

Establishment of Aluminum “Sash to Sash” Recycling by using XRT and XRF Sorters

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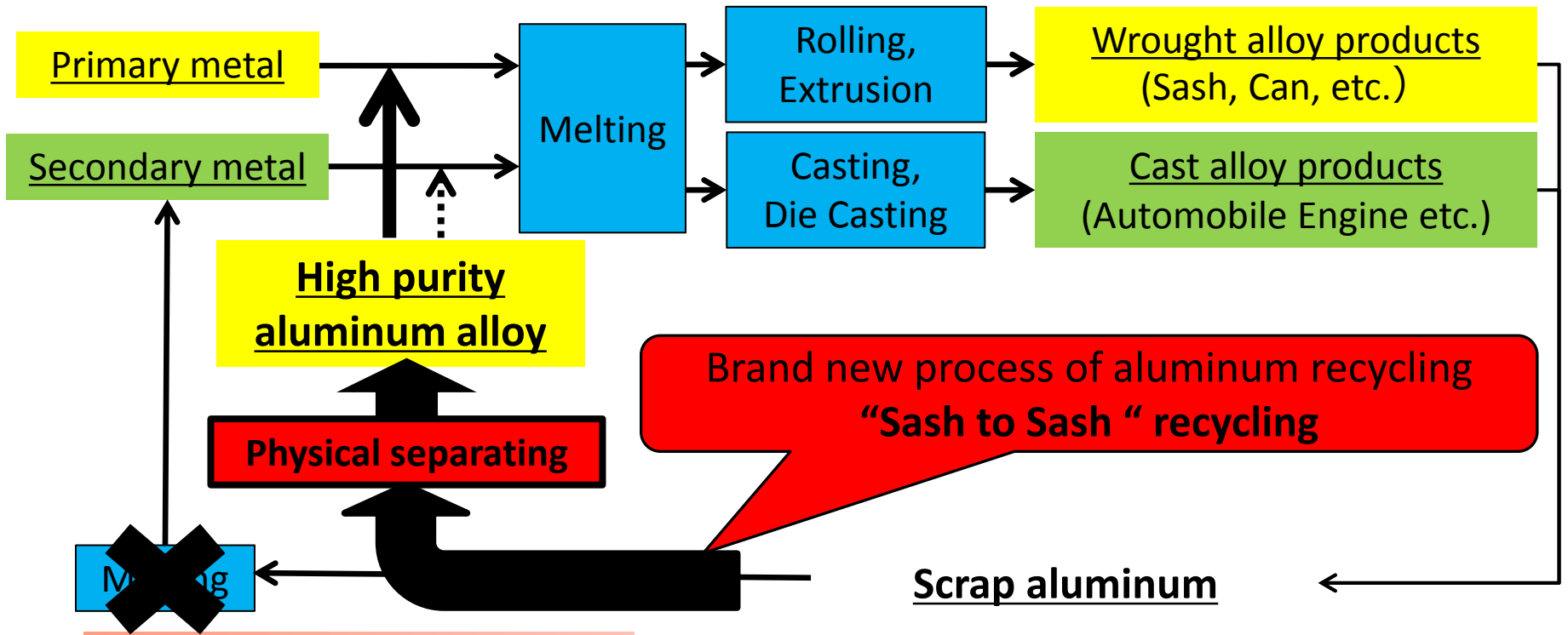
4. EarthTechnica Co., Ltd.

5. Pony Industry Co., Ltd.

6. Eriez Magnetics Japan Co., Ltd.

7. LIXIL Corporation

Background



Save huge energy

Calculated by Japan Aluminum Association

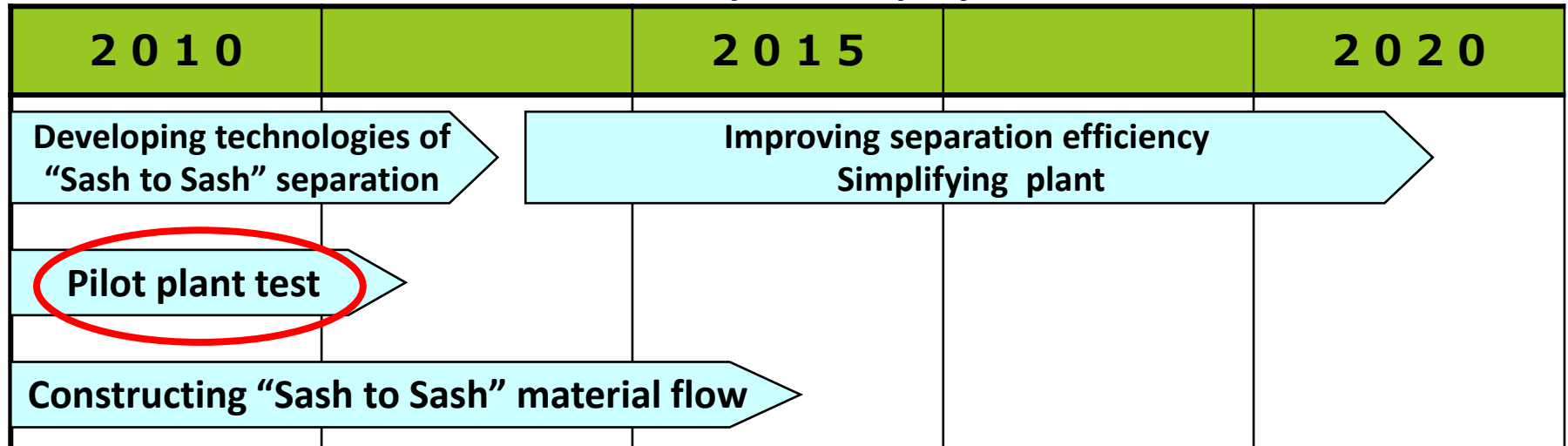
	2015	2020	2030
Amount of Energy Saving (ML/y, Crude Oil base)	140	470	1,630

* the energy consumption of rolling aluminum industry of Japan is **700 ML/y.**

Purpose

- Optimization of XRT and XRF sorters for achievement of “Sash to Sash” recycling.
- Evaluation of the grade and recovery of 6063 alloy in the final products processed by our original program in the Pilot Plant.
- Analysis of the chemical composition of the final products to determine if they had appropriate qualities as raw materials of aluminum sash.

