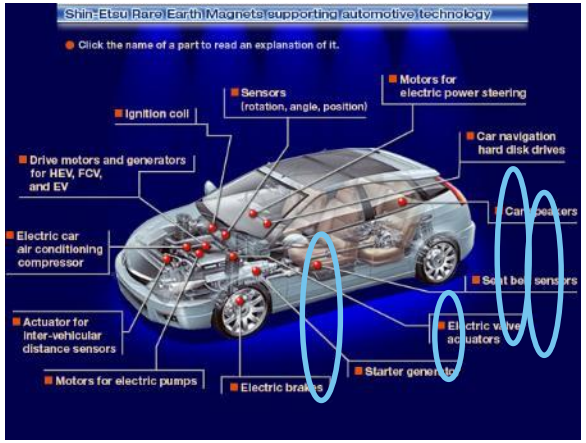






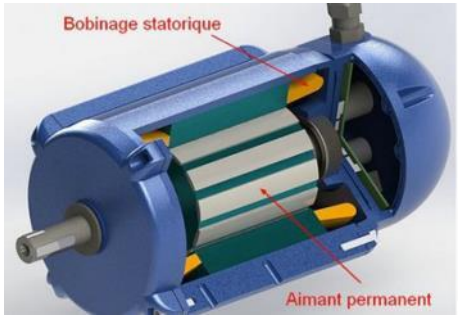
Hard disc drives from computers

Electric vehicles



Electric scooter

Electrical motors



METHODOLOGY

HDD magnets

Sampling → Representative samples and control of HDD types

Demagnetisation ← TG/DTA determination of Curie temperature

Recovery of magnets by manual dismantling → Using screwdrivers tools

A

Macroscopic analysis → Control the demagnetise magnets and determination of the magnet proportion in HDDs

Chemical analysis → ICP, MP-AES, AAS, MS and XRF analysis of magnets

Morphological aspects, particle size, liberation degree, qualitative analysis and thickness and composition of magnet coating. → Scanning Electron Microscopy analysis (SEM)

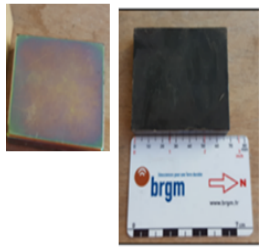
Determination of crystallised phases → X-Ray Diffraction (XRD)

wind turbine magnets

Wind turbine magnets → Representative samples and control of HDD types

Demagnetisation ← TG/DTA determination of Curie temperature

B



Macroscopic analysis → Control the demagnetise magnets and determination of the magnet proportion in HDDs

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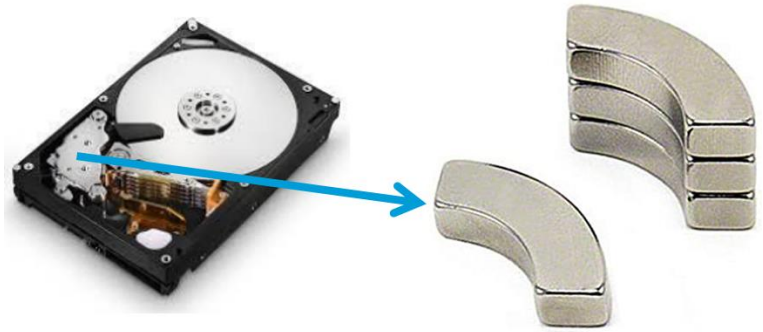
Morphological aspects, particle size, liberation degree, qualitative analysis and thickness and composition of magnet coating. → Scanning Electron Microscopy analysis (SEM)

Determination of crystallised phases → X-Ray Diffraction (XRD)

