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The Effect of Kaolin Addition as a Binder in Making Pellets Iron Concentrate

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ABSTRACT

Pellets iron concentrate are formed from fine particles in the form of iron ore concentrate or iron sand after the ore has undergone the agglomeration stage and taken the shape of tiny, marble-like lumps. Iron pellets are also an important raw element in the steelmaking process. The physical, chemical, and metallurgical standards for iron pellet quality vary depending on the specific processing method used to create the pellets. The purpose of this research is to make iron pellets using iron sand derived from zircon sand processing byproducts by adding binders. There are three primary phases in the production of iron pellets, Mixing of iron pellet materials, the second balling process and the third induration process. Materials needed to make iron pellets include water, binder, and iron ore/sand. Typically, bentonite, limestone, and/or similar compounds are used as binder. However, in this study kaolin was used as a substitute for commercial binders with variations of (5; 10; 15 and 20%) binder. Based on the test results kaolin greatly affects the hardness of iron pellets. This can be seen from the results of the Compression Strength Test an average of 107.8 to 156.9 N/Pellet or the equivalent of 11 to 16 Kg/Pellet and the results of the drop test pellets broke at a height of 3 - 4 meters. This indicates that the pellets contain good qualities and exhibit resistance to impacts or mechanical pressure that may arise during transportation or utilization.

INTRODUCTION

As the demand for steel grows, the industry must discover ways to improve raw material quality, one of which is the use of iron pellets with excellent physical and chemical qualities. Good iron pellets must have strength, stability, and the ability to survive during transportation and further processing. Iron Pellets are iron concentrate raw materials used in the manufacture of steel. The process of making iron pellets can be done by pelletizing process where the iron material is mixed with a binder and a little water by agglomeration[1][2].

The primary raw material used to make pellets is iron sand, which is obtained from black sand, a byproduct of processing zircon sand. The primary mineral in the sand is magnetite (Fe_3O_4), which is combined with hematite, limonite, and ilmenite. In order to increase productivity and decrease waste in the steel industry, iron sand is essential for producing iron pellets. The ever-

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expanding steel industry may be supported by making the best use of this natural resource by employing the plentiful iron sand, particularly in regions that produce it [3].

Beside that Kaolin is a natural material has good plasticity and binding properties. Its application as a binder during pelletizing can enhance the mixture's homogeneity and pellets mechanical strength. Using kaolin, a natural mineral substance, industry can limit the usage of synthetic chemicals that are potentially hazardous to the environment. The addition of kaolin is expected to improve the efficiency of the pellet production process, including reducing drying time and roasting process, thus saving energy and production costs[4][5].

The process of making pellet iron is known as the Pelletizing Process where iron ore or iron sand by the method of rotating fine and moist iron sand in a drum to form iron ore balls and then drying them, It was first patented by AG Andersson in Sweden in 1912[4]. The process of creating iron pellets, which involves using raw materials obtained from zircon sand concentration process or quarry processing by products in the form of separated iron sand, serves as the foundation for the problem solving methodology. Aside from that, the binder used kaolin from the Ketapang district as an alternative to commercial binders. So that the pelletizing process will produce products in the form of iron pellets that are ready to be used as raw materials in steel smelting[2][6][7][11].

In this study, iron containing sand is used as the main raw material. Given that there may not be many previous studies examining by-products from the zircon sand processing process that have not been optimized for use in the production of pellets or binders for industry. While Kaolin has been used as a binder in many previous studies for various purposes, including the production of industrial pellets and as a component in other manufacturing procedures. It has been shown that kaolin has good physical properties for attaching particles, providing mechanical strength to pellets, and increasing stability in certain situations [6][8][9][10]. By using this binder, namely kaolin as a substitute, the iron pellet sector can reduce production costs in certain situations, increase productivity or reduce the environmental impact of the pellet production process.

METHODS

In this study, kaolin was added as a binder during the pelletizing process to create iron concentrate pellets. The composition of the pellets varied, and the impact of the binder was subsequently observed. The stages of the process are: The First stage of raw material **Preparation,** iron sand is mashed using a ball mill to a size of ± 0.149 mm and sieved using 100# mesh, The Second stage is the ***Balling*** process **or** the formation of ball-sized pellets with a pellet diameter of 15-25 mm where iron sand and kaolin as a binder are mixed with a composition variation of 95: 5 (%w/w); 90: 10 (%w/w); 85: 15 (%w/w) and 80: 20 (%w/w) and mixing water until the mixture is evenly distributed. Furthermore, The Third stage is the **Induration** process, which is the process of increasing the strength of the pellets where the pellets are dried and metallized at a temperature of 1000^{o}C - 1300^{o}C for 1 - 2 hours. Iron *concentrate* pellets are then tested for durability using 2 testing parameters, Compression Strength Test and Drop Test. A flow diagram of the production process for iron pellets is shown below.

