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Water Hyacinth Char Addition in Iron Ore Pellet: An Exploratory Study

R. C. GUPTA, J. P. GAUTAM and Sunil MOHAN

Department of Metallurgical Engineering, Institute of Technology, Banaras Hindu University, Varanasi-221 005, India.
Email: rcgupta@banaras.ernet.in, gautam@banaras.ernet.in

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1. Introduction

Water hyacinth is considered to be world's worst aquatic weed and it is known to grow fast in tropical and sub-tropical areas. As of today, this weed does not have any suitable application on large scale though it has a very high biomass yield[1,2] of 154 ton/ha/yr which is equivalent to 2 680 GJ/ha/year of energy. The aim of the present investigation is to explore the possibility of utilising water hyacinth as an additive in the preparation of iron ore pellet which is renewable and abundant in nature.

2. Experimental

2.1. Raw Material

The water hyacinth char was prepared in the laboratory by carbonizing water hyacinth at 600°C for 1 h. The iron ore and coke fines were obtained from Bihar state in India and screened to have $-210\,\mu$m fraction for pelletisation. The composition of iron ore and proximate analysis of water hyacinth char and coke fines are given in **Tables 1** and **2**. The size analysis of iron ore, water hyacinth char and coke fines is shown in **Fig. 1**. The bentonite having composition 90 mass% sodium montmorillonite [$(OH)_4Al_4Si_8O_{20}\cdot nH_2O$] and 10 mass% quartz ($SiO_2$) with particle size less than 0.25 μm was used in this study.

2.2. Pellet Preparation and Firing

The iron ore pellets were made with 5 mass% coke, 5 mass% water hyacinth char, 1 and 2 mass% bentonite and without any additive by hand rolling using 12 mass% moisture. The size of the pellets made was ascertained by a screen (15 mm diameter). These pellets were air dried for 6 h and were heated at a rate of 0.075 K/s (4.5°C/min) under oxidizing atmosphere in the silicon–carbide muffle furnace. The pellets were fired for particular time and temperature.

2.3. Pellet Examination

The cold crushing strength (CCS) was determined by a universal testing machine using 3 ton load scale though it had maximum load capacity of 30 tonnes. The fracture strength was taken as cold crushing strength.

Table 1. Chemical analysis of iron ore (mass%).

Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	LOI	Average particle size (μm)
88.04	2.92	3.62	Trace	Trace	4.27	118

Table 2. Proximate analysis of coke fines and water hyacinth char.

	COKE FINES	WATER HYACINTH CHAR
VOLATILE MATTER (mass %)	13.62	22.69
MOISTURE (mass %)	1.48	5.59
ASH (mass %)	13.56	42.04
FIXED CARBON (mass %)	70.96	29.68
BULK DENSITY (kg/m^3)	745	233
TRUE SPECIFIC GRAVITY (kg/m^3)	1611	1078
AVERAGE PARTICLE SIZE (μm)	83	64

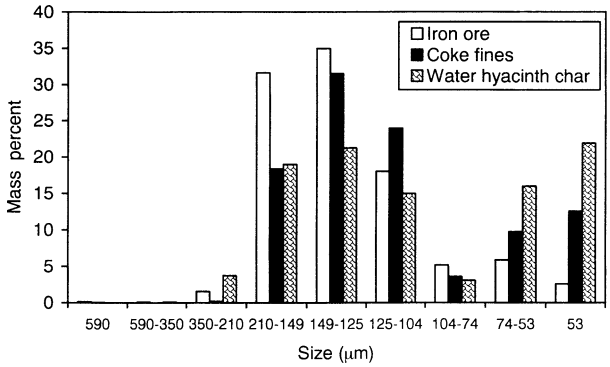

Fig. 1. Particle size analysis of raw materials.