CHARACTERISATION OF NdFeB MAGNETS

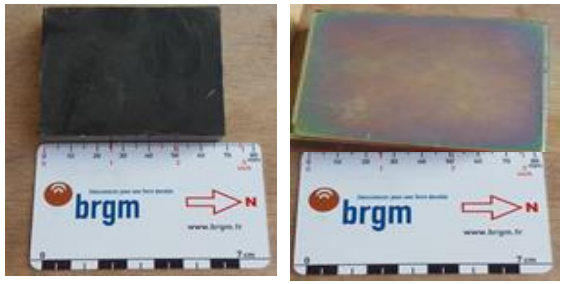
Chemical composition



HDD magnets

elements	B	Co	Dy	Fe	Nd	Ni	Pr
Wt %	0.9	1.5	1.2	62.6	22.8	0.6	3.3
RSD (%)	1.4	3.2	3.0	1.4	7.9	8.5	1.9

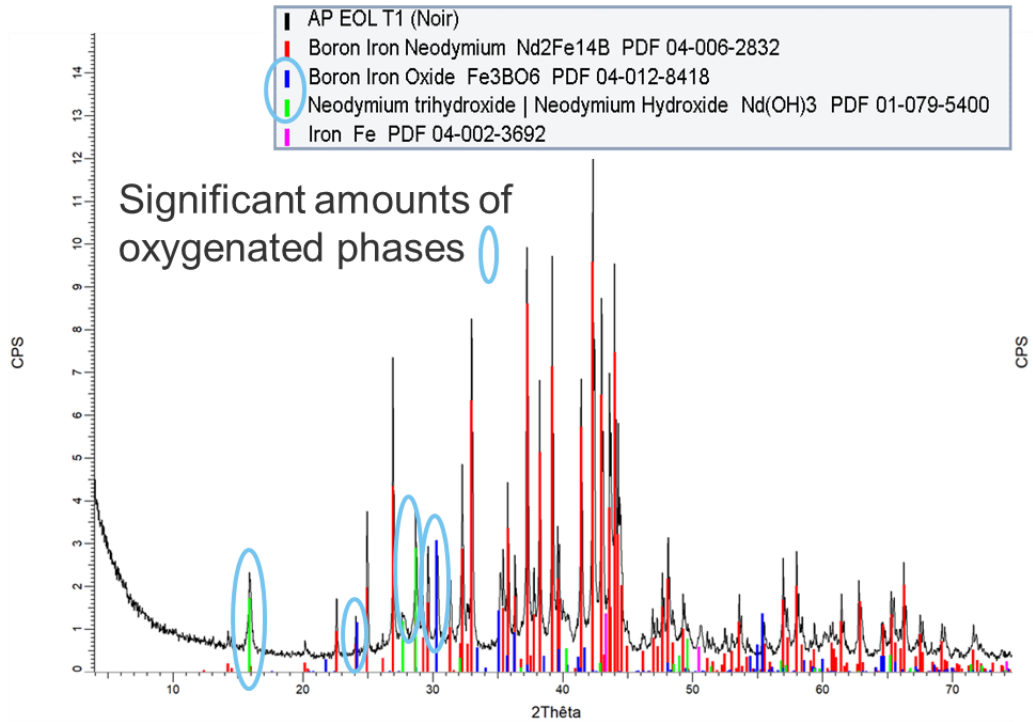
WT magnets

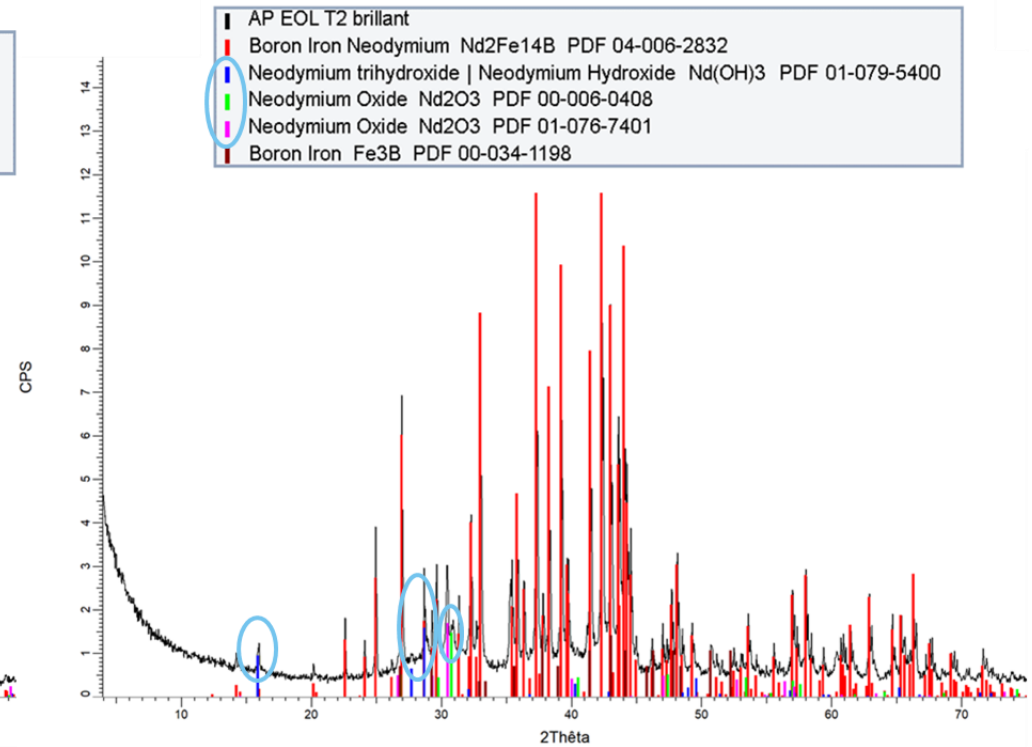


	Shinny PM		Black PM	
%	Mean value	RSD	Mean value	RSD
Fe	64.6%	5.4%	68.0%	2.0%
Nd	23.9%	0.2%	19.0%	0.6%
Dy	3.1%	1.1%	0.0%	2.1%
Co	1.4%	4.9%	0.1%	0.5%
B	1.0%	6.3%	1.0%	1.3%
Pr	0.7%	1.1%	6.0%	0.3%
Ca	0.7%	1.6%	0.5%	2.3%
Al	0.6%	3.9%	0.7%	1.5%
Zn	0.4%	7.3%	0.0%	10.6%
Cu	0.1%	9.0%	0.2%	1.3%
Tb	0.1%	1.2%	0.00%	4.6%