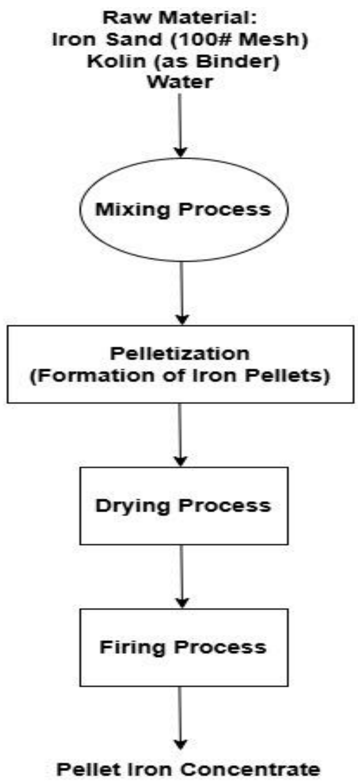


Figure 1. Flow Chart for Iron Pellet Production Process

RESULT AND DISCUSSION

Raw materials in the manufacture of Iron Concentrate Pellets are obtained from black sand which is a by-product of the separation process of zircon sand minerals. The following are results of analysis chemical composition material analyzed using XRF (*X-Ray Flourocence*)

Table 1. XRF Test Result

No.	Compounds	Chemical Contents (%)
1	Fe_2O_3	43.781
2	TiO_2	27.843
3	ZrO_2	15.342
4	SiO_2	4.422
5	P_2O_5	1.436
6	Cr_2O_3	1.342
7	MgO	1.123
8	MnO	1.046
9	CaO	0.881
10	Al_2O_3	0.727
11	Ag_2O	0.577
12	V_2O_5	0.26
13	CuO	0.149
14	Y_2O_3	0.185
15	K_2O	0.102

