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臺灣의 EAF 더스트(電氣爐 製鋼粉塵)의 處理에 관하여†

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Status of EAF Dust Management in Taiwan†

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요　약

대만의 제강생산량은 21,290천톤이고, 전기로제강량은 제강생산량의 약 반, 즉 11,200천톤이다. 그리고 이 전기로 제강시 발생되는 더스트량은 160천톤(2009년도)이다. Walez 프로세스(탄소강 EAF 더스트)에서 약 70천톤, RHF/SAF 프로세스(스테인레스강 EAF 더스트)에서 약 60천톤을 처리하고 있다. 그리고 약 90천톤/년의 조산화아연(ZnO)이 생산되고 있는 것으로 추정된다. 현재 새로운 EAF 더스트 리싸이클링법이 개발되고 있고, 조산화아연의 품위향상이 앞으로 과제이다.

주제어 : EAF 더스트, 조산화아연, 염소제거, 리싸이클링, 슬래그

Abstract

Taiwan's annual steel production reached 21.29 million tons. EAF accounted for about half of this total, or 11.2 million tons in 2008. The other 10.09 million tons came from blast furnace and converter process methods. The annual EAF carbon steel production is about 9.76 million tons, and the quantity of dust generated from the EAF process is 160 thousand tons, or about 16kg of dust per ton of steel was produced. In 2009, there is Walez process for carbon steel EAF dust recycling, and the capacity is about 70,000 tons per year; and there is RHF/SAF process for stainless steel EAF dust, the capacity is 60,000 tons per year which is enough to treat stainless steel EAF dust in Taiwan. There are many new treatment facilities processes will be that introduced to recycle the EAF dust in the near future, these processes will perform smoothly and sucessfully in Taiwan. The estimation of recycled crude ZnO is about 90,000 tons each year. The recycling and upgrading crude zinc oxide will be the next important issue in Taiwn zinc and steel industry.

Key words : EAF dust, zinc oxide, chloride removal, recycling, slag

1. Introduction

In order to prevent attacks, Taiwan sank numerous ships in its harbors to block waterways during World War II. When these waterways were dredged after the war, Taiwan found itself with an abundance of scrap metal. EAF Industrial (Electric Arc furnace) was founded in the 1950's to melt, cast, and roll the scrap steel and use it to reconstruct Taiwan. EAF Industrial grew and became more successful in the 1960's, due to the abundance of scrap-metal in Taiwan.[1,2] In 2008, Taiwan's annual steel production reached 21.29 million tons. EAF accounted for about half of this total, or 11.2 million tons. The other 10.09 million tons

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came from blast furnace and converter process methods. The annual EAF carbon steel production is about 9.76 million tons, and the quantity of dust generated from the EAF process is 160 thousand tons, or about 16kg of dust per 1 ton of steel was produced. On the other hand, the annual stainless and alloy steel production reach to 1.41 million tons each year. The EAF dust production of stainless and alloy steel mills is about 42 thousand tons in 2008 fiscal year.[3)]

EAF dust containing a wide variety of heavy metals and is regarded as hazardous waste. In the past, landfill with slag was the major treatment process for disposal of EAF dust, but standards to treat this type of waste have become much more stringent around the world. Since EAF dust containing valuable Zn and Fe, increasing attention is being directed to recover these metals in the treatment process.

Taiwan Environmental Protection Administration (EPA) began to recognize EAF dust as a process hazardous waste in 1994, and regulate EAF dust has to be recycled in 1996 by the regulations of the Methods and Facilities Standards for the Storage, Clearance, and Disposal of Industry Waste. Therefore, the EAF dust treatment and recycling became important issue and general practice in the 1990's.

In order to help EAF steel mills achieve cleaner production, Taiwan EPA and the Ministry of Economic Affairs encouraged EAF mills to set up joint treatment facilities to solve the dust problem. Construction on joint treatment facilities for 12 EAF steel mills began in 1996, and trial production began in 1998. However the design capacity of these joint recycling plants totals only 70,000 tons/year. Therefore, 100,000 tons of untreated EAF dust is stockpiled in domestic mills each year. Reducing this stockpile (now over 500,000 tons) has become an urgent issue in Taiwan.[2,4,5)]

2. Present status of EAF Mills in Taiwan

Currently there are 21 operating EAF steel mills in Taiwan. As shown in Table 1,[6)] the crude steel production of EAF steel mills increased from 8.52 million tons (2005) to 11.2 million tons(2008) that is equal to an increase of 12.7% in four years. The geological distribution of EAF mills is shown in Fig. 1. Apparently, southern Taiwan is the main area for EAF steel production around the island.