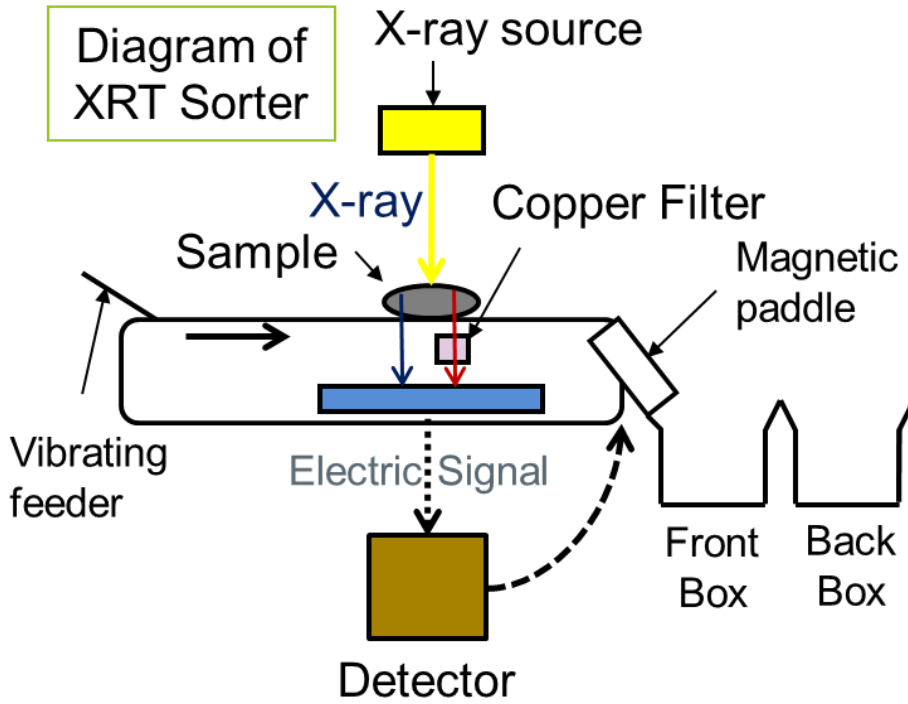
Roadmap of this project



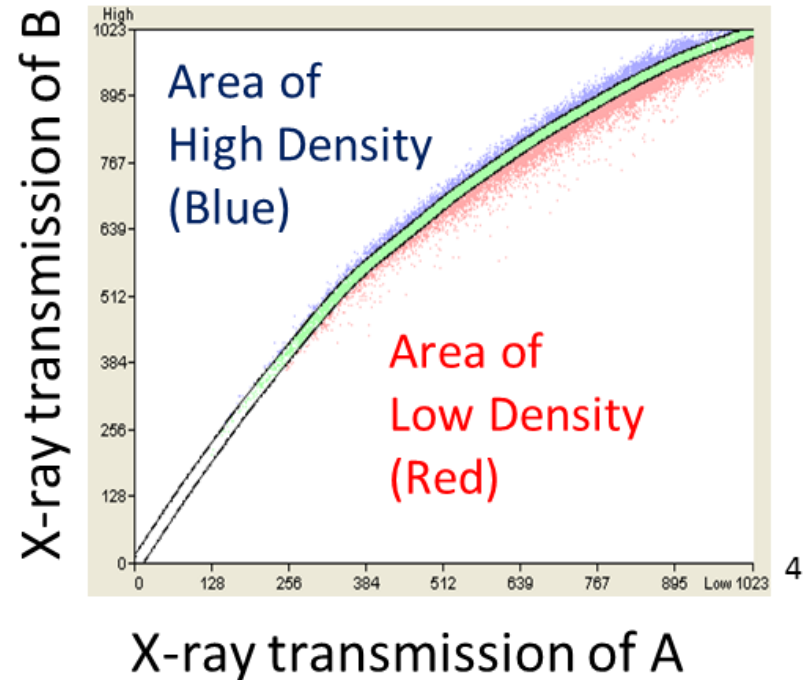
XRT Sorter

- Detecting the X-ray intensity transmitted.
- Separating materials by difference of mass absorption coefficients and density of compositional elements.

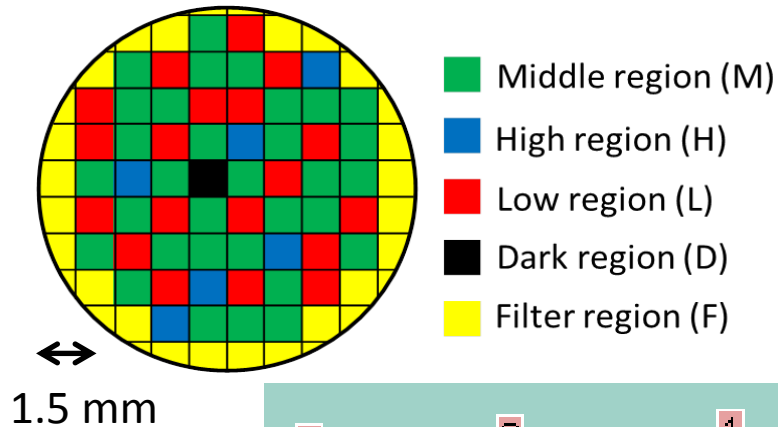
Diagram of XRT Sorter



Analyzing 2 types of XRT



Design the Optimum Program for Separation of 6063 Aluminum Alloy

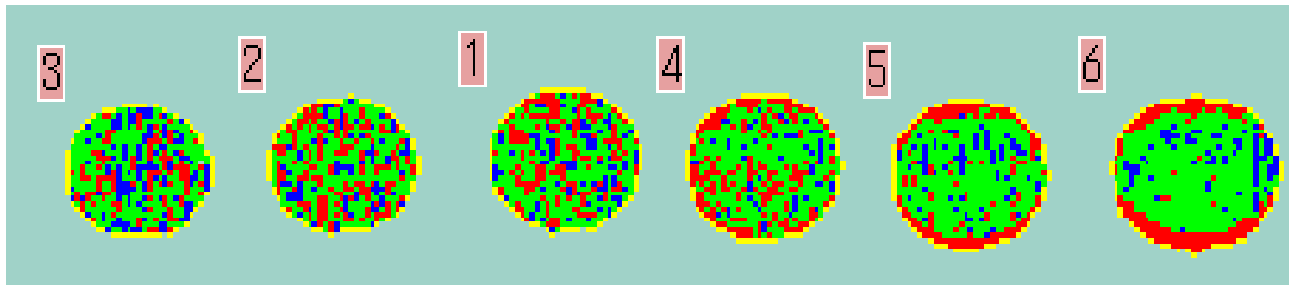


Dark region...

the area in which the X-ray intensity transmitted is lower than the threshold

Filter region...

the area in which the X-ray intensity transmitted cannot be measured



Simulation of the X-ray intensity transmitted through 6063 alloy standard sample
Thickness: 1, 1, 3, 7, 14, 25 mm (from left)