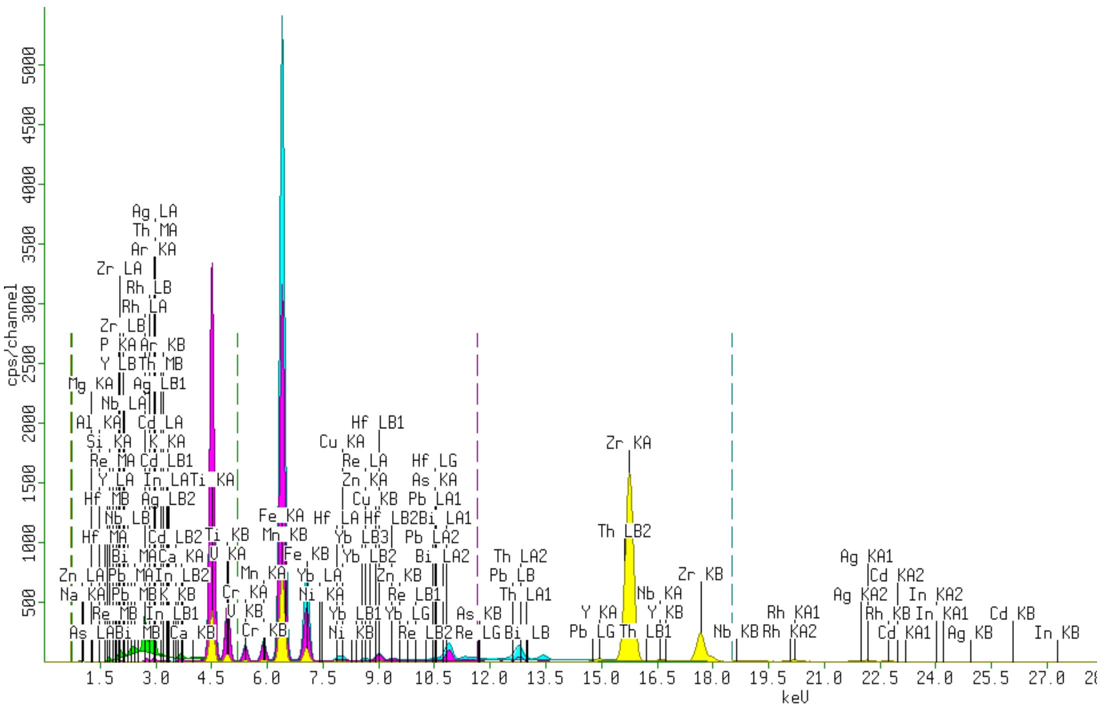


Figure 2. XRF Element analysis

Based on the results of chemical composition analysis on the black sand. It can be seen that high iron content found in iron oxide compounds (Fe_2O_3) of 43.781% followed by titanium oxide (TiO_2) of 27.843%, Zirconium Oxide (ZrO_2) of 15.342%, Silica (SiO_2) of 4.422% and other compounds in small quantities. Therefore, black sand contains iron sand, which can be used as the main raw material in the manufacture of iron pellets.

Furthermore, iron concentrate pellets are made using kaolin as a binder. The results of the analysis were carried out using X-RD (*X-Ray Diffraction*) which aims to find out what minerals are contained in kaolin. The following are results of analysis:

