# 19.Characteristics of mechanical strength on pellet catalysts from Bandung natural zeolite material due to the influence of

*by* Sulardjaka Sulardjaka

RESEARCH ARTICLE | MAY 08 2023

# Characteristics of mechanical strength on pellet catalysts from Bandung natural zeolite material due to the influence of variations in mesh size

Norman Iskandar; Sayyied Al-Kareem; Sulardjaka ✉; ... et. al



*AIP Conference Proceedings* 2706, 020032 (2023)
https://doi.org/10.1063/5.0120837

# Characteristics of Mechanical Strength on Pellet Catalysts from Bandung Natural Zeolite Material due to the Influence of Variations in Mesh Size

Norman Iskandar[1, a)], Sayyied Al-Kareem[1, b)], Sulardjaka[1, c)], Syaiful[1, d)] and Widayat[2, e)]

[1]Departement of Mechanical Engineering, Diponegoro University, Semarang, 50275, Indonesia
[2]Departement of Chemical Engineering, Diponegoro University, Semarang, 50275, Indonesia

[a)] norman.undip@gmail.com
[b)] sayyiedalkareem@gmail.com
[c)] Corresponding author: sulardjaka@gmail.com
[d)] syaiful.undip2011@gmail.com
[e)] widayat@live.undip.ac.id

**Abstract.** Zeolite is a multifunctional material that has properties as an absorber, ion exchanger, molecular filter, and as catalyst. This study aims to measure the mechanical strength and soluble resistance of Bandung natural zeolite as a heterogeneous catalyst in the form of pellets because the application of zeolite as a catalyst in powder form still has drawbacks. Bandung natural zeolite was varied in particle size by using a sieve with a mesh of 60, 120, and 250 then formed into pellets using a 5mm diameter die using a hydraulic press with a compaction pressure of 1.5 tons. The catalyst pellets were tested for compression and soluble tests. The compression test method is Side Crush Strength (SCS) with reference to the ASTM D4179 standard. The soluble test method was carried out by dissolving the pellet in water which was rotated with a magnetic stirrer with a rotation of 250 rpm with variations in time of 30 minutes, 60 minutes, and 90 minutes. From the test results, it can be concluded that the smaller the particle size, the stronger the relationship between the powder particles because the micro-sized powder can fill the empty gaps in the pellet better. This can lead to an increase in the mechanical strength of the pellets and the value of the pellet dissolving resistance rate.

## INTRODUCTION

Indonesia is a country with abundant natural mineral wealth. The minerals produced can be in the form of metals such as gold, nickel, copper, silver, iron, and so on, while non-metallic minerals such as zeolite, bentonite, phosphate, limestone, and others. Zeolites are hydrated aluminosilicate crystalline materials of alkali or alkaline earth metals which are interconnected in the presence of oxygen atoms, thus forming a three-dimensional framework formed by $[SiO4]^{4-}$ and $[AlO4]^{5-}$ tetrahedral and containing cavities filled with metal ion [1]. These cavities can be filled with water and exchangeable cations and have a certain pore size that makes zeolites can be used as catalysts. In Indonesia, zeolites are found in many areas such as Sukabumi, Bogor, Tasikmalaya, Lampung, Bayah, Malang, etc. Zeolite can be formed naturally in nature which is called natural zeolite. In addition to natural zeolites, zeolites can also be synthesized from various materials containing alumina and silica.

The development of research on the benefits of zeolite has been very developed and can be utilized in various fields such as industry, agriculture, and the environment. Zeolite is a multifunctional non-metallic mineral because it has several unique properties such as adsorption, ion exchange, molecular filter, and catalyst (catalytic activity). Zeolite is one of the catalysts that is often used in various fields because of its constituent content that is rarely found in other conventional catalysts [2]. Zeolite catalysts have been widely developed and applied for industrial applications [3].

*3rd Borobudur International Symposium on Science and Technology 2021*
AIP Conf. Proc. 2706, 020032-1–020032-6; https://doi.org/10.1063/5.0120837
Published by AIP Publishing. 978-0-7354-4447-8/$30.00

The use of catalysts that are most often used today is homogeneous catalysts because they have high availability. But on the other hand, homogeneous catalysts still have many disadvantages, such as difficulty separating from the substrate and high manufacturing costs [4]. Disadvantages of homogeneous catalysts can be anticipated by using heterogeneous catalysts [5]–[8]. The use of heterogeneous catalysts has lower production costs, is non-corrosive, environmentally friendly, and is easier to separate from the substrate compared to homogeneous catalysts.