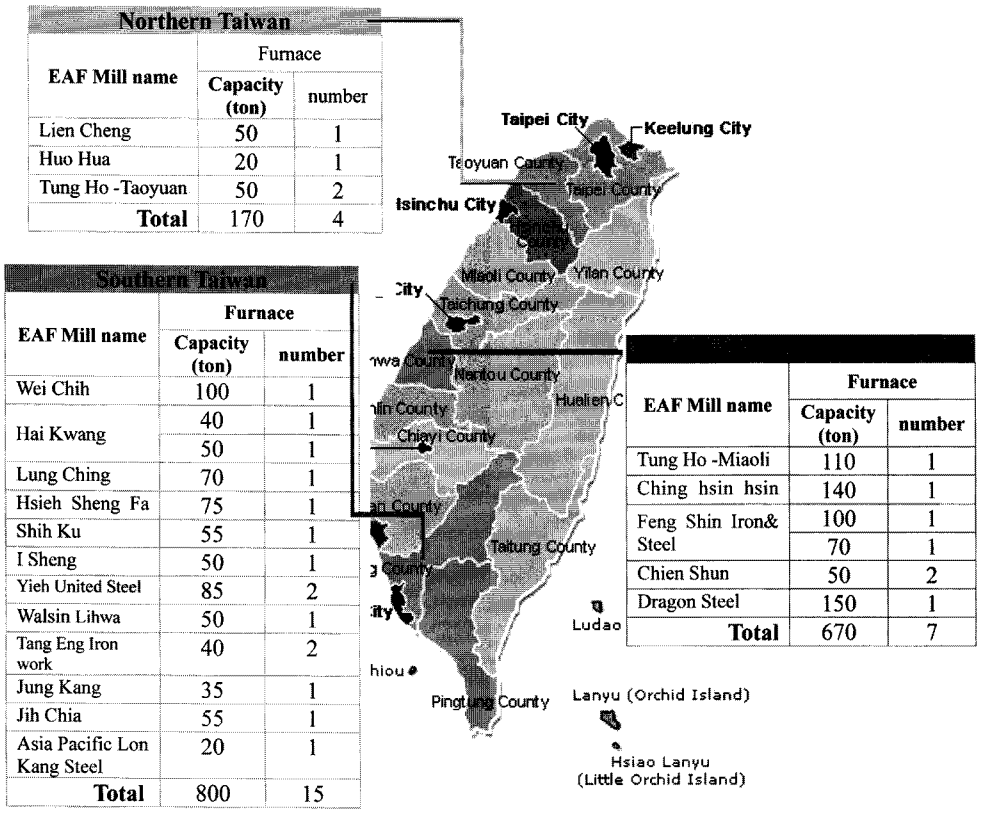
3. Generation and Composition of EAF Dust

3.1. Generation of EAF dust

Total quantity of dust (carbon steel) generated from EAF steel mills in Taiwan is about 160,000 tons/year in 2008, consisting of 500,000 tons of residual dust which is stockpiled inside domestic mills and waiting for proper treatment and recycling. The excess EAF dust is generated in various EAF mills, due to the limited capacity of Taiwan Steel Union Co. / Ltd. (TSU); and more than 90,000 tons/year of excess EAF dust needing proper treatment in Taiwan. The Taiwan Steel Union Co. / Ltd. (TSU), a joint venture of 12 EAF steel mills, started its hot run with the Waelz Kiln in 1999. The design capacity of TSU is only 70,000 tons of dust per year. Hence, the residual EAF dust that can not be sent to TSU are either recycled at EAF mill by returning to EAF or temporary stockpiled waiting for other solutions. Meanwhile, the dust production of stainless and alloy steel mills in 2008 was 42,000 tons/ year in which stainless and alloy steel production amounted to 1.41 million tons/year. Because the amounts of temporary storage EAF dust were more than 500,000 tons, therefore, in 2009 the official announcement of reviewing temporary storage of EAF dust enforced

Table 1. Production of crude steel in Taiwan Unit: million ton/ year

Fiscal year	Blast furnace and converter process (1)	Electric arc furnace process			Total (1)+(2)+(3)
		Carbon steel (2)	Stainless, Alloy Steel (3)	Total (2)+(3)	
2005	9.85	6.92	1.60	8.52	18.37
2006	10.68	7.53	1.81	9.34	20.02
2007	10.88	7.80	1.62	9.42	20.30
2008	10.09	9.76	1.41	11.2	21.29



Northern Taiwan

EAF Mill name	Furnace	
	Capacity (ton)	number
Lien Cheng	50	1
Huo Hua	20	1
Tung Ho -Taoyuan	50	2
Total	170	4

Southern Taiwan

EAF Mill name	Furnace	
	Capacity (ton)	number
Wei Chih	100	1
Hai Kwang	40	1
	50	1
Lung Ching	70	1
Hsieh Sheng Fa	75	1
Shih Ku	55	1
I Sheng	50	1
Yieh United Steel	85	2
Walsin Lihwa	50	1
Tang Eng Iron work	40	2
Jung Kang	35	1
Jih Chia	55	1
Asia Pacific Lon Kang Steel	20	1
Total	800	15

EAF Mill name	Furnace	
	Capacity (ton)	number
Tung Ho -Miaoli	110	1
Ching hsin hsin	140	1
Feng Shin Iron& Steel	100	1
	70	1
Chien Shun	50	2
Dragon Steel	150	1
Total	670	7

Fig. 1. Distribution of EAF Mills in Taiwan.