Nb	0.1%	7.6%	0.00%	10.8%
Ti	0.03%	1.0%	0.01%	2.6%
Ni	0.01%	0.7%	0.01%	3.7%
Mo	0.01%	0.7%	0.01%	2.0%
Gd	0.01%	0.8%	2.93%	1.1%
Ce	0.00%	0.3%	0.01%	1.8%
La	0.00%	0.2%	0.00%	1.3%
Ho	0.00%	2.1%	0.01%	4.8%
V	0.00%	2.3%	0.06%	0.6%
Zr	0.00%	30.5%	0.02%	6.8%
Ga	0.00%	7.7%	0.00%	2.3%
Er	0.00%	1.9%	0.00%	2.1%
Si	0.00%	2.9%	0.00%	7.8%
Eu	0.00%	11.5%	0.00%	5.2%

Permanent magnets from wind turbines

Mineralogical characterization





Type 1, Black

Type 2, shinny

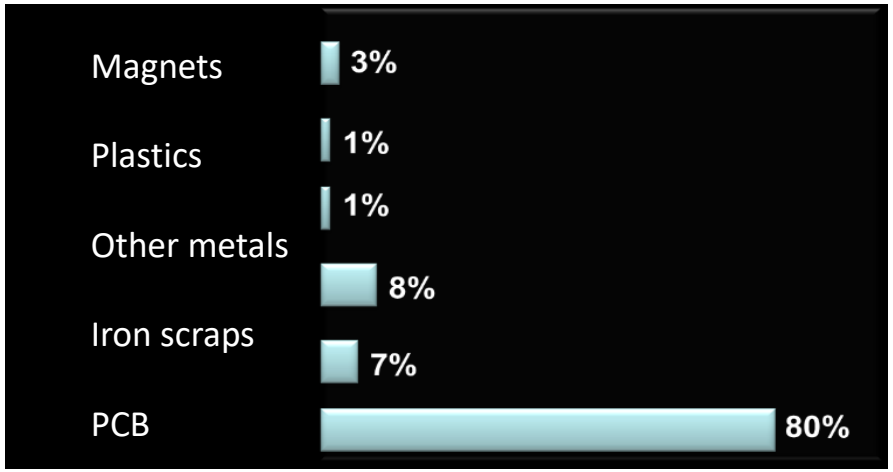
- Those magnets are both NdFeB type permanent magnets
- Type 2 magnet seems to be a higher grade of permanent magnets

