Manufacture Hollow Glass Microsphere (HGS) in University Laboratory Scale (Phase 1)

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Abstract. Hollow Glass Microsphere (HGS) can be used as an additive of drilling fluid to decrease the density and hydrostatic pressure without changing the chemistry characteristic to make underbalanced drilling condition. HGS is relatively easier to be mixed with the fluid without complicated equipment, can prevent formation damage, and can improve oil and gas production. There are various HGS commercial products that have been developed in the industry for various purposes with a density range 0.125-1.1 gr/cm³, grain size range 2-120 μm, and compressive strength up to 200 MPa. HGS has been successfully used in underbalanced drilling operation in several oil and gas fields in Indonesia. HGS costs less than UBD and the application shows good results with the improvement of oil and gas production. However, the cost of commercial HGS products in the market is very expensive. Petroleum Engineering Study Program Institut Teknologi Bandung (ITB) performed the HGS research in three phases. The first phase reported in this paper was to manufacture HGS in the university laboratory scale. HGS was manufactured based on various chemical compositions and temperature and time variation of the burning process. Scanning Electron Microscope (SEM), Energy Dispersive Spectrometry (EDS), and X-Ray Diffraction (XRD) analysis were performed to identify and characterize the raw chemical material and manufactured HGS. HGS was successfully manufactured with the following characteristics: low density (<0.8 gr/cm³) and low grain size (20-40 μm). These characteristics show that HGS can compete with commercial industry HGS products that have been successfully used in the underbalanced drilling operation. The second phase is to scale-up manufacture HGS from university laboratory scale to industrial scale. The third phase is to test the manufactured HGS with drilling fluid according to the American Petroleum Institute (API) Spec. 13A and API Spec. 13B-1.

1. Introduction

1.1. Background
Hollow Glass Microsphere (HGS) can be used as an additive to drilling fluid. HGS is a spherical-shaped filler material that possesses properties such as low density in the range of 0.29 to 0.63 gr/cm³, high-temperature resistance, high compressive strength value in the range of 2,000 to 18,000 psi, homogeneous and dimensional-stable [1]. HGS as a drilling fluid additive was initially researched by the U.S. Department of Energy in the late 1990s [2]. HGS can reduce the drilling fluid density down to 5.5 ppg [1]. Application of HGS in drilling fluid can reduce the lost circulation rate from 100 bbl/hr to...
6 bbl/hr [3], while the differential sticking [4], formation damage issues, and other possible downhole issues are eliminated [2] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16].

However, the commercial HGS products in the market are very expensive [17]. This study was performed to make a first step in fulfilling the necessity of HGS for drilling new wells in mature fields in Indonesia. Institut Teknologi Bandung (ITB) performed the HGS manufacturing process in the laboratory. In 2012, ITB has successfully performed the HGS manufacturing research [18]. Various chemical compositions and temperature and time variations of the burning process were used and applied in the manufacturing process. The identification and characterization of the chemical material and manufactured HGS were performed using Scanning Electron Microscope (SEM), Energy Dispersive Spectrometry (EDS), and X-Ray Diffraction (XRD). The objective of this research was achieved by manufacturing HGS with characteristics such as low density (<0.8 gr/cm³) and low grain size (20-40 μm). The material of manufactured HGS costed $136-218.5/sack, which was much cheaper than several commercial HGS products. The test will be performed according to guidelines and procedures in American Petroleum Institute (API) Spec. 10A [19], API Spec. 13A [20], and API Spec. 13B-1 [21].

1.2. Objectives
The study reported in this paper was the first phase with the following objectives:

1. Manufactured HGS in the laboratory.
2. Analyzed the properties of manufactured HGS.
3. Compared the manufactured HGS among several commercial HGS products.

1.3. Study Methodology
Figure 1 shows the methodology of this study.

Figure 1. The methodology of the study

Figure 2 shows the manufacturing process of HGS.

Figure 2. The manufacture process
2. Result and Discussion

2.1. Characteristic of Manufactured HGS
There were 5 samples shown in this study. Figure 3 and Table 1 show the characterization of the manufactured HGS using SEM, EDS, and XRD.