EAF industry to treat or recycle all the temporarily stored EAF dusts before 2014.

3.2. Chemical Composition

EAF dust could be classified into two groups. One was the dust of carbon steel or low alloy steel; the other was the dust of stainless steel. Table 2 showed chemical composition of EAF dust which was collected from carbon steel mill.[7] The main contents of the carbon steel dust (CS) were FeO(20~46%), Zn(17~38%), Pb(1.9~5.0%), MgO(4.7~9.9%), CaO(4.7~9.9%), and Al_2O_3 (0.9~2.4%); The anion composition (Cl^-)was in the range 3~10%. Table 3 showed chemical composition of EAF dust which was collected from stainless steel mill.[8] The main contents of stainless steel dust (SS) were Fe (25~30%), Zn (6.0~10.0%), Cr (8.0~12.0%), and Pb (2.5~3.0%).The differences between CS and SS dusts were the amounts of Zn content .The higher content of Zn in CS was because of raw material for EAF containing post-consumer scrap. Those scraps could contain electrode plating, surface finish painting and waste cans, which were totally different from the

Table 2. Composition of dust generated in EAF carbon steel mill

EAFD (%)					
FeO	Zn	Pb	Cu	CaO	MgO
20~46	17~38	1.9~5.0	0.18~0.35	4.7~9.9	4.7~9.9
SiO_2	Al_2O_3	Na	K	Cl^-	
1.8~4.8	0.9~2.4	1.6	1.2	3~10	

Table 3. Composition of dust generated in EAF stainless steel mill

EAFD (%)					
Fe(tot)	Zn	Cr	Pb	CaO	MgO
25~30	6.0~10.0	8.0~12.0	2.5~3.0	6.0~8.0	2.5~3.5
SiO_2	Al_2O_3	Ni	K	Cl^-	
5.0~7.0	0.5~0.7	0.5~0.7	1.0~1.5	2.0~3.0	

raw materials for stainless steel furnace. Particle sizes of EAF dust had a wide range from 0.124 to 6.76 μm. The majority of the particles are smaller than 1.47 μm (D_{75} value) in diameter. EAF dust was easy to fly with wind because of their small particle size and low bulk density causing serious pollution not handled properly.

4. Recycling of EAF Dust

Many industrial wastes can not be readily recycled due to their physical or chemical nature. Compared to other final treatments such as incineration, land reclamation, landfill or solidification, waste recycling is generally much more environment-friendly.[9] EAF dust contains so many valuable metals especially it is rich in Zn and Fe. In order to help the EAF steel mills achieve Cleaner Production through better waste recycling, efforts from Taiwan EPA and Ministry of Economic Affairs, local EAF Steel mills are integrated to move forward to the subsequent stage in EAF dust recycling. The present status recycling in of EAF steel mills in Taiwan is shown in Table 4.

4.1. EAF Dust Recycling Mills

The major EAF dust recycling mills in Taiwan are summarized as follows:

4.1.1 Taiwan Steel Union Co. /Ltd. (TSU)

A Waelz Kiln process has been operated by Taiwan Steel Union Co. /Ltd. (TSU) to recover crude zinc oxide from the dust of EAF carbon steel mills. This treatment facility was a joint venture of 12 EAF steel mills. TSU commenced in 1996 and started its trial production in August 1998. The original design capacity of Waelz Rotary Kiln for EAF dusts treatment was 70,000 ton/year. However, the initial production

Table 4. Recycling in EAF steel mills

Type	EAF dust recycling mill	Process	Furnace	Design capacity (ton/year)	Product
Joint ventures	Taiwan Steel Union (TSU)	reduction	Waelz Kiln	70,000 (90,000)*1	Crude ZnO
Issued Recycling Permit	Yieh United Steel Corporation (stainless steel mill)	reduction pyrometallurgy	Rotary Hearth Furnace Submerged Arc Furnace	60,000*2	Steel billet (Ni, Cr, Fe) Crude ZnO
	Katec Creative Resources Corporation	ESRF*5	Reducing furnace Submerged furnace	40,000*3*4	Pig iron Crude ZnO
	Dragon Steel Corporation (DSC)	reduction pyrometallurgy	Multiple-Hearth Furnace Electric Arc Furnace	100,000*4	Steel billet Crude ZnO
	China Steel Corporation	reduction	Rotary Hearth Furnace	120,000*4	DRI Crude ZnO

*1 The second furnace of TSU
*2 EAF dust for stainless steel
*3 The stage of trial run
4 The capacity include EAF dust and other solid waste (dust/sludge/sinter) in mill
*5 ESRF be defined (Electric Smelting Reduction Furnace) technology