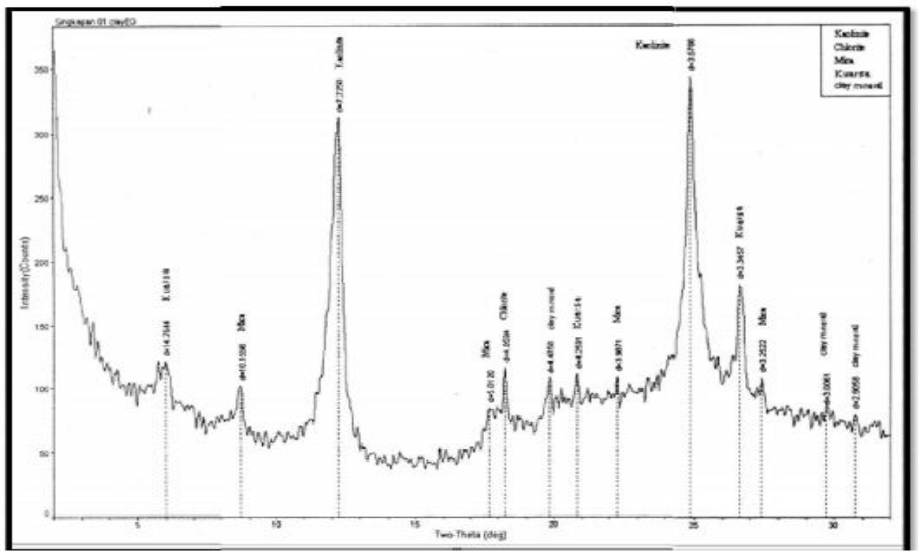


Figure 3. XRD Diffractogram of Kaolin

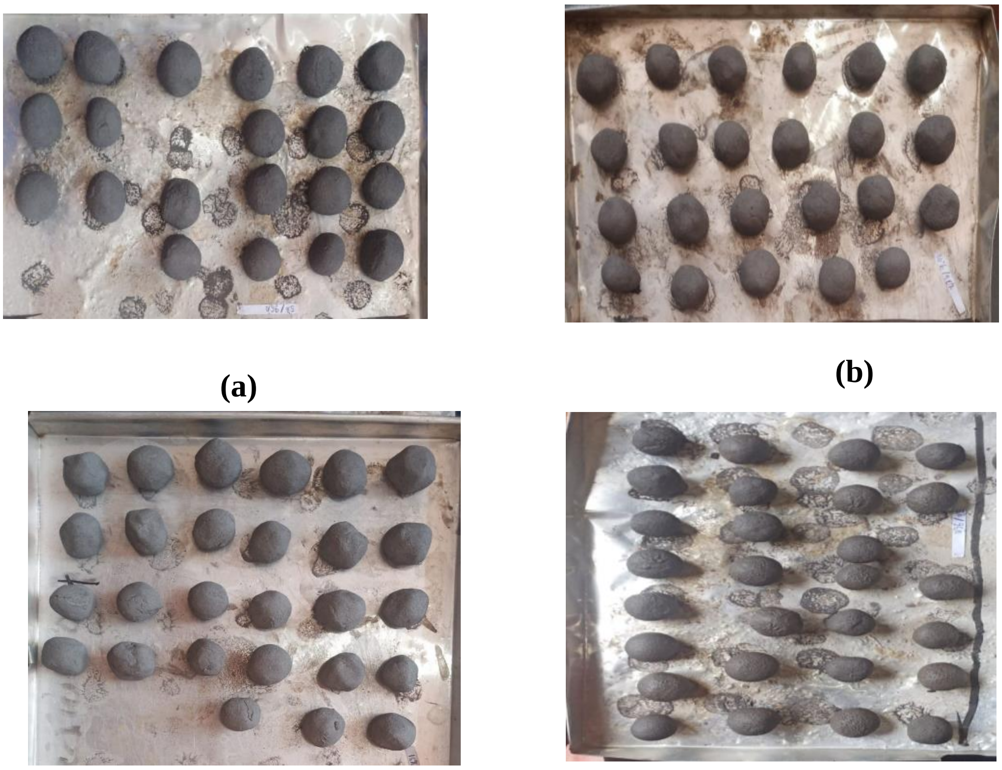
The XRD diffractograms of kaolin samples (**Figure 3**) provide information about type of mineral and degree of crystallinity structure components that make up the sample. Theta (deg) absorption peak pattern indicates the sort of mineral that is present in the sample. On the other hand, peak intensity indicates the degree of crystallinity of the component structure. The greatest peak, which emerges at peak d (Å) = 7.2250 at kaolinite two-Theta = 12.24, and the second-highest peak, which appears at peak d (Å) = 3.5786 at kaolinite two-Theta = 24.86, show that the major peak that appears is the distinctive peak of kaolinite, chlorite, the most kaolin component mineral. In addition, the XRD analysis also provides information on the content or composition of minerals contained therein, which can be seen in **Table 2.**

Table 2. Content of Kaolin Compounds

No.	**Compounds**	**Result (%)**
1	Kaolinite	74,13
2	Kuarsa	6,71
3	Chlorite	10,38
4	Mica	8,42
5	Clay Min.	0,35

The results of chemical composition test of *fresh* kaolin using XRD as in table 2. it turns out that there are several mineral components contained such as *kaolinite* has the highest content among other mineral components 74.13%, *chlorite* has a content of 10.38%, mica 8.42% and quartz has a content of 6.71%, and *clay* minerals 0.35%. It is expected that the high kaolin content will certainly help increase the mechanical strength of iron pellets, so that the pellets become resistant to damage or rupture during handling, transportation, and heating processes in the furnace.

A mixture of iron sand and kaolin as a binder is mixed which is then compacted through a pelletizing process to form small balls of 15 - 20 mm. These pellets are still in the "Green Pellet" stage, this indicates that the pellets have not fully formed or hardened. The outcomes of combining and shaping into green pellets are shown below.