In its application, heterogeneous catalysts are often used in powder or solid form (pellets or tablets). The use of catalysts in powder form has a disadvantage, namely in the form of powders that are easily soluble when mixed with liquids which can cause blockage and pressure drop [9]. Catalysts in the form of pellets can overcome the problems that occur in powder catalysts. In addition to eliminating the lack of powder catalyst, it also serves to increase the strength of the zeolite so that it is not easily destroyed and can be modified in forms and mixtures as needed [10].

From the explanation above, it can be seen that the utilization of natural resources in Indonesia is still very limited and its utilization has not been maximized. Natural zeolite is one example of a resource that must be developed to be utilized so that its potential can be developed optimally.

This study aims to utilize Bandung natural zeolite as a heterogeneous catalyst in the form of pellets. This research was conducted by analyzing the effect of particle size variations (mesh) on the process of making zeolite catalyst pellets on the mechanical strength of zeolite catalyst pellets and the speed of dissolving.

## METHOD

### Material Preparation

Bandung natural zeolite was ground using a grinder to become a powder and then sieved using a mesh size of 60, 120, and 250. The zeolite powder was then dried in an oven at 110$^{o}$C for 3 hours. Zeolite powder is ready to be made into pellets.

### Pelletizing Process and Testing Process

The process of making pellets is carried out using a die with a diameter of ±5 mm and pressed with a hydraulic press machine with a pressure of 1.5 tons and held for 20 seconds. To determine the mechanical strength of the pellet, a compression test was carried out using the side crush strength (SCS) method based on the ASTM D4179 standard with a pressure rate of 0.5 mm/minute.

The solubility test is based on the drug dissolution test method. To determine the value of the speed of dissolving the catalyst pellet was inserted into 300 ml of water fluid with a magnetic stirrer in it. The catalyst pellet was conditioned in a non-impact position with a magnetic stirrer. The process parameters in the test include the rotating speed of the magnetic stirrer 250 Rpm, fluid temperature 55oC, and mass weighing was carried out on the catalyst taking after 30 minutes, 60 minutes, and 90 minutes.

## RESULT AND DISCUSSION

The following are the results of the density test, crushing strength test, solubility test, and XRF on Bandung natural zeolite pellet catalyst.

### Physical Measurement and Density

From the measurement results of several catalyst pellets, the average value of different dimensions in different meshes is shown in Table 1. This is because the die holes are bending due to the compaction process at the time of making pellets [11]. Dimensional differences can be represented by the ratio of diameter to pellet height (D/h). The D/h ratio at mesh 60 is 0.87, at mesh 120 is 0.90 and at mesh 250 it is 1.20.

**TABLE 1**. Pellet Catalysts Physical Measurement

| Mesh | Diameter (mm) | High (mm) | Volume (mm$^3$) | Mass (g) | Density (g/mm$^3$) |
|---|---|---|---|---|---|
| 60 | 5.10 | 5.83 | 119,77 | 0,1900 | 1,59 x 10-3 |
| 120 | 5.10 | 5.63 | 115,09 | 0,1863 | 1,62 x 10-3 |
| 250 | 5.33 | 4.45 | 99,35 | 0,1497 | 1,51 x 10-3 |

From the density data obtained various data. The difference in the mass of powder that enters the die is one of the causes of the calculated density to be very diverse. However, when viewed at relatively the same mass, then in a larger mesh, such as a mesh of 120 to 60, the smaller the particle size can increase the density value of the catalyst pellet product. This is because the more space that can be filled by the particles, reduces the number of pores that occur so that the density increases.

## Compression Test

Table 2 shows the compressive test results of Bandung natural zeolite catalyst pellets from each mesh variant. In the catalyst pellet with a mesh of 60, the highest force value was 45.07 N with a compressive strength of 1.43 MPa. Catalyst pellets with a mesh of 120 on a test object of 120 mesh obtained the highest force of 46.45 N with a compressive strength value of 1.48 MPa, and on a catalyst pellet with a mesh of 250 mesh the highest force value of 46.95 N with a compressive strength value of 1,49 MPa. The comparison of these values is also presented in Figure 1 which illustrates the variations that appear in the 5 sample testing processes for each existing mesh.