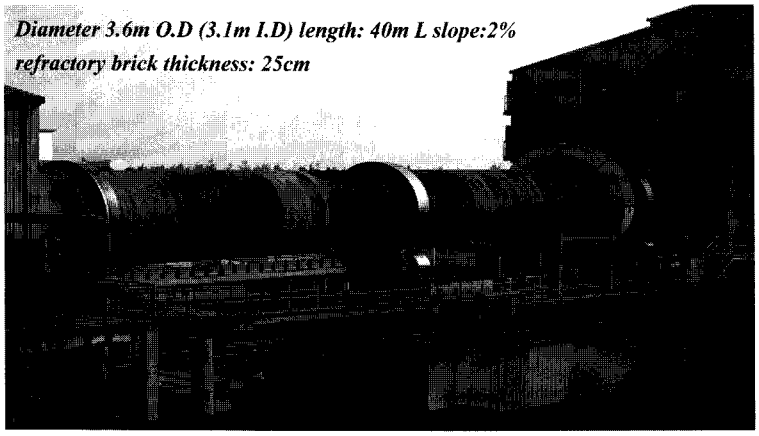


Fig. 2. The present view of Waelz Rotary Kiln in TSU.

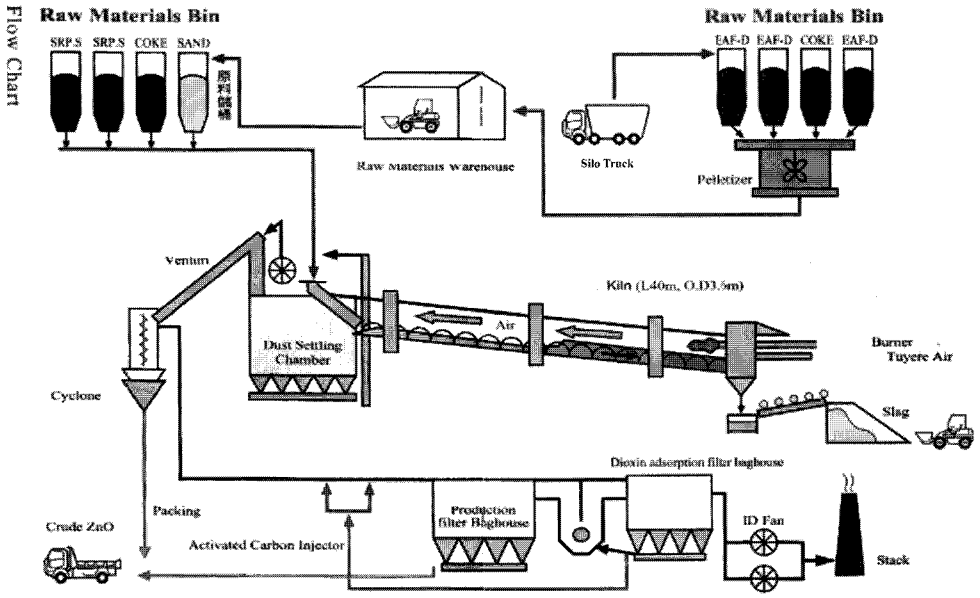


Fig. 3. Recycling of crude ZnO from EAF dust at TSU plant.[10)]

only reached to 50,000 ton in 2003 and further increased to 70,000 ton in 2007. In addition, TSU began planning for the second set of Waelz Kiln equipment in 2009. The present view of Waelz Rotary Kiln in TSU is shown in Fig. 2. Recycling of crude ZnO from EAF dust at TSU is shown in Fig. 3.[10)] The design capacity of TSU for EAF dust treatment is 70,000 ton/year. The total quantity of crude ZnO recycled from TSU plant was 25,000 ton/year (zinc content is about 57~62%), while the non-hazardous slag (34,000 ton/year) was produced. The typical compositions of crude ZnO and slag generated in TSU plant are shown in Table 5.

4.1.2 Yieh United Steel Corporation (YUSCO)[8,11)]

Yieh United Steel Corporation (YUSCO) was founded in December 1988. The plant is located in Kaohsiung County, southern Taiwan. YUSCO is the largest EAF stainless steel mill in Southeast Asia. The steel melting operation has an annual capacity of

Table 5. Chemical compositions of crude ZnO and slag (TSU)[7]

ZnO (%)				
FeO	Zn	Pb	Cl^-	F^-
1.9~3.2(2.3)	56.8~61.8(58.7)	4.4~6.8(5.9)	5.4~8.7(7.5)	0.29~0.33(0.31)

Slag (%)							
FeO	Zn	Pb	Cu	CaO	MgO	SiO_2	Al_2O_3
21.4~49.5 (40.1)	0.6~5.1 (2.8)	0.01~0.38 (0.2)	0.19~0.29 (0.24)	5.5~8.4 (7.4)	0.8~1.75 (1.27)	28.4~48.3 (33.4)	2.9~4.9 (3.6)