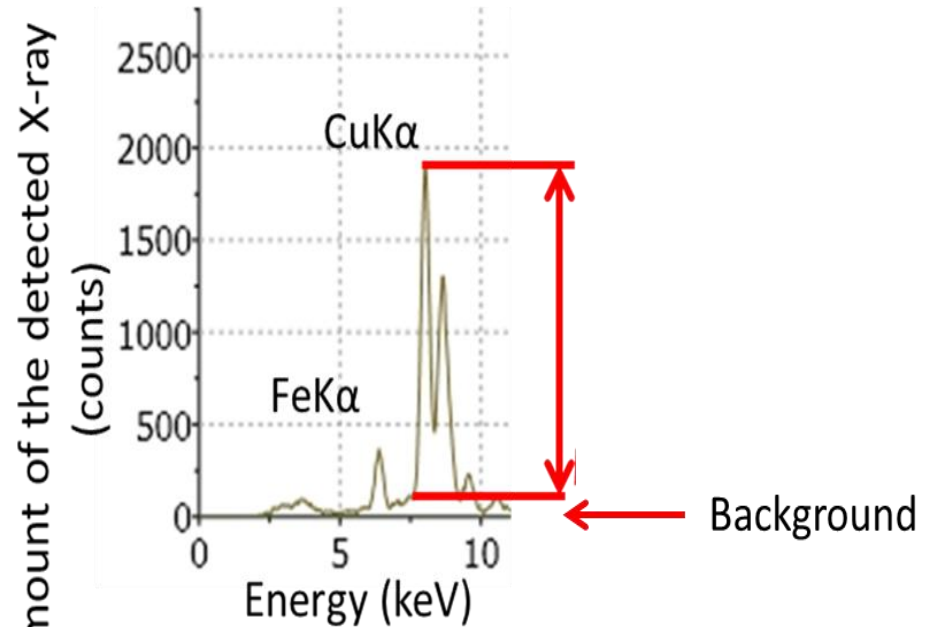
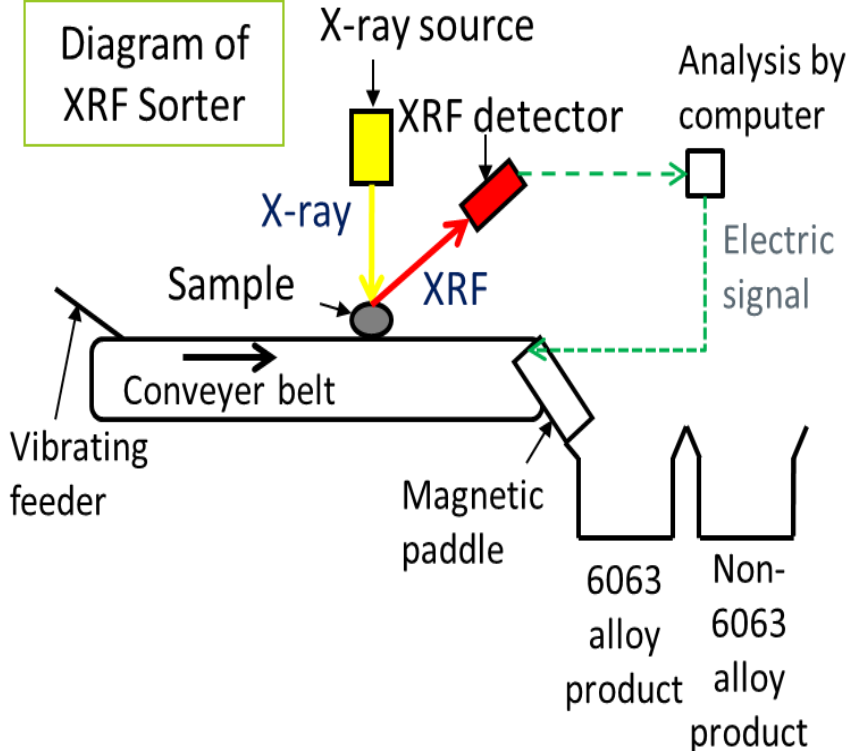
Optimum rates of the regions for separation of 6063 aluminum alloy

M: <46.00 % , H: >24.00 % and D: <1.00 %

XRF Sorter

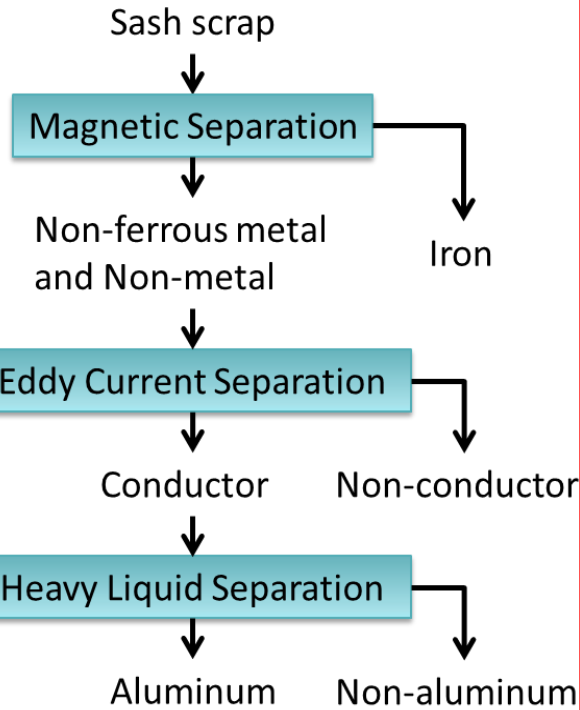
- Detecting specific spectra of the compositional elements
- Separating materials by the chemical composition