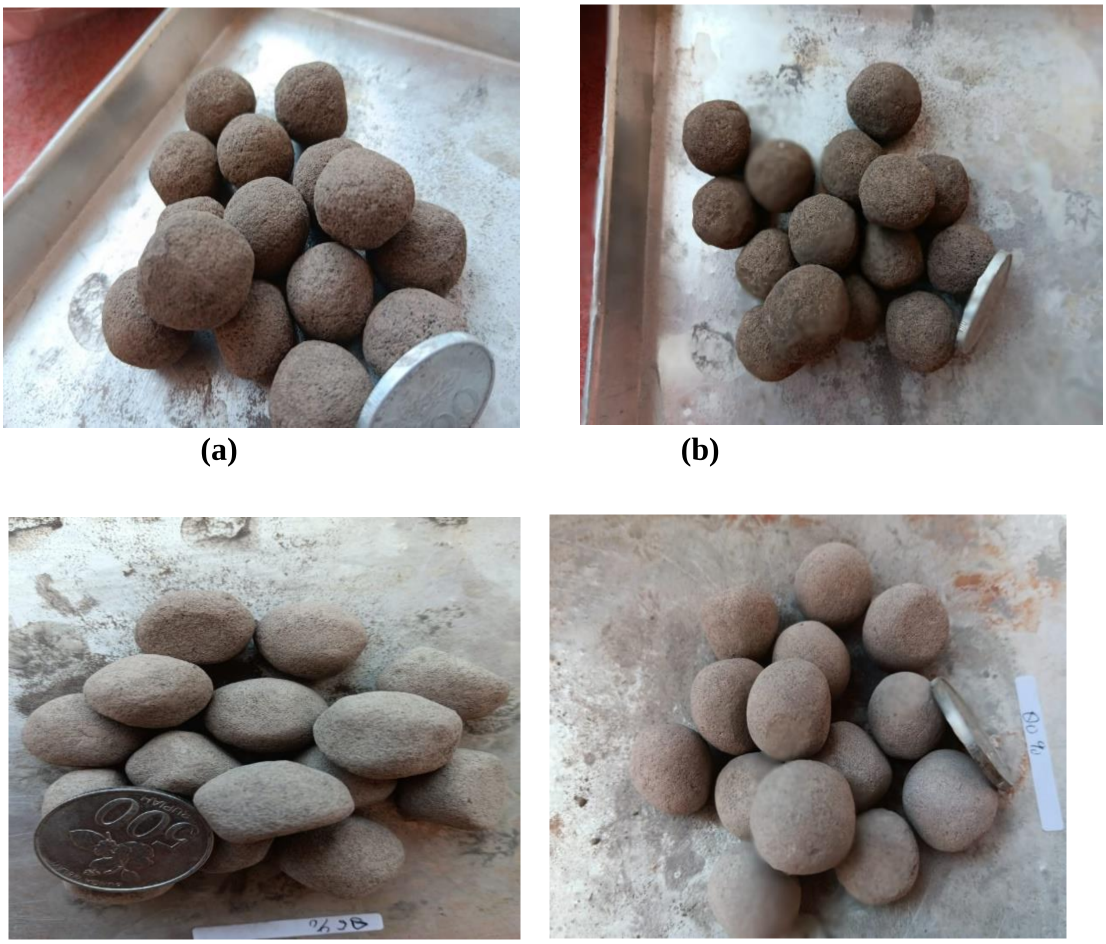


(a) **(b)** **(c)** **(d)**

Figure 4. Green Pellet Product Before Drying and Firing Mixed **a (95:5); b (90:10); c (85:15)** and **d (80:20).**

Based on the initial characteristic results in Figure 4, green pellets still contain high moisture content. This moisture needs to be removed in the drying process before combustion. Since they have not been heated, green pellets have low mechanical strength. This means that the pellets are prone to damage or breakage during handling, transportation or further processing.

The next step is to burn or sinter the iron pellets. This process is carried out at high temperatures in the Furnace with the aim of strengthening the pellet structure where at high temperatures the bond between iron ore particles is stronger while the binder used will burn or decompose which will provide better resistance to the pellets. In addition, the combustion process can reduce moisture and provide mechanical resistance to the iron pellets.The following are the results of iron pellets that have been burned at a temperature of 1000°C – 1300°C.



(a) (b) (c) (d)

Figure 5. Final Product Pellet Iron Concentrate Mixed **a (95:5); b (90:10); c (85:15)** and **d (80:20)**.

Pellet Iron Concentrate have been burned have different size diameters. This can be shown in the pellet diameter size table:

Table 3. Diameter Size Products *Pellet Iron Concentrate*

No	Mixed (95:5) Diameter (mm)	Mixed (90:10) Diameter (mm)	Mixed (85:15) Diameter (mm)	Mixed (80:20) Diameter (mm)
1	17.20	20.88	18.20	19.60
2	18.70	19.20	20.04	19.73
3	20.75	22.03	19.15	19.01
4	18.93	20.03	17.30	18.70
5	18.03	20.70	18.80	19.30
6	18.73	19.76	18.00	18.26
7	17.56	20.06	17.45	17.86
8	18.96	18.10	18.85	19.06
9	17.36	20.36	18.10	19.53
10	18.28	18.31	18.46	18.45
11	18.56	19.23	19.75	19.65
12	19.83	19.40	18.66	19.33

13	18.83	20.20	21.13	19.76
14	18.90	21.20	20.00	19.23
15	18.76	19.33	19.93	17.63
Average	**18.63**	**19.92**	**18.92**	**19.01**

Table 3 shows that the pellets' diameters range from 17 to 20 mm. Because it influences the furnace's heat distribution and melting efficiency, the pellet diameter is crucial.

