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EXPERIMENTAL STUDY ON PELLETIZATION OF BLENDED SEA SAND ORES

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Abstract

Sea sand ore (SSO), an abundant secondary vanadium-titanium magnetite resource formed through fluvial, wave, and current erosional processes, is readily minable yet remains underutilized due to challenges in metallurgical processing caused by its complex mineral composition. This study utilizes SSO as raw material to produce oxidized pellets, thus enabling its application in blast furnace（BF）ironmaking processes and promoting comprehensive utilization of sea SSO resources. This study systematically investigated the effects of SSO blending ratios on the metallurgical properties of vanadium-titanium magnetite oxidized pellets. Results demonstrate that compared with Heishan vanadium-titanium ores, SSO exhibits superior pelletization performance despite slightly higher V-Ti content. As the SSO ratio increased, the strength of green pellets progressively declined, with the 100% SSO pellets showing zero drop strength – failing to meet production requirements. Furthermore, the compressive strength(CP) and low-temperature reduction degradation index ($RDI_{+3.15}$) of oxidized pellets initially decreased then increased with rising SSO ratios. Industrial basket trials using 80% SSO confirmed pellet strength reaching 2,578 N, satisfying BF operational criteria.

***Keywords**: sea sand ore; vanadium-titanium magnetite; oxidized pellets; blast furnace ironmaking*

1. INTRODUCTION

Sea sand ore (SSO), a unique coastal iron ore resource formed by geological processes like fluvial sedimentation and marine erosion, is widely distributed in coastal areas of Japan, the Philippines, Indonesia, Australia, New Zealand, and China's Hainan Island. It boasts abundant reserves, easy mining, and low cost, ranking as the world's second-largest marine mining operation after offshore oil[1].

As a type of vanadium-titanium magnetite, SSO contains about 60% TFe and 6-9% TiO_2, with high refractory components (V_2O_5, Al_2O_3, K_2O, Na_2O) that hinder sintering[2]. Its particles are coarse (0.5-2.0 mm), regularly spherical/ellipsoidal with smooth surfaces, and feature a compact, complex mineral texture[3].

While current research on utilizing SSO as ironmaking feedstock predominantly focuses on sinter production, its blending ratio remains limited due to inherent material constraints[4]. This study pioneers an alternative approach by investigating the metallurgical properties of green pellets and oxidized pellets produced from SSO blends through laboratory-scale pelletizing. Building on experimental findings, industrial strand tests were conducted to validate the technical feasibility of incorporating SSO in pelletization processes.

2. EXPERIMENTAL

2.1 Material

The pelletizing raw materials employed in this study comprised SSO, Heishan vanadium-titanium ore(HVO), conventional vanadium-titanium ore (CVO), and bentonite. Specifically, SSO was processed into concentrate through grinding and beneficiation prior to use. The properties ore powders are listed in Table 1. Based on the data in Table 1, SSO exhibits higher vanadium and titanium content as well as a better balling index compared to HVO.

Table 1. The properties ore powders (mass/%)

Sample	Chemical composition, %									Balling index
	TFe, %	TiO_2	V_2O_5	SiO_2	Al_2O_3	P	S	MgO	CaO	
SSO	61.81	6.09	0.59	2.79	1.84	0.03	0.02	0.95	0.68	1.7
HVO	61.65	6.31	0.67	1.78	2.52	0.02	0.21	0.97	0.34	1.4
CVO	60.62	2.58	0.36	5.10	1.36	0.01	0.01	2.65	1.66	2.1

2.2 Method

The pelletizing experiment with sea sand ore blending was conducted according to the optimized ore blending principle. The proportion of sea sand ore was gradually increased from 0% to 100%, with 1.5% bentonite externally added. The specific blending scheme is presented in Table 2. The roasting regime employed during pellet firing was as follows: the preheating temperature was 950°C for 30 minutes, followed by roasting at 1300°C for 25 minutes. Based on laboratory findings, we conducted two industrial basket trials at the pelletizing line of X Iron and Steel Plant in China, validating the performance of maximum-SSO-loaded pellets under actual production conditions.

Table 2. The blending scheme

Number	Ore， %		
	HVO	CVO	SSO
A	50	50	0
B	50	30	20
C	50	10	40
D	40	0	60
E	20	0	80
F	0	0	100

3. RESULTS AND DISCUSSION

3.1 Analysis of cold-state performance of green pellets

Green ball strength is a crucial indicator for evaluating the quality of pellets during the transportation process from the completion of balling to the start of roasting. Sufficient green ball strength ensures that the pellets do not break during transportation, maintaining a high yield rate. Typically, green balls used for blast furnace smelting require a drop strength >4 drops/0.5m and a CP >10N.

Table 3 presents the experimental strength results of green balls produced by adding SSO. The experiment demonstrates that as the proportion of SSO increases, the green ball strength continuously decreases. When the proportion of SSO reaches 100%, the drop strength of the green balls falls to 0 drops/0.5m, and the CP decreases to 5N. This strength level is too low and fails to meet the actual production requirements for pellets.

