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ALTERNATIVE FUELS FOR ROCKET BASED ON HOUSEHOLD WASTE FROM USED COOKING OILS AND RICE STRAW

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Abstract: Indonesia is a country that is classified as just starting the era of independent space flight research, especially in the development of rocketry. One of the obstacles to the development of rocket technology in Indonesia is the limited funds and the high cost of rocket fuel. The purpose of this scientific work is to produce alternative space rocket fuels that have a strong but economical thrust for rocket technology produced from used cooking oil and rice straw - one of the biggest waste. Used cooking oil contains glycerides which have a long carbon chain, namely esters between glycerol and carboxylic acids which can be used as alternative fuels for rockets. In the use of used cooking oil as a rocket propellant in solid form which tends to be more practical in its manufacture and use, it is necessary to use the oil binding media which is flammable in order to increase the effectiveness of the propellant namely cellulose. In this study used cooking oil is obtained through accumulation of household waste. Then carried out two stages of testing, namely the fuel production test phase to determine the potential of raw materials namely used cooking oil and rice straw as alternative space rocket fuel, the variables seen in this test are ease of production and fuel safety and static tests carried out to determine the magnitude of the power propellant seen from thrust and thrust-weight ratio of rocket fuel tested. Obtained the value of thrust and the highest thrust-weight ratio obtained on the R9 engine, respectively 187.37 - 471.10 Kg and 176.30 - 440.61 for the thrust-weight ratio. The results of the two stages of testing show that the combination of used cooking oil, rice straw and liquid oxygen as an oxidizer can be used as alternative rocket fuels which are relatively safe, economical, and high thrust power.

Keywords: Used cooking oil; Rice straw; Alternative energy; Efficient rocket; Food waste.

I. INTRODUCTION

A rocket is a propulsion system that provides a boost through exchange of momentum with some reaction masses. Rocket works according to Newton's third motion law stating the action and reaction. Gas is a result of a fast reaction that sprayed out through a channel in the section behind the rocket and provide a forward push for the rocket (NSSC, 1999). The energy of the rocket boost depends entirely on the mixture of ingredients of the fuel / propellant carried in it. Propellant is a mixture between fuel and oxidizers needed in an oxidation process that will release energy to push the rocket. Fuel is a chemical substance that forms the basis of oxidation reactions while oxidizer is a substance that oxidizes fuel in the reaction. The presence of oxidizer in propellants is vital because the presence of oxidizer allows the rocket to continue operates in an environment without oxygen in space (Allen and Eggers, 1958). In general, rockets are composed of some parts including parts cargo, controlling parts, fuel tanks, and rocket engines (Ley, 2002).

Based on the shape of the propellant, the rocket is divided into two types, they are liquid fuel rockets and solid fuel rockets. Liquid fuel rocket is a rocket that has stored fuel and oxidizers in liquid form. This type of rocket is relatively more difficult in the way of manufacture and maintenance because of the complicated components (tank separate, pumps, etc.), but it is easier to control because combustion can be done and stopped as needed. Rockets made from solid fuel is a rocket that has a fuel and an oxidizer stored in solid form. This type of rocket is relatively easier to make and maintenance because of the components contained in it less complicated (tank united and without pumps), but it is more difficult to control because combustion will continue as soon as it starts. Therefore, liquid fuel rocket is more commonly used in manned space flight whereas solid fuel rockets are more commonly used in space flight *nirawak* or in the field of defense (rocket-based weapons system).

Indonesia is a country that is classified as just starting the era of independent space flight research. So far, Indonesia has been able to develop micro-fuel and rocket launchers with solid fuel through the National Space Aviation Institute / LAPAN in collaboration with a number of related institutions. However, the development of rocket technology is further constrained by technology, limited funds, and prioritized government defense policies only in urgent situations. One of technological constraints are difficulties in the production of a mixture of rocket fuel / propellant which has a strong but economical driving force (LAPAN, 2010). As long as this problem has not been resolved, Indonesia's rocket development will continue to stagnate. Cooking oil waste (used cooking oil) is one of the ingredients alternative fuels that are developed for use in various vehicles motorized and household. Guangzhou City in China is recorded as using 20,000 tons of used cooking oil are for biodiesel only (Wang et al., 2007).

Used cooking oil, especially in Indonesia, comes from the discarded oil from frying food activities. Used cooking oil and new vegetable cooking oil composed of glycerides which have long carbon chain, which is an ester between glycerol and carboxylic acid. The difference is based on the composition of saturated and unsaturated fatty acids. The composition of used cooking oil is 30% unsaturated fatty acid and 70% saturated fatty acid (Kusuma, 2003). Observation results of used cooking oil showed that acid number, FFA level, saponification number, water content, and peroxide numbers exceed the limits permitted by Indonesia cooking oil industry standard. The complete characteristics of used cooking oil can be seen in the following table 2.

Anthasari (2008) uses coconut oil from household, the dominant fatty acid is lauric acid (Ketaren, 1986). Generally, a frying system in a household frying pan is frying pan system. Oil that is used with high heating is also in a timely manner long as well as contact with oxygen will experience a level of thermal oxidation faster (Perkins, 1967). The heating process is expected can reduce the viscosity of used cooking oil that applied to the machine, hence less damaging the engine.