Diagram of XRF Sorter

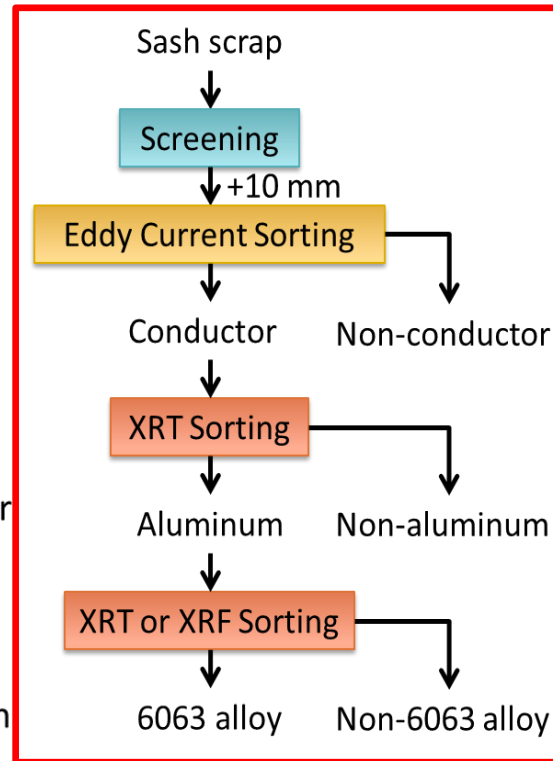


Spectrum of ADC12

Laboratory Scale Study



Traditional method



New method



Sash scrap sample

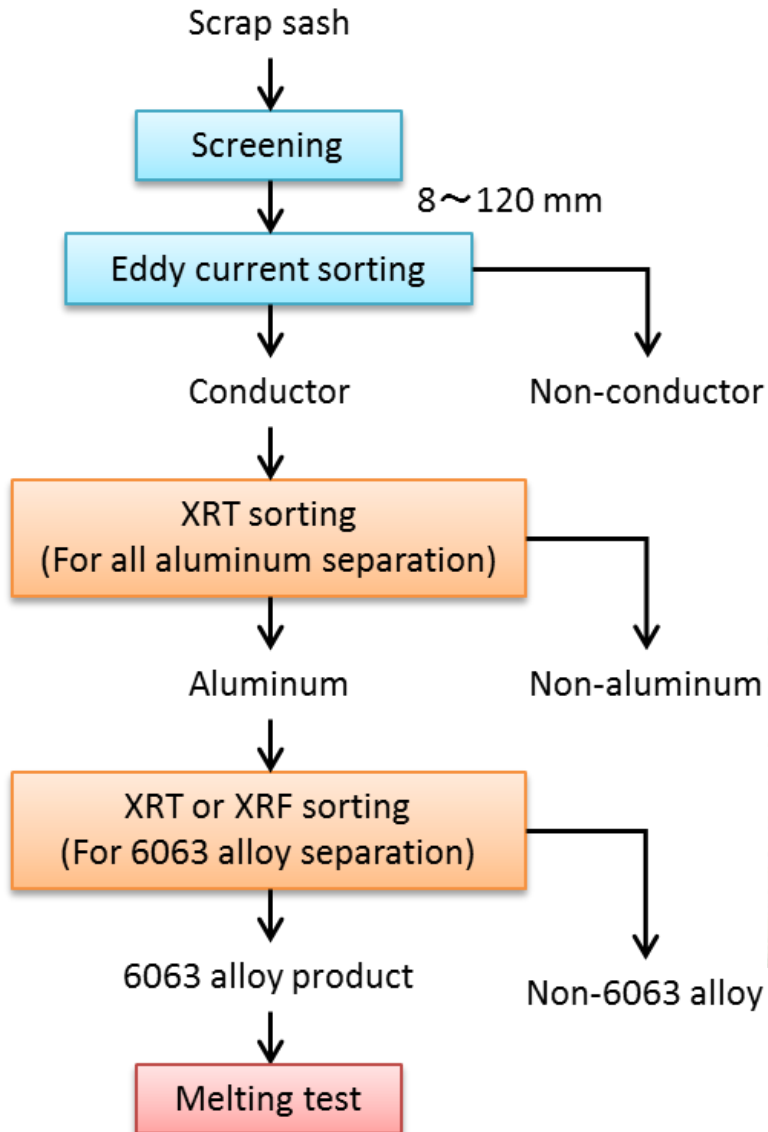
Weight (kg)	Grade of 6063 (wt%)
7.92	90.0

Separation result of 6063 alloy and non-6063 alloy

	Grade of 6063 (wt%)	Recovery of 6063 (%)	Separation efficiency (%)
XRT	99.1	93.0	85.3
XRF	99.2	94.6	87.6

These results show that the obtained products could become a raw material of wrought alloys again.

Process of “Sash to Sash” Recycling in the Pilot Plant



XRT Sorter



EC Sorter



XRF Sorter

Feed Materials



Real scrap sash shredded in a recycler
left: Sample A, center: Sample B, right: Sample C, 800 kg each

Material composition of feed sample to pilot plant tests (wt%)

	Sample A	Sample B	Sample C
6063 alloy	98.76	95.61	84.71
Non-6063 Al alloy	0.01	0.04	0.00
Casting Al alloy	0.31	0.39	0.63
6063 alloy with screws	0.79	2.77	1.78
Non-al metals	0.04	0.72	10.54
Non-metals	0.03	0.40	2.13
Fine particles	0.05	0.07	0.23

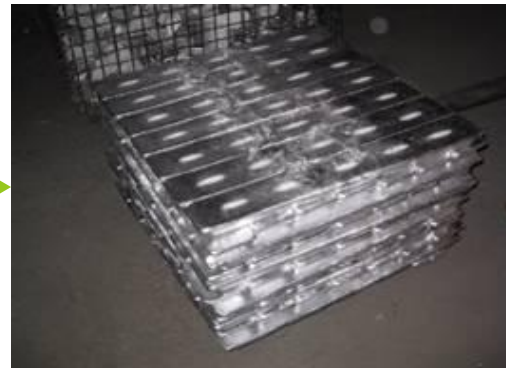
Results of Pilot Plant Test

Process in the final stage	Sample	Weight (kg)	Amount recovered (kg)	Grade (wt%)	Recovery (%)	Separation efficiency (%)	Energy consumed (kWh)
XRT	A	800.7	753.6	99.8	94.9	79.1	94
	B	801.8	713.0	99.6	92.0	84.4	90
	C	801.9	712.2	99.2	96.7	92.6	98
XRF	A	800.4	755.2	99.7	98.1	77.3	71
	B	800.2	758.2	99.5	94.2	84.1	65
	C	800.5	713.8	99.1	95.9	90.9	72

Results are all satisfied with the targets determined in this projects.