**TABLE 2**. Compression Test Results

| Mesh Number | Specimen | Force Peak (N) | Compression Strength (MPa) |
|---|---|---|---|
| Mesh 60 | 1 | 45.07 | 1.43 |
| | 2 | 38.71 | 1.23 |
| | 3 | 37.76 | 1.20 |
| | 4 | 23.73 | 0.76 |
| | 5 | 26.18 | 0.83 |
| Mesh 120 | 1 | 46.05 | 1.46 |
| | 2 | 46.45 | 1.48 |
| | 3 | 37.37 | 1.19 |
| | 4 | 22.20 | 0.71 |
| | 5 | 23.29 | 0.74 |
| Mesh 250 | 1 | 35.09 | 1.12 |
| | 2 | 46.68 | 1.49 |
| | 3 | 37.15 | 1.18 |
| | 4 | 46.95 | 1.49 |
| | 5 | 41.23 | 1.31 |

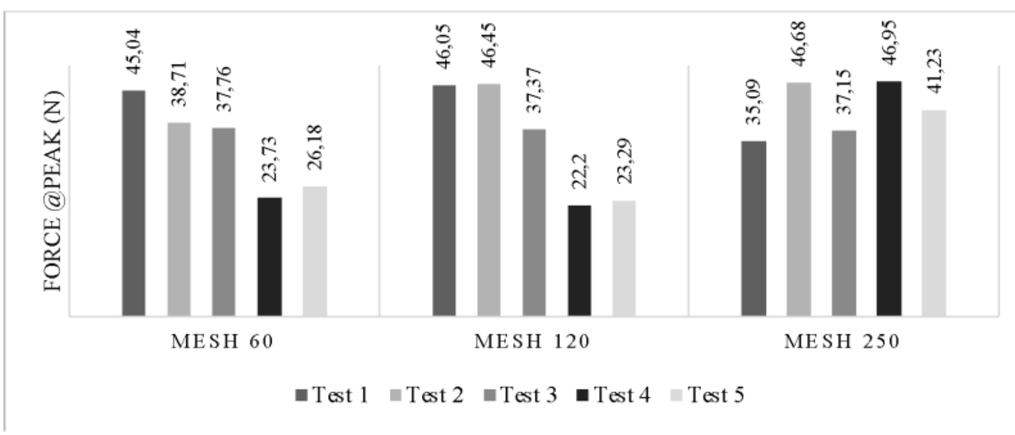
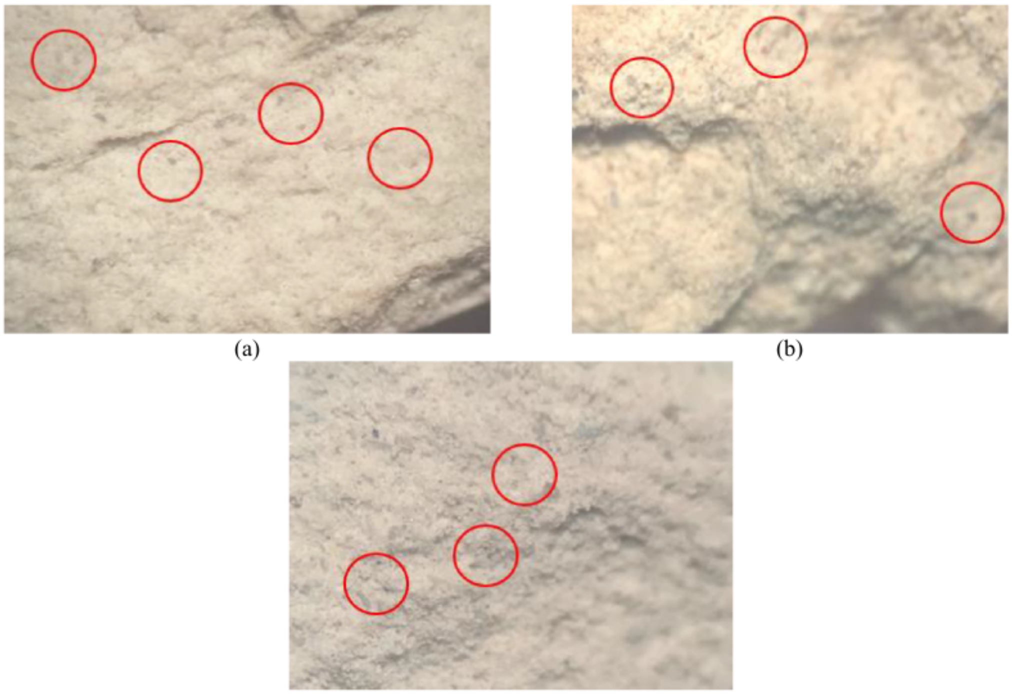