CHARACTERISATION OF NdFeB MAGNETS

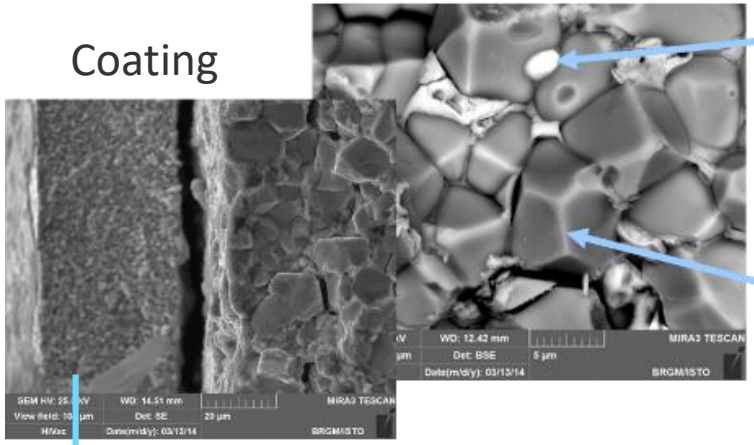
Hard Drive Permanent Magnet:

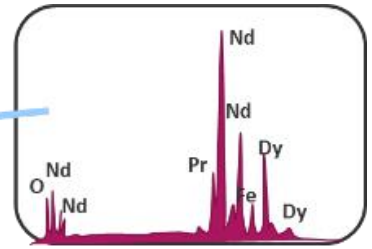
- $Nd_2Fe_{14}B$ phase + intergranular phase
- Coating 20-30µ (Ni, Cu, Zn, epoxy, etc.)

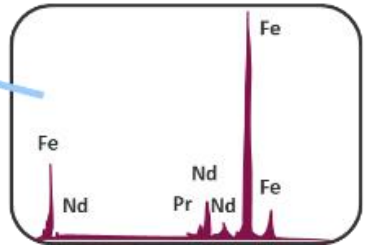
Chemical composition of HDD

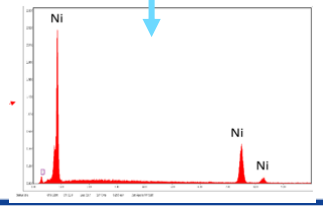


Coating









Morphological aspects of PM (SEM/EDS)

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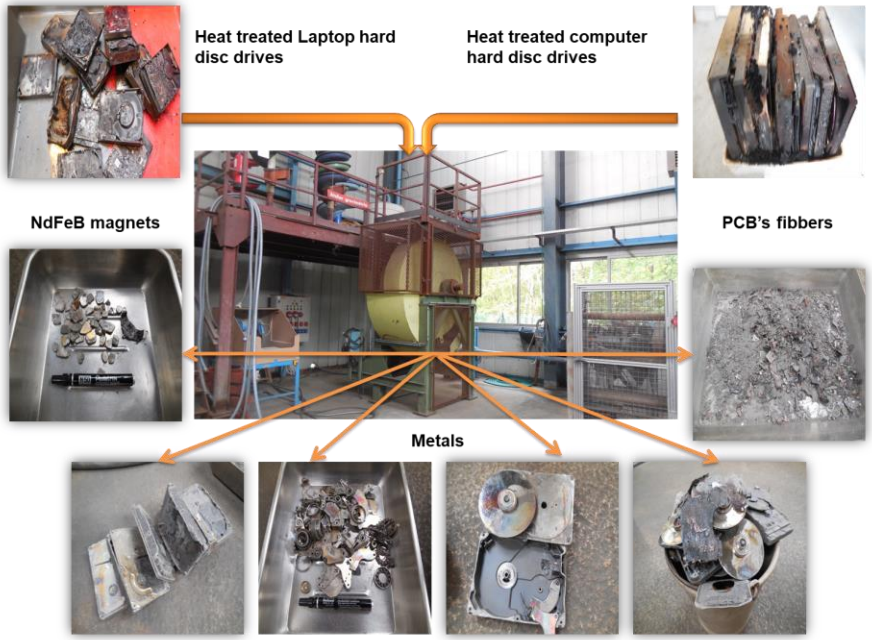
MECHANICAL SORTING (FRAGMENTATION AND CLASSIFICATION)