Furnace to produce the ingots



The ingots

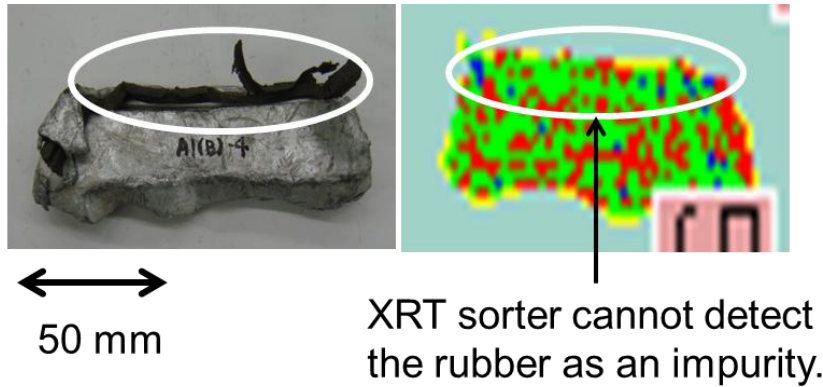
Componential analyses

Chemical Composition of the Final Products Obtained

	Sample A		Sample B		Sample C		Ranges determined by the JIS
	XRT	XRF	XRT	XRF	XRT	XRF	
Si	0.419	0.439	0.468	0.432	0.466	0.457	0.20 ~ 0.60
Fe	0.174	0.173	0.187	0.185	0.179	0.197	~ 0.35
Cu	0.018	0.019	0.023	0.020	0.026	0.017	~ 0.10
Mn	0.008	0.016	0.010	0.015	0.014	0.011	~ 0.10
Mg	0.316	0.336	0.307	0.298	0.317	0.316	0.45 ~ 0.90
Cr	0.005	0.006	0.005	0.006	0.006	0.006	~ 0.10
Zn	0.012	0.013	0.015	0.014	0.015	0.011	~ 0.10
Ti	0.006	0.006	0.007	0.006	0.007	0.007	~ 0.10

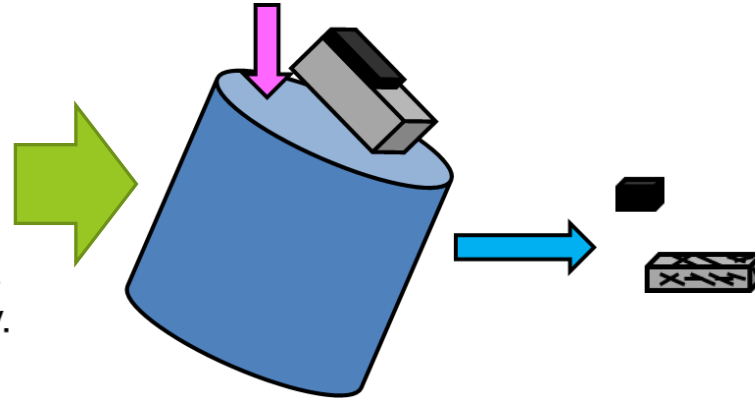
- Comparison of chemical composition of the final products and JIS
- ✓ Heavy metals (Fe, Cu, Zn): Much lower than the JIS
- ✓ Mg: A bit lower than the JIS
But this must be not a practical problem.

Influence of Impurities



Cause of toxic gas and black smoke during melting

Before the screening...



Removing plastic and rubber by intensive mixer

Results of total rejection ratio and other values

Rotating Speed[rpm]	500	1000
Cut Size [mm]	14.0	14.0
Maximum Separation Efficiency [%]	72.0	61.0
Grade of 6063 in oversize products[wt%]	98.5	97.5
Recovery of 6063 in oversize product[%]	85.0	72.0
Rejection Ratio of plastic and Rubber [wt%]	14.3	28.7

Conclusions

1. We developed a brand new process in pilot plant scale to recover high purity 6063 aluminum alloy from scrap aluminum sash in order to establish “Sash to Sash” recycling.
2. Over 99 wt% grade of 6063 alloy was recovered with the recovery of 92 to 98 % depending on the feed quality, whose results are all satisfied with commercial base standard.
3. The quality of final products obtained was conformed to the JIS standard.



Energy Saving

	2015	2020	2030
Effect of energy saving (ML/y, Crude oil base)	140	470	1,630

* Total energy consumption in Japan's Al rolling industry (6 companies) is 700 Mkl/y.

Basic data:

Production energy of secondary Al ingot: **156 L/t**

Production of secondary Al ingot: **1.025 Mt (2015), 1.267 Mt (2020), 1.399 Mt (2030)**

Production energy of virgin Al ingot: **3,688 L/t**

Reduction of virgin Al ingot: **30 kt (2015), 100 kt (2020), 400 kt (2030)**

2015 Energy saving: **20%** of **1.025 Mt** is adopted our process

$$156 \text{ L/t} * 1.025 \text{ Mt} * 20\% + 3.688 \text{ kL/t} * 30 \text{ kt} = \mathbf{140 \text{ ML/y}}$$

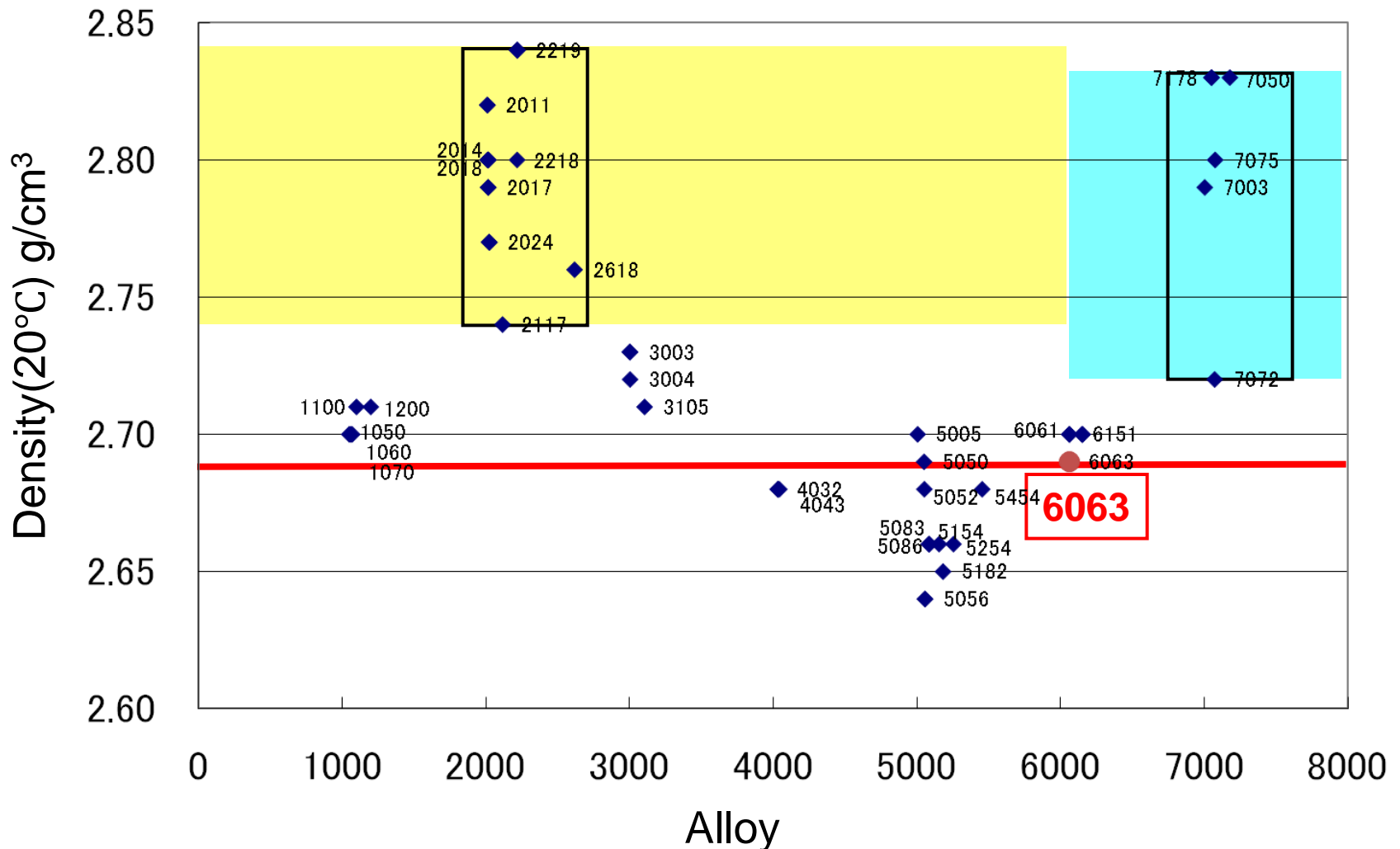
2020 energy saving: **50%** of **1.267 Mt** is adopted our process