In the final stage, the iron pellets made were tested for pellet durability. The pellet durability test is carried out with 2 parameters, namely Compression Strength Test and Drop Test. This test aims to measure the durability and quality of iron pellets. The durability test is very important in the smelting industry, because pellets that have good durability will last longer during the transportation, storage, and smelting process without crumbling or breaking. In addition, the physical durability of pellets also directly affects the efficiency and cost of production in the iron and steel industry. The following are the results of the Compression Strength Test conducted using compressive strength testing on pellets with ISO 4700:2019 or ASTM E382-20 Standards[15][16].

Table 4. Compression Strength Test on Products Pellet Iron Concentrate

No.	Mixed (%)	Average Compression Strength	
		(Newton/Pellet)	(Kilogram/Pellet)
1	95 : 5	107.8	11
2	90 : 10	133.4	13.6
3	85 : 15	147.1	15
4	80 : 20	156.9	16

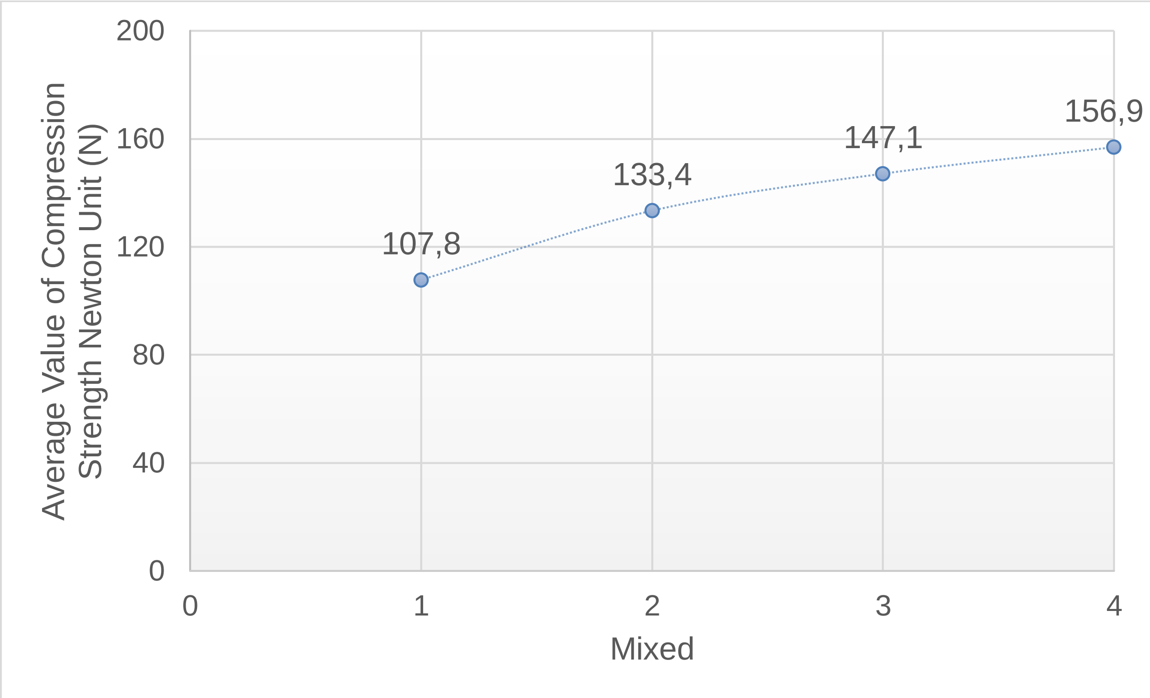


Figure 6. Compression Strength Result (in Newton Units)