In theory, used cooking oil can be used as an alternative of kerosene in liquid and mixed fuel rockets fuel substitute for aluminum pellets in solid fuel rockets. So that used cooking oil can be used as a rocket propellant inside solid form which tends to be more practical in making and using, it is necessary for the oil binding media to which the media can also be obtained burning to increase the effectiveness of propellant. One of the media namely cellulose. In fact, Indonesia has a big source of cellulose from rice straw (Herawati et al, 2010). However, rice straw in Indonesia has not been optimally utilized. These stacks of hay are abandoned and turned into agricultural waste.

Rice straw is a lignocellulose material available in large quantities and rarely utilized in Indonesia. Hay is used for animal feed and the rest of them just left to rot or burn. Hay from rice plants contains 37.71% cellulose; 21.99% hemicellulose; and 16.62% lignin (Pratiwi et al, 2016). In some areas, hay could be utilized as a fuel, namely bioethanol. Bioethanol from rice straw (*Oryza sativa*) is produced through acid hydrolysis and fermentation with *Saccharomyces cerevisiae*.

II. METHODS

2.1. Tools and Materials

Tools and materials can be grouped into three groups, such as tools and materials for the manufacture of rocket engines, tools and materials for the production of rocket propellants, as well as tools and materials for test stand or rocket test platforms. In this study, rocket engines were used in various different shapes, sizes and materials. Making rocket components will be made in the Chemistry Laboratory Sahid University. For propellant production, we need tools and materials in the form of acid resistant glass, fridge, rice straw fiber, concentrated nitric acid (HNO_3), and concentrated sulfuric acid (H_2SO_4) to nitrate cellulose to nitrocellulose. The making of rocket propellant will be carried out in the Chemistry laboratory, Faculty of Food Technology and Health, Sahid University. For a test stand or rocket test pad, a 3-millimeter thick plate of iron is needed to measure the rocket's thrust during a static test. This test runway has a low cube base with a height of 40 centimeters, 60 centimeters long, and 60 centimeters wide, and a 1.5 meter high mast. The making of this test runway will be carried out with the help of many iron craftsmen operating around the campus of Sahid University.

2.2. Stages of research

Test fuel production

Fuel test is a test to determine the potential of raw materials, namely rice straw and used cooking oil as fuel. The variables seen in this test are ease of production and fuel safety.

Static test

Static tests are performed to determine the amount of propellant power seen from thrust and thrust-weight ratio of rocket fuel tested. The thrust is calculated by placing a combustion chamber containing a propellant which will be tested on a test runway and then ignited. The amount of rocket thrust is calculated in kilograms (kg). This value is obtained from multiplying the value of the inlet pressure (psi), the rocket outlet / nozzle (inches2), and the heat coefficient. The value of thrust will be obtained in units of pounds and converted to units of kilograms. The value of this thrust power is then divided by the value of the rocket engine weight to obtain the thrust-weight ratio. The strength of the propellant tested in this study will be compared with the common rocket propellant currently circulating through literature.

Data Analysis

The variable data observed in each test will be leveled even and compared with controls to see differences in performance. The existence of significant differences between the test and control groups will be tested statistically using variance analysis.

Time and Place of Implementation

The research was carried out starting on 9 November 2018 until 23 January 2019. The research was conducted at the Sahid University Chemical Laboratory and the testing field at the Tebet field.

Factual Schedule of Implementation

Tabel 1. Factual schedule for conducting research

No	Activities	Implementation Date
1	Collection of raw materials	9 – 19 November 2018
2	Test fuel production	26 November – 8 December 2018
3	Static Test December	9 December – 23 December 2018
4	Analysis of data December	24 December 2018 – 23 January 2019
5	Making reports	24 December 2018 – 23 January 2019

Implementation Instrument

Acid chambers are used for experiments on nitration of rice straw fibers. To carry out the static test, a set of test equipment was made consisting of a test runway, oxygen tank, and rocket engine. The rocket engine consists of a combustion chamber as well as a fuel tank, a nozzle, and an oxygen channel.

III. RESULTS AND DISCUSSION

3.1 Fuel Test

Most used cooking oil is obtained from household waste and rice straw obtained from agricultural waste in Madiun, East Java, Indonesia. The first experiment was a fuel production test carried out at Chemical Laboratory, Sahid University.

Tabel 2. Fuel production test results

No	Test		Time	Result
1	Fuel Production Test	Nitrocellullose	26 /11/2018	Failed
		Nitroglycerin	29/11/2018	Failed
		Used cooking oil distillation	30 /11/ 2018	Successful; Used cooking gas
		Rice straw as uptake of used cooking oil	6/12/2018	Successful; Rice straw as ardsorpbtion of jelantah (straw-jelantah)

Tests for fuel production show that nitrocellulose cannot be made from rice straw fibers. This is because rice straw fibers have lower cellulose content than rice straw which is a common ingredient of nitrocellulose. Rice straw contains 37.71% cellulose; 21.99% hemicellulose; and 16.62% lignin (Pratiwi et al, 2016). The lower cellulose content makes nitric acid react with other components in rice straw fibers and does not react perfectly with existing cellulose so that the formation of nitrocellulose is inhibited. The results of the fuel production test also show that nitroglycerin cannot be produced from existing raw materials. Nitroglycerin is the result of reaction from concentrated nitric acid (grade 95%) and glycerol (obtained from the reaction of used cooking oil and NaOH) which is reactive to heat and shock. Failure to make nitroglycerin due to nitric acid used in this study only has a level of 68%, less than the requirement of 95%. Nitroglycerin is also not safe to use because it is too reactive.