$$156 \text{ L/t} * 1.267 \text{ Mt} * 50\% + 3.688 \text{ kL/t} * 100 \text{ kt} = \mathbf{470 \text{ ML/y}}$$

2030 energy saving: **70%** of **1.399 Mt** is adopted our process

$$156 \text{ L/t} * 1.399 \text{ Mt} * 70\% + 3.688 \text{ kL/t} * 400 \text{ kt} = \mathbf{1,630 \text{ ML/y}}$$

Density of Aluminum Wrought Alloys



→ Separating by the difference of density is possible.

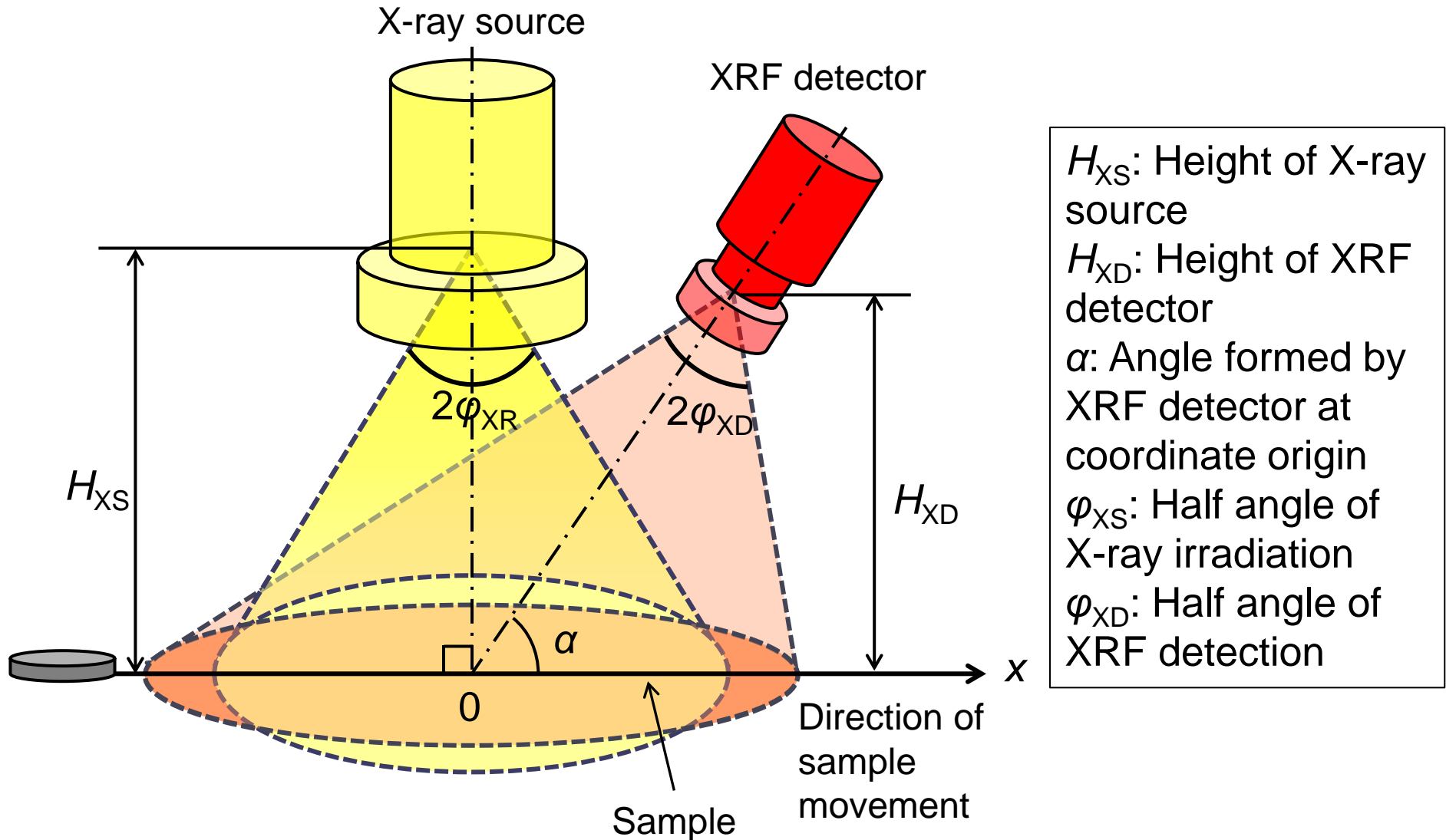
Intensive Mixer



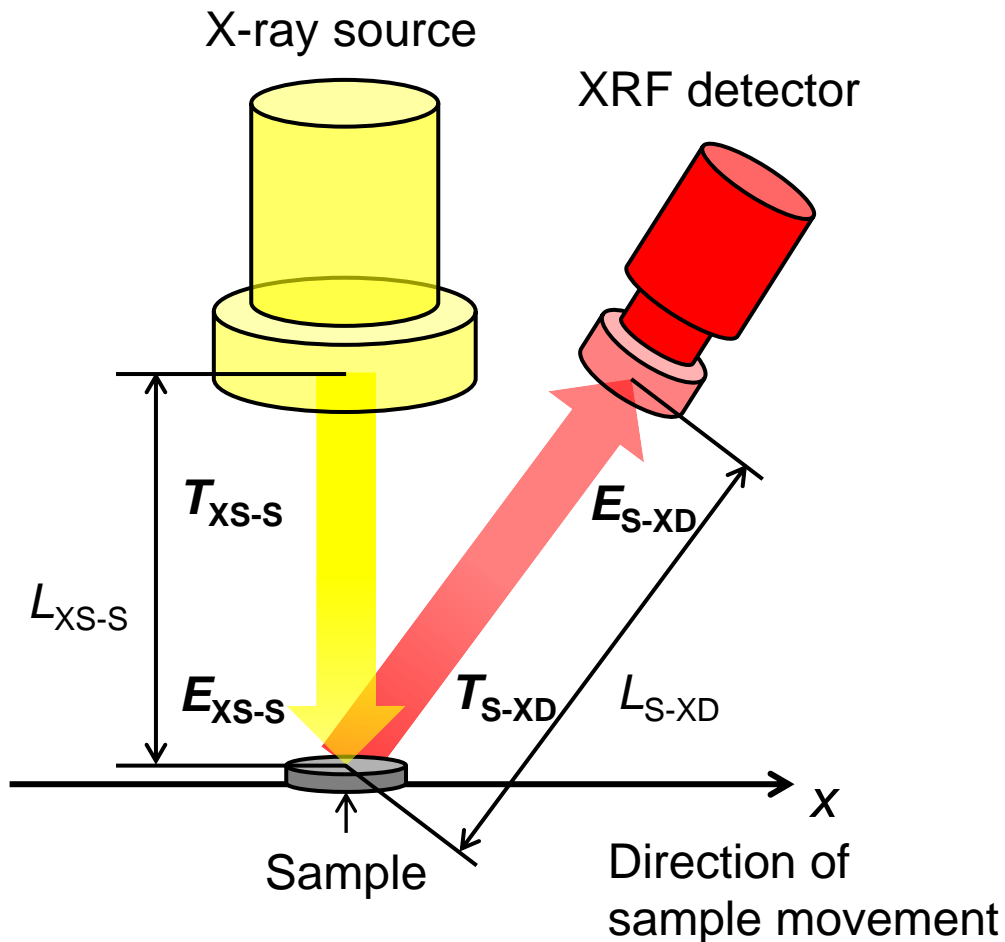
Specification

Capacity : L/batch	75	Capacity : kg/batch	120
Rotor Model	Star Type	Rotation Direction	opposite to pan pan