Hard disk Drives

Demagnetization (300-350°C)

Grinding (Autogenous)

Classification

1/5 mm | *5/16 mm* | *>40 mm* → Metals mix

20/40 mm → magnets rich fraction

Physical sorting

Other metals

Magnets

Crushing

Grinding (-2 mm)

Metallurgy

Nd, Dy, Pr

Fe, Ni, Cu

Metallurgy

Cu

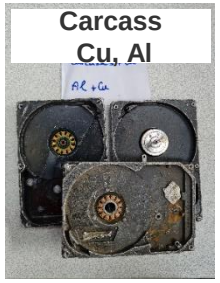
Al

Steel

MECHANICAL SORTING (FRAGMENTATION AND CLASSIFICATION)

HDD Components obtained after classification

Al & PCB rich fraction > 40 mm

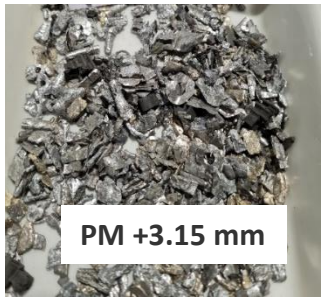


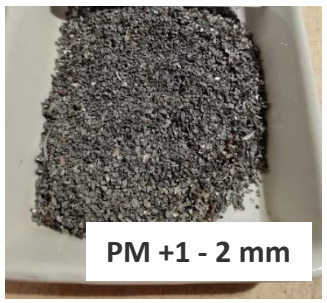
Iron scrap rich fraction 16/20mm and 20/40 mm