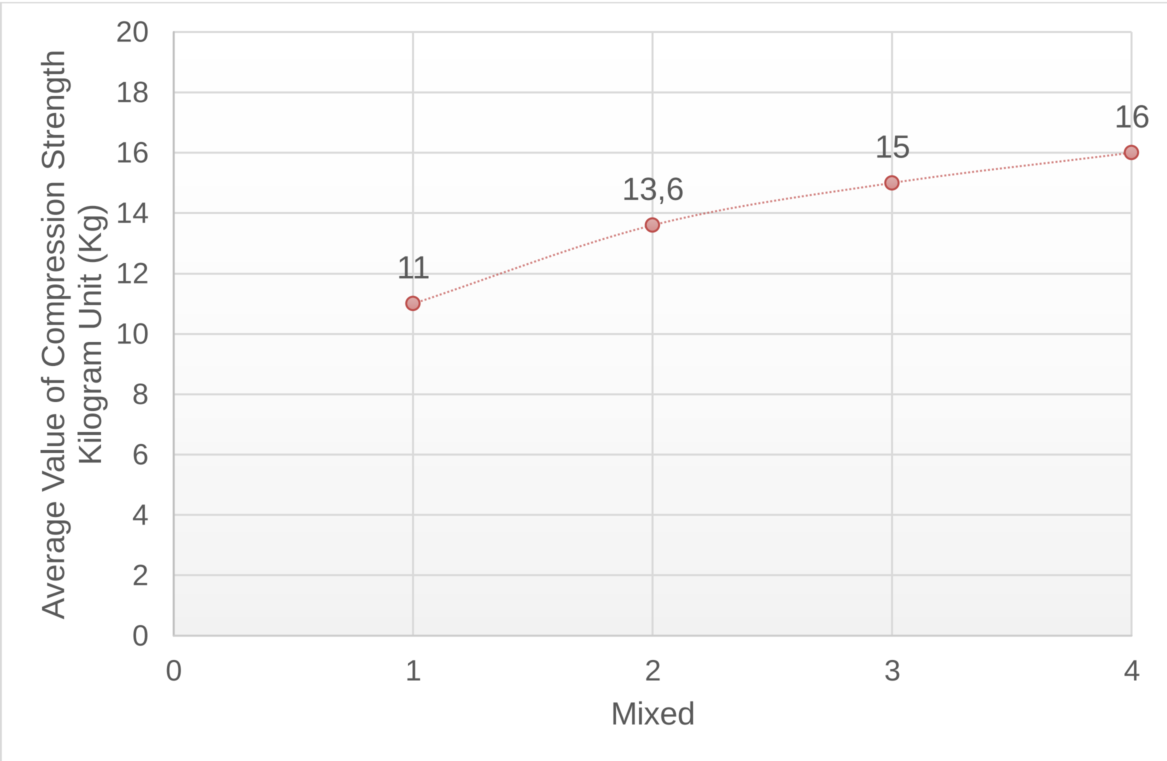


Figure 7. Compression Strength Results (in Kilogram Units)

The test results provide information on the resistance of the pellets to compressive forces. Pellets with higher compressive strength indicate better quality, as they are more resistant to damage during transportation and further processing. It can be seen in graphs 5 and 6 that the effect of kaolin on the compressive strength range of 107.8 - 156.9 N indicates that the pellets are quite strong, with a compressive strength equivalent to 11 to 16 kilograms per pellet.

The following are the results of the drop test on pellet iron concentrate carried out by dropping the pellets at a certain height.

Table 5. Drop Test on Products Pellet Iron Concentrate

No.	Mixed (%)	Drop Test (Meters)			
		1	2	3	4
1	95 : 5	Unbreakable	Break	Break	Break
2	90 : 10	Unbreakable	Unbreakable	Break	Break
3	85 : 15	Unbreakable	Unbreakable	Unbreakable	Break
4	80 : 20	Unbreakable	Unbreakable	Unbreakable	Break

Based on the table above, it can be seen durability of iron pellets from a height of 1 - 4 meters. Iron pellets with a little kaolin binder mixture are more easily broken at a height of 1 - 2 meters. While more kaolin binder mixture is not easily broken until the height of 1 - 3 meters but at the height of 4 meters the pellets begin to broken.

A high adequate compressive strength is essential for good iron pellets to avoid damage during production and transportation. For industrial applications, iron pellets with a compressive strength more than 100 N/pellet are often deemed strong enough. Pellets need to be robust enough to endure knocks while being transported. This test is crucial to make sure the pellets can be treated correctly in a blast furnace or kiln since crushed or brittle pellets might impede the smelting process. The industry can ensure the quality of the pellets produced in accordance with production goals and objectives by employing test standards like ISO 4700 or ASTM E382[15][16].

CONCLUSION

Based on the results of research and experiments, it can be concluded that the process of making iron pellets using kaolin binder greatly affects the hardness of iron pellets. This can be seen from the results of the Compression Strength Test testing an average of 107.8 N/Pellet to 156.9 N/Pellet or the equivalent of 11 Kg/ Pellet to 16 Kg/Pellet and the results of the drop test the pellet broke at a height of 3 - 4 meters. This indicates that the pellets contain good qualities and exhibit resistance to impacts or mechanical pressure that may arise during transportation or utilization.

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