Diameter [φ mm]	350	Range of Rotation Speed[rpm]	180-1800

Theoretical Model



Calculation of the amount of detected XRF



The amount of XRF detected from sample

$$F_S = E_{XS-S} \times T_{XS-S} \times E_{S-XD} \times T_{S-XD}$$

Inverse-square law

$$I = I_0 \times \frac{1}{l^2} E$$

I : Intensity of X-ray emitted on targeted material

I_0 : Intensity of original X-ray

l : Distance from X-ray source to targeted material

Lambert-Beer law

$$I = I_0 \times \exp(-\mu l) T$$

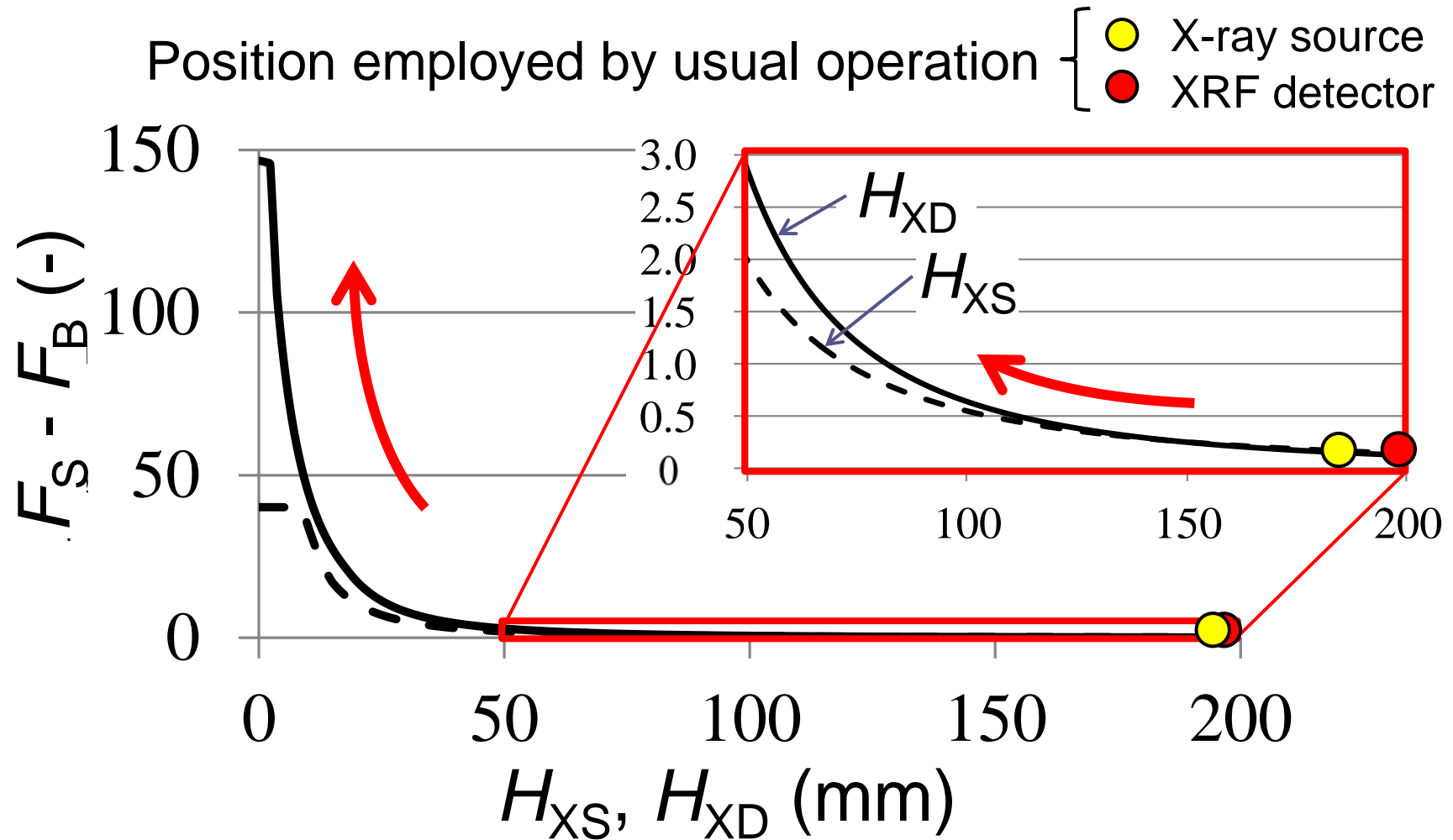
I : Intensity of X-ray transmitted through the targeted material