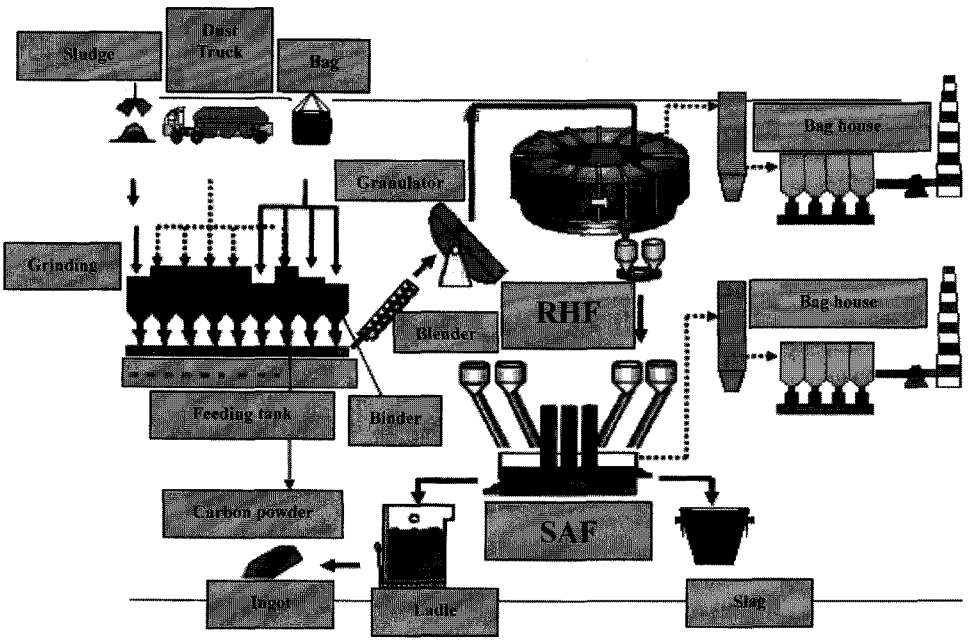


Fig. 4. Recycling by IMMETCO process at YUSCO plant.[10]

1,000,000 metric tons producing stainless steel slabs and billets. An IMMETCO process was introduced by Yieh United Steel Corporation (YUSCO) in1999, which started to recover Ni, Cr, and Fe from the dust of stainless steel mills in 2003. Dust is being recycled by a rotary hearth furnace (RHF) and a submerged arc furnace (SAF) in YUSCO plant (Fig. 4). The design capacity of YUSCO's plant for dust treatment is 60,000 ton/year. The compositions of RHF dust, SAF dust and Steel ingot generated in YUSCO plant are shown in Table 6.

4.1.3 Dragon Steel Corporation (DSC)[12]

Dragon Steel Corporation (DSC) was founded in 1993 and operated as a subsidiary of China Steel Corp in 2004. DSC plant manufactured steel plates, wire rod, and hot and cold rolled products by a DC electric arc furnace (150 ton). The blast furnace ignition ceremony held in February 2010, it symbolized DSC's move forward to a new, improved productivity. As a result of a large quantity of EAF dust generated, Dragon Steel Corporation (DSC) is currently performing the hot commissioning of a new PRIMUS plant which will recycle fine materials (dusts, sludge, etc.) from the existing electric arc furnace shops and from future sintering, blast furnace ironmaking and BOF steelmaking. The PRIMUS technology, developed by PAUL WURTH and introduced by Dragon Steel Corporation

Table 6. Chemical compositions of RHF dust, SAF dust and Steel ingot (YUSCO)[7]

RHF dust (%)										
Fe_2O_3	Ni	Cr_2O_3	PbO	Cd	SiO_2	MnO	ZnO	CaO	Cl^-	F^-
8.56	0.43	2.95	15.23	0.23	1.03	0.74	47.37	1.35	9.46	1.04
SAF dust (%)										
Fe2O3	Ni	Cr_2O_3	PbO	Cd	SiO_2	MnO	ZnO	CaO	Cl^-	F^-
10.97	0.47	3.41	6.31	0.01	1.80	1.22	52.20	1.96	4.04	0.67
Steel ingot (%)										
Fe		Ni		Cr		Mn		C		
70		4.7		16.2		4.2		3.8		