**FIGURE 1.** Maximum Compressive Strength Value of Each Test Specimen

The force at peak value obtained shows that the catalysts pellet with a mesh size of 250 has a more stable value than the 60 and 120 mesh. These results are in line with research conducted by Hasna and Zainollah where pellets are made from powder with smaller particle sizes, it will increase the value of the mechanical strength of the pellet because the powder size is more uniform [12].

The macro photo is presented in Figure 2 where it can be seen that the Bandung natural zeolite pellet fragment which has been subjected to a compression test has holes on its surface. The hole can be indicated as a result of the release of granules from the zeolite catalyst pellet after the compression test was carried out because the zeolite powder did not stick together perfectly or did not have a strong bond between the zeolite powder particles.



(a) (b) (c)

**FIGURE 2.** Macro Photo on Zeolite Pellet Fraction (a) Mesh 60; (b) Mesh 120; (c) Mesh 250

When the catalyst pellets are pressurized, the zeolite particles are released from their bonds. If the particles have good bonding strength, then when pressure is applied, the zeolite particles in the pellet will break or break through the particles. This can occur when the bond strength between particles is greater than the strength of the particles themselves to withstand a given load. So that when the zeolite pellets are under pressure, the cracks that occur will cause the zeolite particles to split.

## Solubility Test

From the test results shown in Table 3, it shows that there is a decrease in the dissolution rate from powder size (mesh) 60 to powder size (mesh) 250. The lowest dissolution rate value was found in specimens with a mesh of 250 with a value of 0.0006 gram/minute while the highest dissolution rate value was found in specimens with a mesh of 60 with a value of 0.0029 gram/minute. From the test results, it is evident that the smaller the particle size of the zeolite powder, the faster the pellet dissolving rate will decrease. It is stated that the compressive strength of pellets is directly proportional to the value of pellet density [13]. The smaller the particle size of the zeolite powder, the value of pellet density will increase and make the pellets more difficult to dissolve in the substrate.

TABLE 3. Solubility Test Result

| Mesh Number | Test Duration (min) | Initial Mass (gr) | Final Mass (gr) | Mass Loss (gr) | Soluble Rate (gr/min) |
|---|---|---|---|---|---|
| Mesh 60 | 30 | 0.1856 | 0.0343 | 0.1513 | $5.0\times10^{-3}$ |
| | 60 | 0.1900 | 0.0443 | 0.1457 | $2.4\times10^{-3}$ |
| | 90 | 0.1900 | 0.0734 | 0.1166 | $1.2\times10^{-3}$ |
| | **Average** | | | **0.1379** | $\mathbf{2.9\times10^{-3}}$ |
| Mesh 120 | 30 | 0.1812 | 0.0556 | 0.1256 | $4.2\times10^{-3}$ |
| | 60 | 0.1834 | 0.0407 | 0.1427 | $2.4\times10^{-3}$ |
| | 90 | 0.1863 | 0.0360 | 0.1503 | $1.7\times10^{-3}$ |
| | **Average** | | | **0.1395** | $\mathbf{2.7\times10^{-3}}$ |
| Mesh 250 | 30 | 0.1488 | 0.1070 | 0.0418 | $0.7\times10^{-3}$ |
| | 60 | 0.1419 | 0.1253 | 0.0167 | $0.6\times10^{-3}$ |
| | 90 | 0.1497 | 0.1011 | 0.0486 | $0.5\times10^{-3}$ |
| | **Average** | | | **0.0357** | $\mathbf{0.6\times10^{-3}}$ |

## XRF Test

Figure 3 shows the dominant content of metal oxides in natural zeolite from Bandung. $SiO_2$ has the highest percentage content, followed by $Al_2O_3$. These two compounds have the highest amount of content because these two compounds are the main constituents of zeolites. In addition to these two elements, there are other elements such as MgO, $SO_3$, $K_2O$, CaO, $TiO_2$, MnO, $Fe_2O_3$, SrO, and $ZrO_2$ which are contained in zeolite but the amount is below 10% which is included in the category of additional compounds in the zeolite content.