![Figure 3. Characterization of the manufactured HGS using SEM and EDS](image)

Table 1. The characterization of the manufactured HGS using XRD

| Sample | XRD                                              |
|--------|--------------------------------------------------|
| 1      | low Synthetic Tridymite                         |
| 2      | low Synthetic Tridymite and Calcium Carbonate   |
| 3      | low Tridymite, low Cristobalite, Parawollastonite, and Clinoptilolite |
| 4      | low Tridymite, low Cristobalite, and Parawollastonite |
| 5      | low Tridymite, low Cristobalite, and Parawollastonite |

Table 2 shows the density and grain size measurement of the manufactured HGS.

Table 2. Density and grain size of the manufactured HGS

| Sample | HGS Density (gr/cm³) | Grain Size (μm) |
|--------|----------------------|-----------------|
| 1      | 0.65                 |                 |
| 2      | 0.6                  |                 |
| 3      | 0.4                  | 20-40           |
| 4      | 0.65                 |                 |
| 5      | 0.55                 |                 |

2.2. Comparison Analysis of Manufactured HGS with Commercial HGS Products
Table 3 shows the properties comparison of manufactured HGS among commercial HGS products from six companies. The density and grain size of the manufactured HGS can be well compared to the commercial HGS products.
Table 3. Comparison of manufactured and commercial HGS products [22] [23] [24] [25] [26] [27] [28]

| Commercial HGS products | Manufactures | Density (g/cm³) | Average Diameter (µm) |
|-------------------------|--------------|-----------------|-----------------------|
| MS - VP - A9            | NPO Stekloplastik (Russia) | 0.22 - 0.42      | 40 - 100              |
| Sinosteel               | Zhejiang Co, Ltd. (China)   | 0.25 - 0.6       | 9 - 120               |
| Ceno Series HGT         | Ceno Technologies (USA)     | 0.28 - 0.63      | 2 - 110               |
| 3M                      | 3M Deutschland GmbH (Germany) | 0.125 - 0.6     | 30 - 120              |
| Hollow Glass Beads Catalogue 19823 | Polyscience, Inc. (USA) | 1.1 | 2 - 20 |
| Hollow Glass HK20       | Zhengzhou Hollowlite Materials Co., Ltd. (China) | 0.18 - 0.22 | Lower than 120 |
| Manufactured HGS        | ITB           | 0.4 - 0.65       | 20 - 40               |

3. Conclusion
Following are the conclusions of this study:
1. HGS has been successfully manufactured in the laboratory.
2. Based on identification and characterization using SEM, EDS, and XRD, the manufactured HGS has proper properties that can be well compared among the commercial HGS products: low density (<0.8 gr/cm³) and low grain size (20-40 µm).

4. Further Study
Following are steps for further study:
1. Measure other properties such as compressive and collapse strength, surfacing, pH, and thermal resistance of the manufactured HGS.
2. Scale-up manufacture HGS from university laboratory scale to industrial scale (Phase 2).
3. Test the manufactured HGS with drilling fluid according to the American Petroleum Institute (API) Spec. 13A [20] and API Spec. 13B-1 [21] (Phase 3).

5. Nomenclature and List of Abbreviations
API: American petroleum institute
EDS: Energy Dispersive Spectrometry
HGS: Hollow Glass Microsphere
HSE: Health, Safety, and Environment
SEM: Scanning Electron Microscope
UBD: Underbalanced Drilling
XRD: X-Ray Diffraction
3H₂O: Ethanol
CaCO₃: Calcium Carbonate
CaCO₃: Calcite
Ca₃(PO₄)₂: Calcium Phosphate
CaSiO₃: Parawollastonite
Ca₃(Si₃O₉)O₇·20H₂O: Clinoptilolite
K₂CO₃: Potassium Carbonate
Na₃[BO₃(OH)₂]·8H₂O: Borax
Na₂SO₄: Sodium Sulphate
SiO₂: Tridymite
SiO₂: Cristobalite
SiO₂: Silicon Dioxide
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