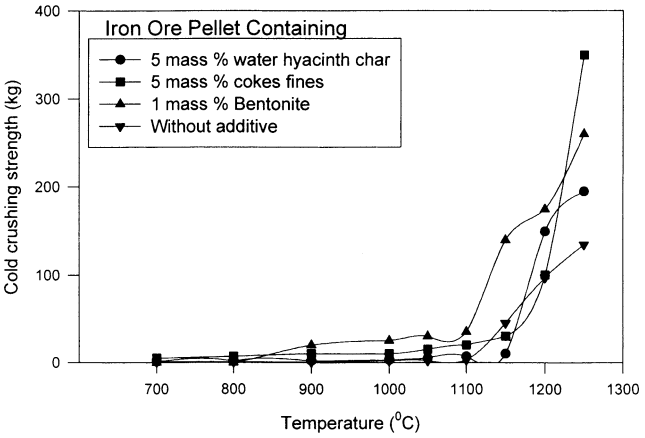

Fig. 2. Strengthening behaviour of different pellets in oxidising atmosphere without soaking at max. temperature (1 250°C).

3. Results

3.1. Heating Temperature and Time

The heating temperature is essential to render pellet strength due to slag bonding. The **Fig. 2** shows the effect of

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Table 3. Effect of 1.2 ks (20 min) soaking time at 1 250°C and total gangue content on cold crushing strength.

Additives	Total gangue content (mass %)	Cold crushing strength (kg)	
		Soaking time (ks)	
		Nil	1.2 ks (20 min)
Without additive	6.54	135	150
5 mass % coke fine	6.88	350	290
1 mass % bentonite	7.21	260	340
5 mass % water hyacinth char	8.30	195	345

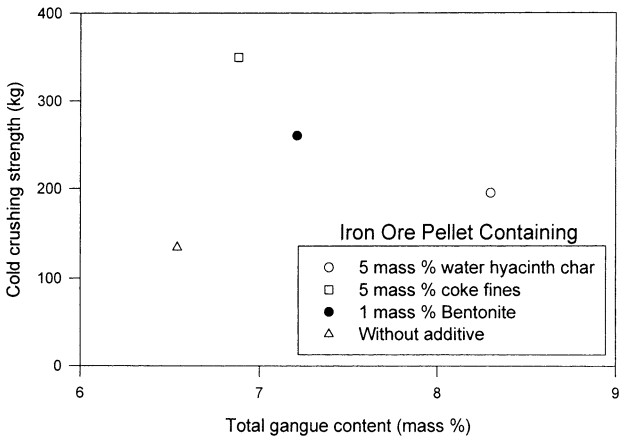

Fig. 3. Effect of total gangue content on the crushing strength of iron ore pellet using various additives at 1 250°C without soaking time.

increased temperature on pellet strength which reveals that no strengthening occurs before 1 050°C. The pellets become stronger when heated upto 1 250°C temperature without any soaking time. The effect of soaking time at 1 250°C is shown in **Table 3**, which reveals that 5 mass% water hyacinth char added pellet gains strength from 195 kg (without soaking time) to 345 kg after 1.2 ks soaking. The pellets without any additive improved strength from 135 to 150 kg and 1 mass% bentonite pellet indicated increase in strength from 260 to 340 kg due to 1.2 ks soaking time. However, the pellets with 5 mass% coke fines showed a decrease in strength from 350 to 290 kg with 1.2 ks soaking time.

3.2. Additives

The strengthening behaviour of pellets during the course of heating in oxidizing condition affected by additives *e.g.* water hyacinth char, coke fines and bentonite has been shown in Fig. 2.

The strengthening of iron ore pellets using 5 mass% water hyacinth char starts after reaching 1 150°C during heating and increases with temperature rising upto 195 kg at 1 250°C without soaking time. It is important to note that no noticeable reduction was caused due to added carbon.

The iron ore pellet with 5 mass% coke fines also exhibited identical strengthening behaviour giving 350 kg strength at 1 250°C without soaking.

The iron ore pellets prepared with 1 mass% bentonite exhibited strengthening behaviour when temperature reaches 1 050°C and continues to give higher strength with temperature rising upto 1 250°C. The maximum pellet strength of 260 kg was noted at 1 250°C without any soaking time. The pellet strength values with additive are found to be higher than pellet made without additive (135 kg).