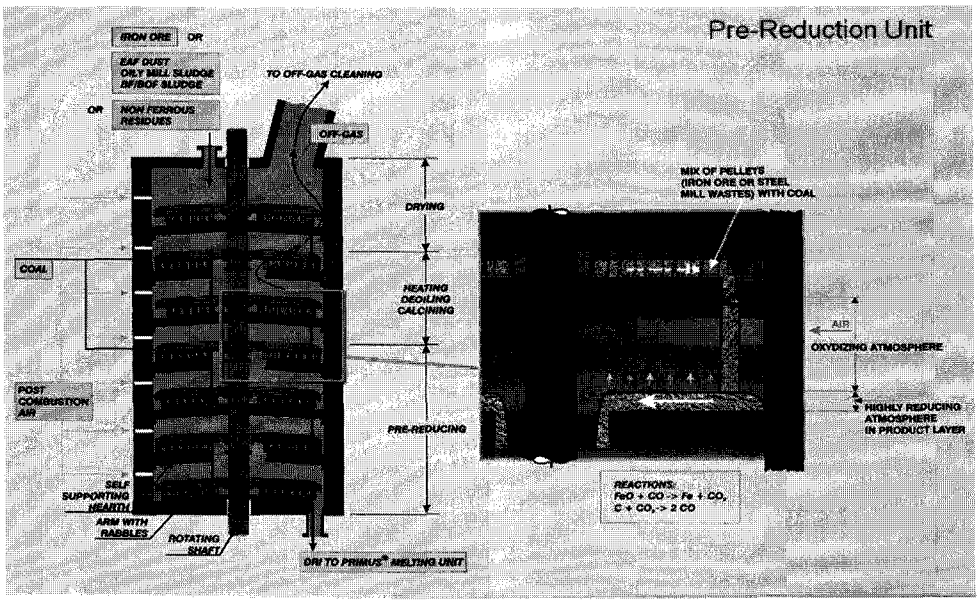


Fig. 5. A multiple hearth furnace (MHF) in DSC.

(DSC), is based on a multiple hearth furnace (MHF) (Fig. 5) used for pre-heating, calcining and pre-reducing the residues using economical coal, it is combined with a specially designed electric arc furnace for smelting the charge from the MHF and fuming off the zinc. It offers an innovative method for recovering and separately iron and zinc as the added value materials from iron and steelmaking residues: zinc is recovered as zinc oxide, iron as pig iron and gangue materials as inert slag. At Dragon Steel, the Primus plant will provide a nominal recycling capacity of 100,000 tons (dry basis) of fine material per year and will be operated with different feed mixes, ranging from 100% EAF dust to a high proportion of blast furnace residues. The total quantity of crude ZnO recycled from DSC plant was 15,000 ton/year (zinc content: about 50%), while the pig iron (12,000 ton/year) was produced. Fig. 6 shows the basic flowsheet of the Primus process adapated by DSC for EAF dust recycling. The typical compositions of crude ZnO and slag generated in DSC plant are shown in Table 7.

4.1.4 Katec Creative Resources Corporation (KCRC)[13]

Katec Creative Resources Corporation (KCRC) com-

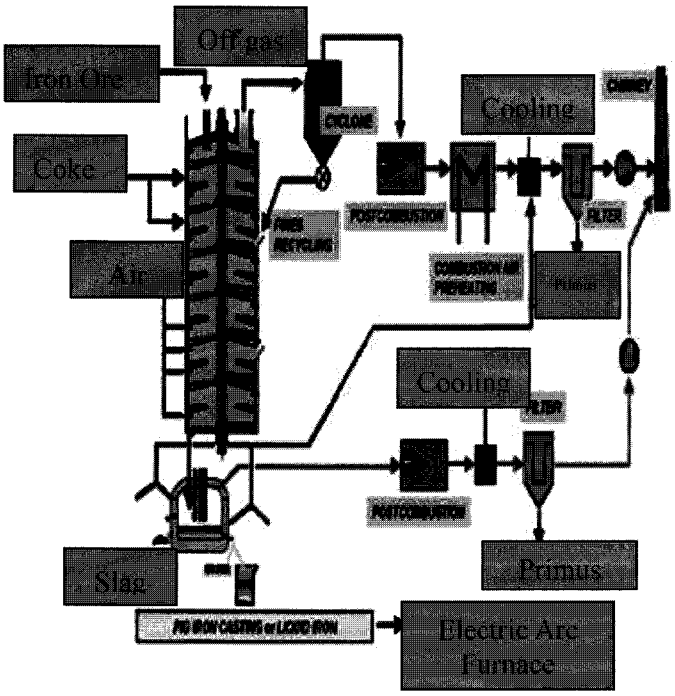


Fig. 6. Primus Process for EAF dust.[10)]

Table 7. Chemical compositions of crude ZnO and slag (DSC)

ZnO(%)								
Zn	Fe	Cu	Mn	Al	Si	Ca	Mg	P
46.55~54.08	5.39~11.43	N.D~0.47	0.54~0.86	0.12~0.17	N.D~0.98	0.85~1.55	0.22~0.45	0.08~0.12

Slag(%)									
SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	ZnO	SO3	TiO2	P2O5	MnO
25.16	5.5	34.56	7.53	10.46	0.17	2.05	0.53	0.58	8.49

menced in 2008 and started its production in March 2009. The plant is located in Taoyuan County, Northern Taiwan. KCRC plant is a new recycling plant which will process EAF dust, electroplating greasy sludge, waste batteries, wasted carbon powder, plastic waste and any metal-containing residue by ESRF (Electric Smelting Reduction Furnace) technology (Fig. 7) to produce pig iron, stone products and recovered crude ZnO. All feed materials are pelletized by brequtting (? briquette) machine. Two different reducing agents, carbon and waste plastic, are used in the reduction process. The design capacity of KCRC plant for EAF dust treatment is 40,000 tons/year and Medical Waste is 5,000 tons/year. The total quantity of crude ZnO recycled from KCRC plant is 15,500 tons/year (zinc content is about 65%), while the pig iron (12,500 tons/year) is produced. The typical compositions of crude ZnO, Pig iron and slag generated in KCRC plant are shown in Table 8.