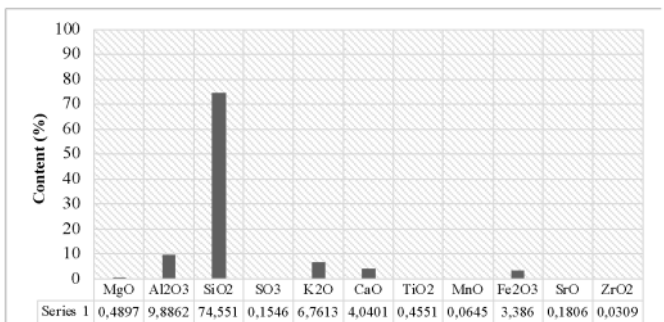



**FIGURE 3.** Percentage of Zeolite Composing Elements from Bandung

Additional compounds in the zeolite in each area can be different in number because the content of these compounds depends on the natural conditions around the zeolite mining site. The higher Si/Al ratio can increase the hydrophobic properties of the zeolite. Appropriate calcination in temperature and time will be able to change the ratio.

## CONCLUSION

Variations in mesh size affect the mechanical strength of Bandung natural zeolite pellet catalyst. The larger the mesh size or the smaller the particle size, it will increase the density of the catalyst pellets so that the compressive strength of the pellets will also increase and tend to be more stable. The effect on the average value of the solubility rate of each sample of mesh 60 and mesh 120 specimens, the value of the mass reduction rate reached 80%, while the 250 mesh specimen only decreased about 25%. This can happen because the larger the mesh size will produce a smaller and uniform powder particle size and the given compaction pressure will make the bonds between powder particles stronger so that the pellets are not easily dissolved in the substrate.

## REFERENCES


1. M. Gougazeh and J. C. Buhl, "Synthesis and characterization of zeolite A by hydrothermal transformation of natural Jordanian kaolin," *J. Assoc. Arab Univ. Basic Appl. Sci.*, vol. 15, no. 1, pp. 35–42, 2014, doi: 10.1016/j.jaubas.2013.03.007.
2. R. S. Harjanti, "Pemanfaatan Zeolit Alam Klinoptilolite Sebagai Katalisator dalam Alkoholisis Minyak Jarak," *J. Rekayasa Proses*, vol. 2, pp. 28–32, 2012, doi: 10.22146/jrekpros.552.
3. R. Hull, C. Jagadish, R. M. Osgood Jr, J. Parisi, Z. Wang, and H. Warlimont, *Characterization and Design of Zeolite Catalysts*. 2010.
4. R. Hartono, Rusdi, A. Wijanarko, and H. Hermansyah, "Pembuatan Biodiesel Dari Minyak Dedak Padi Dengan Proses Katalis Homogen Secara Asam Dan Katalis Heterogen Secara Basa," *Semin. Nas. Sains dan Teknol.*, no. November, pp. 1–9, 2016.
5. M. R. Abukhadra and M. A. Sayed, "K+ trapped kaolinite (Kaol/K+) as low cost and eco-friendly basic heterogeneous catalyst in the transesterification of commercial waste cooking oil into biodiesel," *Energy Convers. Manag.*, vol. 177, no. September, pp. 468–476, 2018, doi: 10.1016/j.enconman.2018.09.083.
6. Y. Ma, Q. Wang, X. Sun, C. Wu, and Z. Gao, "Kinetics studies of biodiesel production from waste cooking oil using FeCl3-modified resin as heterogeneous catalyst," *Renew. Energy*, vol. 107, pp. 522–530, 2017, doi: 10.1016/j.renene.2017.02.007.
7. N. S. Lani, N. Ngadi, N. Y. Yahya, and R. A. Rahman, "Synthesis, characterization and performance of silica impregnated calcium oxide as heterogeneous catalyst in biodiesel production," *J. Clean. Prod.*, vol. 146, pp. 116–124, 2017, doi: 10.1016/j.jclepro.2016.06.058.
8. Y. C. Chen, D. Y. Lin, and B. H. Chen, "Transesterification of acid soybean oil for biodiesel production using lithium metasilicate catalyst prepared from diatomite," *J. Taiwan Inst. Chem. Eng.*, vol. 79, pp. 31–36, 2017, doi: 10.1016/j.jtice.2017.05.001.
9. N. Y. Chen, M. C. Liu, S. C. Yang, H. S. Sheu, and J. R. Chang, "Impacts of Binder-Zeolite Interactions on the Structure and Surface Properties of NaY-SiO2 Extrudates," *Ind. Eng. Chem. Res.*, vol. 54, no. 34, pp. 8456–8468, 2015, doi: 10.1021/acs.iecr.5b01369.
10. O. F. Science, "(12) Patent Application Publication (10) Pub. No. US 2016/0271610 A1 Patent Application Publication," 2016.
11. H. H. S. Santana, G. Maier, and J. Ródenas, "Diametral compression test: Analysing the H/D ratio influence on the mechanical resistance of UO2-green pellets," *Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip.*, vol. 619, no. 1–3, pp. 449–452, 2010, doi: 10.1016/j.nima.2009.10.114.
12. A. H. Hasna, J. P. G. Sutapa, and D. Irawati, "Pengaruh Ukuran Serbuk dan Penambahan Tempurung Kelapa Terhadap Kualitas Pelet Kayu Sengon," *J. Ilmu Kehutan.*, vol. 13, no. 2, p. 170, 2019, doi: 10.22146/jik.52428.
13. D. Irnawan and B. Karomah, "Pengaruh Mesh (Ukuran Serbuk) Terhadap Sifat Mekanik Komposit Panel Dinding Hiasan," pp. 273–279, 2019.