Used cooking oil is distilled to get a distilled product. Three refined products were produced and combustion tests were carried out. The first result is black oil (which does not evaporate), this result is burned but the fire dies. The second result is clear oil (evaporated oil). The result is burned but the fire remains dead, does not want to ignite in oil. The third result is steam used cooking at 0° in the form of solid objects such as the wax layer and then burned, the combustion test burns stably and has high energy. The collection of distillate used cooking oil fuel and turning it into a solid form was carried out on December 8, 2018. As a result, the cooking oil vapor would not enter the reservoir hose and the desired steam leaked through the heated kettle cracks.

Static test is a test to measure rocket thrust. The rocket is held at a test stand equipped with a scale, then the rocket is turned on to find out the thrust in kg. Liquid oxygen is replaced with natural oxygen obtained from the wild with the compressor as an oxidizing simulator. The test that is done is the static combustion test of rockets used by air compressors as simulators, as a result the compressor pressure is not strong enough to give good results, so that the compressor regulator is destroyed. If the static test has been successfully carried out, the next test will be carried out, such as launch test and data analysis.

In static tests the components used are pressurized oxygen cylinders, oxygen hoses, test bases and rocket engines. The rocket engine consists of 9 types with different designs and materials, from various kinds of machines, the machine that is most resistant to pressure and heat produced from combustion is made from steel.

Tabel 3. Static test results of rocket engines with propellant of used cooking oil and hay

Rocket engine code	Rocket weight (grams)	Fuel weight (grams)	Pmin non-fuel (Psi)	Pmin fuel (Psi)	Pmax fuel (Psi)	Heat coefficient	Thrust (kg)	Thrust / weight	Information
R1	946	-	300	-	-	-	-	-	not fly ; weight reference for R2
R2	450	-	-	50	50	2.85	18	39.55	fly; destroyed
R3	285	44	80	40	40	2	64.22	224.222	drift; destroyed
R4	339	154	120	40	40	3	14.44	42.115	fly; destroyed
R5	366	29	-	-	-	-	-	-	not fly ; heat resistance test
R6	273	52	50	20	80	2.5	3.01 -8.90	8.19 - 32.80	fly; secure
R7	946	201	200	120	150	1.67	8.90 - 11.00	9.46 - 11.89	fly; secure
R8	527	83	180	100	150	1.8	135.36 - 201.01	255.55 - 384.43	fly; secure
R9	1069	276	100	40	100	2.5	187.76 - 471.10	176.30 - 440.61	fly; secure

P min fuel is the pressure that the rocket needs to glide without burning while P min burns is the pressure that the rocket engine needs to glide with the help of the used rice straw burner in the rocket engine, the P max burn is the pressure that the rocket engine can hold to continue sliding. From the results obtained on rocket engines R3, R4, R6, R7, R8, and R9 the addition of fuel combustion reduces the pressure needed for the engine to glide, indicating that burning rice straw and used cooking oil affects the increase in rocket engines. The heat coefficient value is obtained by dividing P min burn with P min non-fuel, the biggest result is obtained from R4 with a value of 3, this shows that the heat in R4 is very influential on the pressure required by the engine. The value of thrust is obtained based on the product of the multiplication of A (rocket engine cross section nozzle) and P (pressure). The highest results on the R9 engine with a value of 187.37 - 471.10 kg. This shows that R9 has the largest load capacity. The amount of thrust is influenced by the shape and size of the engine. R9 uses two combustion chambers which make it capable of burning more fuel than other engines. The biggest thrust-weight ratio is also produced by the R9 engine with a value of 176.30 - 440.61. The push-weight ratio determines the acceleration limit of the rocket which is greater if the value is greater. With the value of the thrust-weight ratio obtained by R9, in theory this machine can be used to launch space vehicles free of gravity if scalatically enlarged because the value of the power of the rocket engine is already above the average conventional rocket value currently available. F1 engine (Saturn V rocket in mission Apollo) which has a thrust-weight ratio of 94.1.

Results should be clear and concise. Results should be clear and concise Results should be clear and concise. Results should be clear and concise. Discussion must explore the significance of the results of the work. Adequate discussion or comparison of the current results to the previous similar published articles is recommended to shows the positioning of the present research (if available).

IV. CONCLUSION

The combination of used cooking oil and rice straw fibers (Oryza sativa) can be used as a rocket fuel that is relatively safe, economical, and high thrust with used cooking oil as fuel, rice straw fibers as absorption media, and liquid oxygen as an oxidizer.

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