4.1.5 China Steel Corporation (CSC)

The blast furnace is the first step in producing steel from iron ores. Many waste materials from the steel plant that contained some iron were sintered to

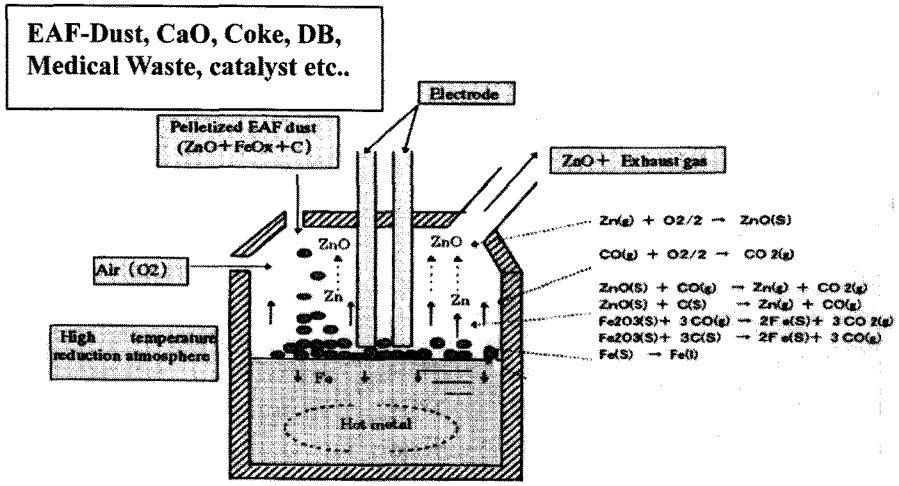


Fig. 7. Basic concept of ESRF.

Table 8. Chemical compositions of crude ZnO, Pig Iron and slag (KCRC)

Crude ZnO(%)									
Zn	Pb	Cd	Fe	Cu	Si	Ca	Cl^-	Na	K
63.30 (50.2~73.7)	4.21 (0.35~7.22)	0.06 (0.01~0.18)	3.49	0.13	1.12	5.18	6.51	2.46	2.35

Pig iron(%)							
C	Si	Mn	P	S	Cu	Ni	Cr
3.29	0.47	1.02	0.036	0.027	0.47	0.05	1.26

Slag(%)								
CaO	MgO	SiO_2	Al_2O_3	FeO	Zn	Pb	Cu	Cr
28.61	9.16	20.86	9.02	2.86	0.48	0.04	0.03	0.54

produce strong, marble-sized pellets and then charged into the blast furnace when the furnace was heated; most of the volatile gases, such as dioxin and sulphur, were released. China Steel Corporation (CSC) utilized pyro-metallurgical processes, Rotary Hearth Furnace (RHF), that can avoid dioxin emission and produce Directly Reduced Iron (DRI) and recover ZnO.The produced Direct Reduced Iron (DRI) can be recovered as the raw material for EAF or BF. Furthermore, the recovered ZnO has the higher purity and value. The design capacity of RHF in CSC's plant for waste scrap and dust recycling is 120,000 ton/year. The ability to treat EAF dust is only 400 tons per month, which is 4% of the total feed in the process. Fig. 8 shows the basic flowsheet of the RHF process CSC for ZnO and DRI recycling. The typical compositions of DRI and crude ZnO generated in CSC plant are shown in Table 9.

5. Conclusions

It should be noted that zinc is a metal that is in high demand in the 21st century. The annual EAF dust (carbon steel) generation in Taiwan is 160,000 tons, and 42,000 tons for stainless steel EAF dust. The EAF dust (carbon steel) recycling capacity is only 70,000 tons per year so far. The amounts of annual temporary

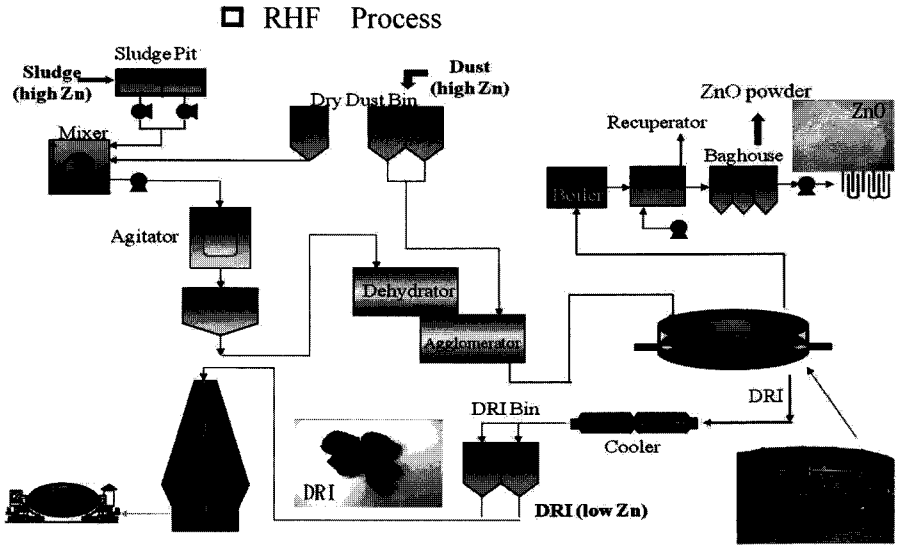


Fig. 8. RHF Process to recover ZnO and DRI in CSC plant.[14]