I_0 : Intensity of original X-ray

μ : Specific linear absorption coefficient of each element

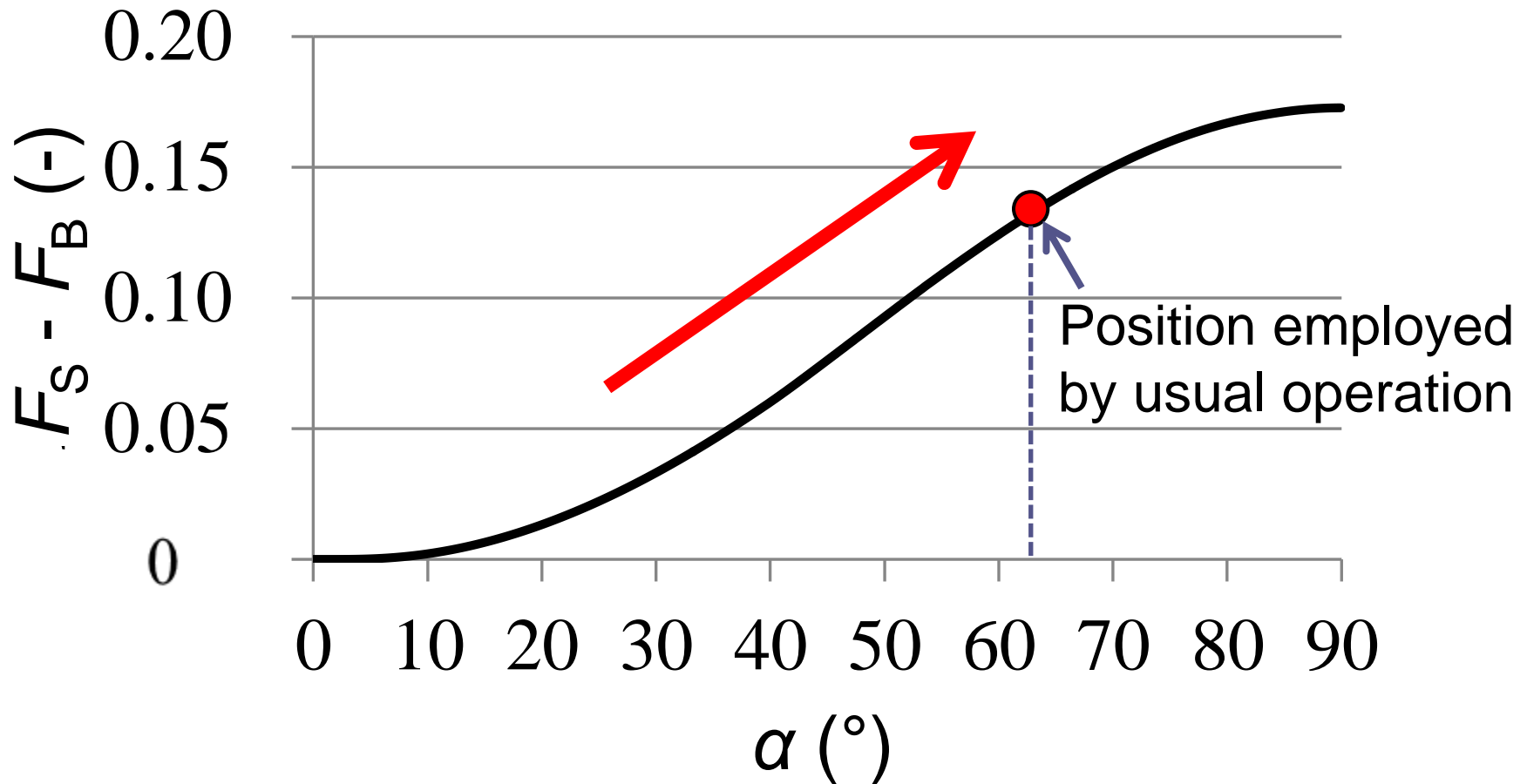
l : Thickness of targeted material (here, air is targeted material)

Change in " $F_S - F_B$ " as functions of H_{XS} and H_{XD}



As H_{XS} or H_{XD} decreases, " $F_S - F_B$ " increases.

Change in " $F_S - F_B$ " as a function of α



As α increases, " $F_S - F_B$ " increases.

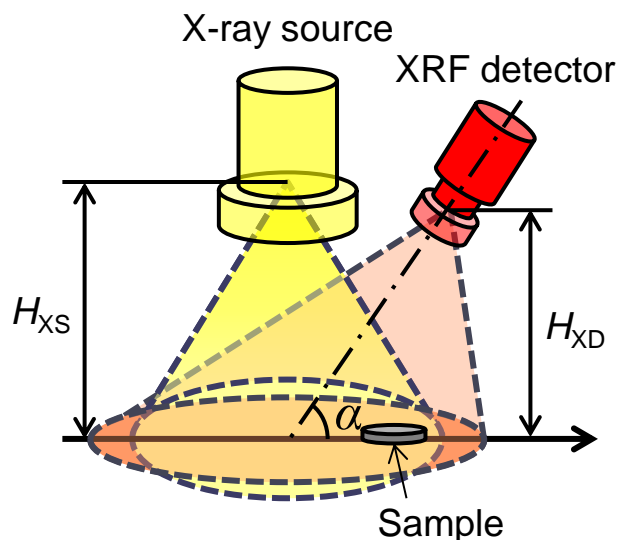
Conclusion

- **Improvement of the separation flowchart of 6063 alloy**

We found out the combination of conventional magnetic and eddy current separation could replace the eddy current sorting which costs much in the capital and running stages.

- **Improvement of XRF Sorting**

We developed a calculation model to quantify the amount of XRFs emitted from sample and background to determine the optimum positions of X-ray source and XRF detector.



To improve the selectivity...

- The distance of X-ray source or XRF detector from sample should be small. Especially, the sensitivity of the distance of XRF detector to the selectivity is high.
- XRF detector should be set vertically as much as possible .