# 19.Characteristics of mechanical strength on pellet catalysts from Bandung natural zeolite material due to the influence of

ORIGINALITY REPORT

| 12% | 6% | 11% | 7% |
| --- | --- | --- | --- |
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | | |
| --- | --- | --- | --- |
| 1 | Submitted to School of Business and Management ITB<br>Student Paper | 4% |
| 2 | Norman Iskandar, Sulardjaka Sulardjaka, Syaiful Syaiful, Widayat Widayat. "The effect of binder concentration on characteristic of pellet catalyst", AIP Publishing, 2023<br>Publication | 2% |
| 3 | Rizka Mayasari, Miftahul Djana. "Improving effluent water quality of rubber liquid waste treatment using ceramic membranes based on bentonite, zeolite and iron additives", AIP Publishing, 2022<br>Publication | 1% |
| 4 | elar.usfeu.ru<br>Internet Source | 1% |
| 5 | Submitted to University of California, Merced<br>Student Paper | 1% |
| 6 | Manu Ravuri, R. Pugazhenthi. "The effect of sintering temperature on components | 1% |

prepared by Cu powder mixed with binder", AIP Publishing, 2020
Publication

| | | |
|---|---|---|
| 7 | Submitted to Universiti Teknologi Malaysia<br>Student Paper | 1% |
| 8 | Rudi Hartono, Anondho Wijanarko, Heri Hermansyah. "Modification of bayah banten natural zeolite as heterogeneous catalyst in biodiesel production", Journal of Applied Engineering Science, 2019<br>Publication | 1% |
| 9 | D.Y. Dhande, D.V. Nighot, Nazaruddin Sinaga, Kiran B. Dahe. "Corrigendum to “Extraction of bioethanol from waste pomegranate fruits as a potential feedstock and its blending effects on a performance of a single cylinder SI engine”[Renew. Sustain. Energy Rev. 149, October 2021, 111349]", Renewable and Sustainable Energy Reviews, 2021<br>Publication | <1% |
| 10 | etd.repository.ugm.ac.id<br>Internet Source | <1% |
| 11 | Shunli Zhou, Chengxi Zhang, Yongxiang Li, Yibin Luo, Xingtian Shu. " Effect of Particle Size of Al O Binders on Acidity and Isobutane–Butene Alkylation Performance of Zeolite Y-Based Catalysts ", Industrial & Engineering Chemistry Research, 2020 | <1% |

Publication

| | | | |
|---|---|---|---|
| 12 | jurnal.polines.ac.id<br>Internet Source | | <1 % |
| 13 | www.stpauls.pvt.k12.al.us<br>Internet Source | | <1 % |
| 14 | www.tdx.cat<br>Internet Source | | <1 % |

| | | | |
|---|---|---|---|
| Exclude quotes | Off | Exclude matches | Off |
| Exclude bibliography | On | | |

# 19.Characteristics of mechanical strength on pellet catalysts from Bandung natural zeolite material due to the influence of

GRADEMARK REPORT

FINAL GRADE

/100

GENERAL COMMENTS

**Instructor**

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7