Table 3 The experimental strength results of green balls produced by adding SSO

Number	SSO, %	drop strength, drops/0.5m	CP, N
A	0	6	15
B	20	5.5	14.2
C	40	5.2	13
D	60	4	11
E	80	5	12
F	100	0	3

3.2 Analysis of metallurgical properties of oxidized pellets

Following oxidation roasting, the CP of pellets significantly increases due to solid-phase bonding between ore particles. The metallurgical properties of the oxidized pellets after roasting are shown in Figure 2. As shown in Figure 1, pellets blended with SSO exhibit strengths ranging from 2100N to 3000N. The CP initially decreases then increases with higher SSO proportions, reaching its minimum (2195N) at 60% SSO loading. This occurs because CVO (critical bonding component) is fully replaced at this ratio, leaving only HVO and SSO – both inferior in consolidation properties. All other blends exceed 2500N, meeting blast furnace specifications. All oxidized pellets exhibit a Low-Temperature Reduction Disintegration Index ($RDI_{+3.15}$) exceeding 90%, effectively preventing excessive pulverization during blast furnace smelting that could degrade burden permeability.

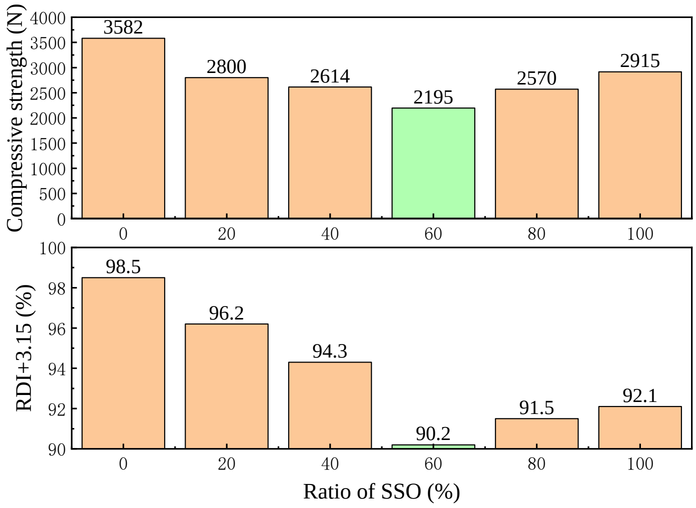

Figure 1. The metallurgical properties of oxidized pellets

3.3 Analysis of industrial basket trial results

Building on prior laboratory research confirming a maximum 80% sea sand ore (SSO) ratio, we initiated industrial basket trials to facilitate scaled-up application. Pellets were produced via a six-stage grate-kiln process: downdraft drying → updraft drying → preheating → roasting → primary cooling → secondary cooling. Two trials employed raw material Blend E (consistent with lab Study E). Process parameters for each stage in both trials are detailed in Table 4, with key schemes: Scheme 1 (standard production parameters) and Scheme 2 (laboratory-optimized parameters with adjusted thermal profiles). This experimental design enabled systematic evaluation of pellet quality evolution under industrial conditions with controlled parameter variations.

Table 4. The Process parameters for each stage in both trials

Stage	Scheme 1		Scheme 2	
	Temperature, ℃	Time, min	Temperature, ℃	Time, min
Downdraft dry	90	4	95	5
Updraft drying	308	4	310	5
Preheat	1044	7	1070	9
Roast	1270	11	1300	14
Primary cool	--	11	--	14
Secondary cool	--	7	--	9

The metallurgical properties of oxidized pellets after two industrial basket trials are presented in Table 5. Results reveal that increasing both preheating-roasting temperature and holding time significantly improves the CP and RDI of oxidized pellets. Under the operational conditions of Scheme 1, the produced oxidized pellets exhibited relatively low strength, primarily attributed to the high contents of Al, V, and Ti in the raw materials. These components, as high-melting-point compounds, necessitate elevated roasting temperatures and extended holding times for complete sintering. Consequently, adjusting the preheating-roasting temperature and prolonging the holding duration led to substantial enhancements in the metallurgical performance of the pellets.

Industrial basket trial results confirm that blending 80% SSO in the pelletizing process can yield oxidized pellets meeting the technical requirements for blast furnace operation, thereby establishing a novel approach for the resource utilization of SSO.

Table 5. The metallurgical properties of oxidized pellets after two industrial basket trials

Sample	CP, N	RDI, %		
		$RDI_{+6.3}$	$RDI_{+3.15}$	$RDI_{-0.5}$
Scheme 1	1437	93.4	93.5	6.4
Scheme 2	2578	95.1	95.3	4.7

4. CONCLUSION

This study investigates the influence of iron sand ore blending ratios on the metallurgical properties of pellets. Industrial basket trials were conducted to validate pellet performance at the highest iron sand ore ratio. The main conclusions are as follows:
(1) As the SSO ratio increases, the strength of green pellets decreases. Pellets made entirely from SSO exhibit zero drop strength, failing to meet production requirements.
(2) The CP and RDI of fired pellets first decrease and then increase with rising SSO ratios.
(3) Industrial basket trials using pellets with an 80% SSO ratio demonstrated that their compressive strength reached 2578 N, satisfying blast furnace production requirements.
(4) Comparison of industrial basket trial results under different thermal parameters revealed that producing SSO pellets requires higher preheating/roasting temperatures and longer durations compared to conventional pellets.

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