Table 9. Chemical compositions of DRI and crude ZnO (CSC)

DRI(%)												
TFe	M-Fe	CaO	MgO	Al_2O_3	SiO_2	ZnO	PbO	K_2O	Na_2O	FeO	Fe_2O_3	C
65.18~ 69.62	30.86~ 42.73	6.65~ 8.22	1.09~ 2.54	0.73~ 0.83	4.7~ 6.16	0.04~ 0.06	0.01~ 0.03	0.05~ 0.08	0.64~ 0.65	31.99~ 45.86	0.17~ 1.53	1.98~ 4.69

Crude ZnO(%)										
TFe	CaO	Al_2O_3	SiO_2	Zn	PbO	K2O	Na_2O	Cl^-	F^-	C
0.47~ 1.17	0.12~ 0.82	0.02~ 0.05	0.07~ 0.32	71.31~ 75.91	12.30~ 13.25	2.21~ 3.55	0.80~ 1.20	2.77~ 4.7	0.3~ 0.54	0.01~ 0.08

stockpile are near 90,000 tons per year. Furthermore, 500,000 tons of temporarily stored EAF dust is still waiting for proper treatment in Taiwan. The EAF dust (stainless steel) recycling capacity is about 60,000 tons per year. There are some space for the facility to treat the other metal-containing solid and sludge in steel mill as well.

In 2009, there is Walez process for carbon steel EAF dust recycling, and the capacity is about 70,000 tons per year; and there is RHF/SAF process for stainless steel EAF dust, the capacity is 60,000 tons per year which is enough to treat stainless steel EAF dust in Taiwan. There are many new treatment facilities processes will be that introduced to recycle the EAF dust in the near future, especially for the carbon steel EAF dust. These processes include Waelz Kiln, Submerged Arc Furnance, Mutiple Hearth Furnance, and Rotary Hearth Furnance. Hopefully, these processes will perform smoothly and sucessfully in Taiwan. The estimation of recycled crude ZnO is about 90,000 tons each year. The recycling and upgrading crude zinc oxide will be the next important issue in Taiwn zinc and steel industry.

References

1. Department of Science and Technology Consultant of Executive Yuan, R.O.C.(Taiwan), 1980: Report of current metal materials, August 1980.
2. Chung-Lee Li and Min-Shing Tsai, 1993: *A crystal phase*

study of zinc hydroxide chloride in electric-arc-furnace dust, Journal of Materials Science, vol. V28, pp. 4562-4570.
3. Enviromental Production Administration Executive Yuan, R.O.C.(Taiwan), 2009: Internet website http://waste.epa.gov.tw/.
4. Kuo-Chung, 1999: *Implementation of Recycling Technology in EAF Steel Mills—A Critical Issue to Cleaner Production*, Cleaner Production Workshop in Taiwan, October 1999.
5. Kuo-Chung Liu, Yih-Feng Chiu, Hsin-Jong Chen, 2000: *Updated Overview of Dust/Scale/Sludge Recycling in Taiwan Steel Industry*, Cleaner Production Workshop in Taiwan, May 2000.
6. Taiwan Steel & Iron Industries Association.
7. Yan-Bin Fang, 2008: *The operation status of zinc oxide by a rotary kiln (waelz kiln) recovery EAF dust in Taiwan*, Cross-strait Technology Symposium of EAF dust recycling furnace smelting of zinc oxide and secondary resources regeneration, March 2008.
8. Enviromental Production Administration of Executive Yuan, R.O.C.(Taiwan), 2006: EPA-94-U1H1-02-101, February 2006.
9. J.G.Eacott, M.C.Robinson, E.Busse, J.E.Burgener and P.E.Burgener, 1984: *Techno-economic Feasibility of Zinc and Lead Recovery from Electric Arc Furnace Baghouse Dust*, CIM Bulletin, vol.77, pp.75~81.
10. Taiwan Steel Union Co., Ltd., 2008: Recycling of EAF dust.
11. Yieh United Steel Corporation, 2009: About YUSCO.
12. Dragon Steel Corporation, 2009: Dragon Steel taps first hot metal from PRIMUS, April 2009.
13. Katec Creative Resources Corporation, 2009: About KCRC, August 2009.
14. Xin-Rong Chen, 2009: *The study of industrial waste incinerator ash used in steel-making process (Case of China Steel Corporation)*, The Symposium of resourcing technology for industrial waste incineration ash and slag, July 2009.

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