Magnet rich fraction 5/16mm

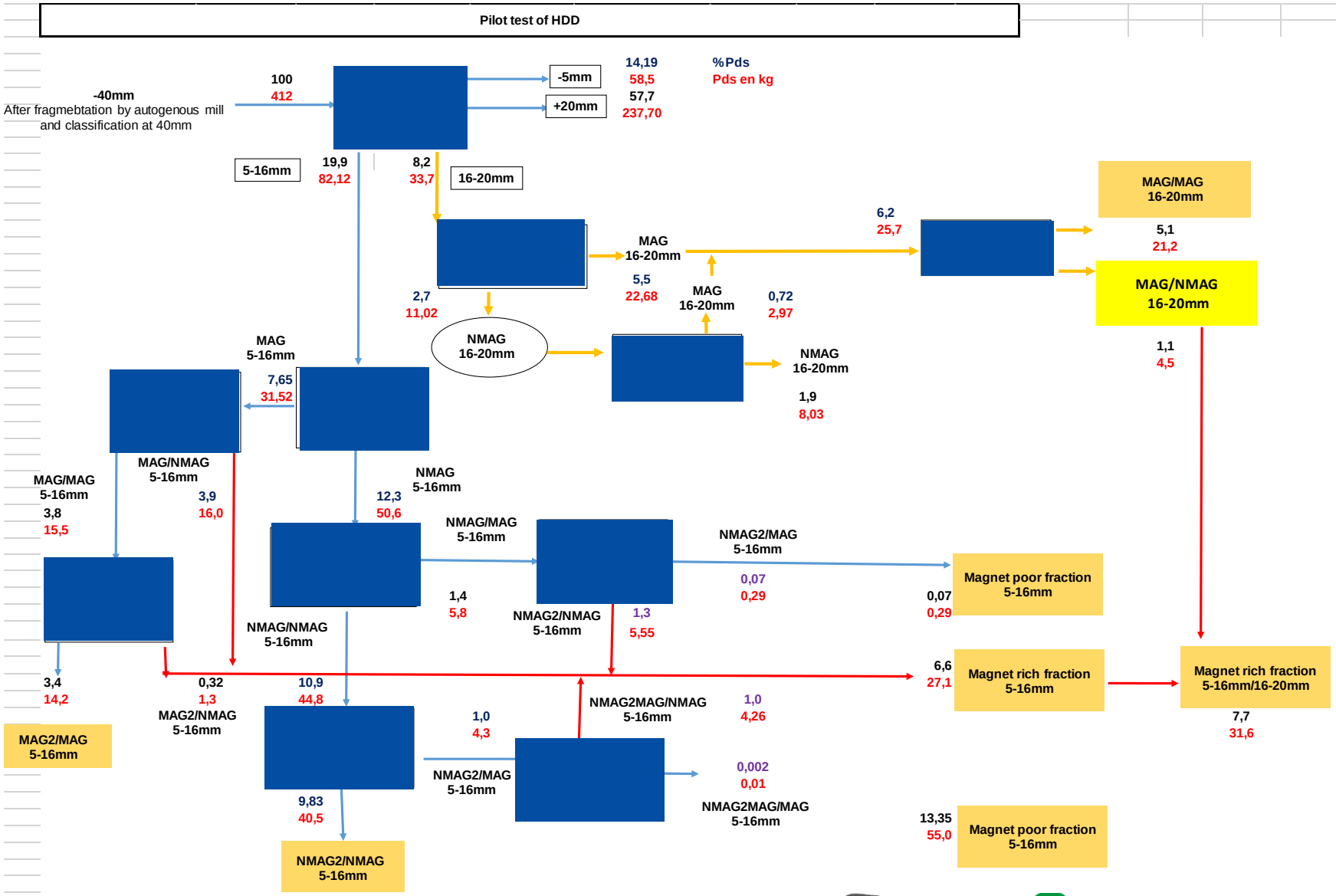
Metal mixtures rich fraction < 5 mm

SMART SIZE REDUCTION TEST OF PERMANENT MAGNETS RECOVERED FROM HDDS





MASS BALANCE



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MASS BALANCE

Products	kg	%Wt
Input	1705	100
Classification		
Iron scrap	142,72	8,37
PCB	39,44	2,31
Aluminium	1027,08	60,24
mixture	83,76	4,91
+40mm	**1293**	**75,84**
Classification		
20/40 mm	**237,70**	**13,94**
Physical sorting		
MAGMAG	21,2	1,24
MAGNMAG	4,5	0,26
NMAG Sep MF	8,03	0,47
16/20mm	**33,7**	**2,0**
Physical sorting		
Mag poor fr 5-	0,3	0,02
MAG2NMAG	40,5	2,37
Mag rich fr	**27,1**	1,59
MAG2MAG	14,2	0,83
5/16mm	**82,1**	**4,8**
- 5mm	**58,48**	**3,43**
Total	**1705**	100,00

CONCLUSIONS

Characterisation

- Microstructure: Matrix phase ($Nd_2Fe_{14}B$), intergranular phase REOx,
- Chemical composition: 70-72% Fe, 27-28% Nd, 2% Dy, 1%B, and 1-5% Pr.
- More other metals are present in WT magnets
- Optimization of parameters for the thermal treatment and fragmentation of HDD in order to recover PM

Process

- High performances of the developed processes, tested at pilot-scale:
  - PM Recovery about 95%
  - Magnet content: 88%
- Treatment of several tonnes of HDD
- Mass balance were done for LCA and LCC

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