4. Discussion

The practice of adding carbonaceous[3] material into the pellet before firing was found to be a very good method of substituting expensive oil energy by adding coal/coke fines as a cheaper energy source. The addition of carbonaceous fines led to decrease in total oil consumption and thereby affecting the economics of pellet making in mid seventies. In the recent past, there has been increased awareness[4] in minimising the consumption of all fossil fuels in the light of environmental considerations which led to a world wide effort in substituting fossil fuel by renewable energy source to the maximum feasible extent. The present study is an attempt in the said direction to utilize water hyacinth as a renewable energy source for some useful application and also explore an avenue to find a means of disposing world's worst aquatic weed (water hyacinth).

The carbonaceous fines added to the iron ore pellet have two functions. It serves as a source of energy due to its oxidation during pellet firing and then corresponding amount of energy from other sources are saved. The ash present in the carbonaceous material, mainly silica, acts as a slag generating constituent resulting into good crushing strength of the pellet. In order to have good pellet properties, it becomes essential that these carbonaceous fines are uniformly distributed which requires thorough mixing before pelletization. These carbonaceous materials are also helpful in providing increased local temperature at the point of carbon combustion and thereby it helps in good slag formation and good strengthening of the pellet.

In the present study, it was found that the use of water hyacinth char could render iron ore pellet with strength upto 195 kg without soaking time at 1 250°C in comparison to pellet with additives like 5 mass% coke fines (350 kg pellet strength) and 1 mass% bentonite (260 kg pellet strength).

It is well understood that the total gangue content affects the crushing strength. The **Fig. 3** shows the crushing strength values of pellets with various additives considering the total gangue content in the pellet originating from raw materials. Keeping the identical heating condition (1 250°C without soaking) it can be noted that with increase in gangue content by the addition of bentonite a linear relationship follows whereas the strength values from coke fines and water hyacinth indicate a deviation. The strength value of 195 kg with 5 mass% water hyacinth char (8.3% mass total gangue) may be due to its high combustibility. The water hyacinth is a highly active form of carbon and may get burnt at lower temperatures and is not able to promote fusion of gangue material. In case of coke fines the higher strength (350 kg) with lower total gangue (6.88% mass) content can be attributed to its less reactive carbon form which allows carbon combustion only at elevated temperature (1 150–1 200°C) thereby adding higher local temperature leading to slag fusion and high strength.

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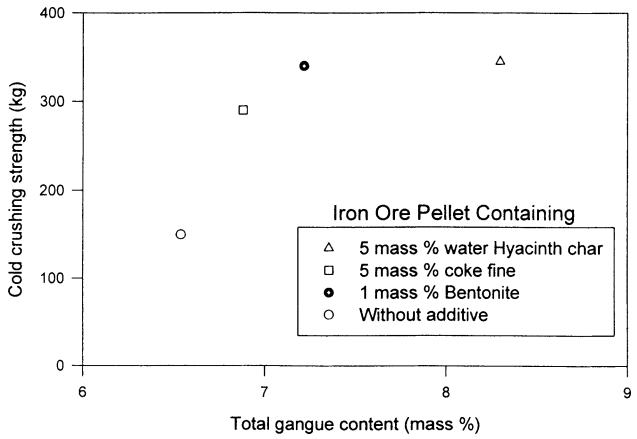

Fig. 4. Effect of total gangue content on the crushing strength of iron ore pellet using various additives at 1 250°C with 1.2 ks (20 min) soaking time.

When the pellets having various additives were soaked for 1.2 ks (20 min) at 1 250°C then their strength increased due to sintering. It may be interesting to observe that after soaking the maximum strength of 345 kg was with 5 mass% water hyacinth char having maximum total gangue content (8.3 mass%) and lowest strength (150 kg) was with pellet without additive having least total gangue content (6.5 mass%). The strength obtained with 1 mass% bentonite and 5 mass% coke fines were found to have strength in order of their total gangue content as shown in **Fig. 4**. It appears that with 1.2 ks soak time the pellet strength increased with total gangue content as it got time to fuse and homogenise.

5. Conclusions

The present exploratory study indicate that water hyacinth char could be a potential additive for making iron ore pellet with good crushing strength (345 kg) coupled with advantages associated with renewable energy source and useful means of disposing world's worst aquatic weed.

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