Kinetic Effects as the Balancing Factor on α-Cellulose Conversion into D-Glucose in Hydrolysis Process of Pt. Tanjung Enim Lestari Solid Waste Using Oscillated Flow

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A solution to find the best alternative to minimize industry pollution is very necessary especially in pulp and paper manufacturing. One of the alternatives is using waste as feed that will be converted into chemical compound and fuel. Solid waste from pulp and paper manufacturing that contains lignocellulose which is a biomass has potency to be processed for chemical compounds, such as sugar solution (D-glucose), Furfural, and Acetone-Buthanol-Ethanol (ABE). The solid waste in this research is hydrolyzed generating D-glucose solution. The purpose of this research is to study the variables of α-cellulose conversion kinetics as the balancing factor between α-cellulose conversion and energy and mass consumptions. The value of energy and mass consumptions, along with temperature and acid concentration, can be minimized to get higher conversions. Two processes in this method are the preparation and the hydrolyses of α-cellulose by using delignified feed. The hydrolyses process occurs in the Oscillated Reactor Column. The highest conversion was about 50-55% at 10% of sulfic acid concentration.

INTRODUCTION

The international community has taken serious interest in environmental conservation. Consequently, all industrial sectors must do their part to do conduct their processes in an environmentally friendly way. Pulp and paper manufacturing is one of industry activities that will had some bad impacts on the environment. It

produces wastes—wastewater, solid, and gas— that contain poisonous chemicals. Reducing industry pollution need some solutions to achieve the best way in pulp and paper production, such as to convert lignocellulose from the solid wastes of pulp and paper industries into fuel-oil and chemicals. Solid wastes from agriculture biomass that contains lignocellulose and can be converted into chemical include sugar solution (D-glucose), furfural, and Acetone-Buthanol-Ethanol (ABE) (Atkins 1987).

Research of lignocellulose hydrolysis technology resulting in glucose in acid condition has been developed by researchers in the 1980s. Rugg and Stant (1980) researched about acid hydrolysis process of lignocellulose waste into glucose by using sawdust as feed. When sulfic acid had been used as catalyst and reacted at 28.79atm and 228.3°C, the highest glucose conversion attained was 50%.

Rugg and Brenner (1983) tried to reduce operation temperature and pressure to be 204.4°C and 17atm and the flowrate of sulfic acid was 100lb/hr with 1.8%wt of its concentration. They used 10%wt slurry of cellulose waste with flowrate 300lb/hr that rotated continually at 100rpm in twin screw extruder. The results obtained were at 40% of glucose conversions, 20% of sawdust products that consist of 6lb/hr glucose, 9lb/hr cellulose, 5lb/hr lignin, 5lb/hr hemicellulose, and 100lb/hr water. This research concluded that the rotation speed of extruder, feed phase, temperature, and concentration of solvent would influence the reaction of hydrolysis.

Clausen and Gaddy (1993) researched on the two methods of the hydrolysis process. First method was in single step, where solid biomass was used as feed into a vessel with sulfic acid was inside. Then, the hydrolysis product was filtrated to separate acid, sugar solution, and lignin. Second method was a modification of the single step by developing the hydrolysis process in two steps: the first step was the *prehydrolysis*, wherein biomass was hydrolyzed using sulfic acid in high concentration; and, the second step was *posthydrolysis,* along with the addition of solute

sulfic acid and water. After that, the filtration process was continued to separate lignin from the product solution. The resulting conversion of prehydrolysis and posthydrolysis were 56% and 92%, respectively.

Brelsford and Bozeman (1995) was hydrolyzed lignocellulose by using two-stage plug flow reactor. This research obtained higher efficiency than the previous researches. The combination of double heat exchanger and plug flow reactor in series reduced the failure of glucose formation, reduced the reaction time, and increased the process capacities. The products were glucose syrup with 58.4% of conversion (without recycle) and 65.2% (with recycle) with high total production cost.

Torgel and Padukone (2000) researched about acid hydrolysis process using a series of fractionation columns done in four steps. In the first step, the preface extraction, temperature was 120-140°C and pH was constant at 1.3-3.0. In the second step to the fourth step, temperature was raised from 160-200°C to 200-260 °C up to 280°C. The feed was sawdust of 0.07%(wt) sulfic acid solution and glucose conversion about 92%. The advantage of this research was the high rendemen but it is a high-temperature process.

The purpose of this research was to study and discuss the effects of the kinetic variable as balancing factor between the α-Cellulose that is generated from energy consumption and the utilized mass. Hence, the value of energy and mass consumption is signed by high temperature and acid concentration could be minimized to obtain higher conversion.

RESEARCH METHODS

This research used two kinds of raw materials: fresh *Mangium acacia* and solid waste from digester of Pt. Tanjung Enim Lestari Pulp and Paper. *M. acacia* as feed was needed to find the optimum process condition. So the condition from hydrolyses of fresh *M. acacia* could be used as base for waste from digester of Pt. Tanjung Enim Lestari Pulp and Paper.
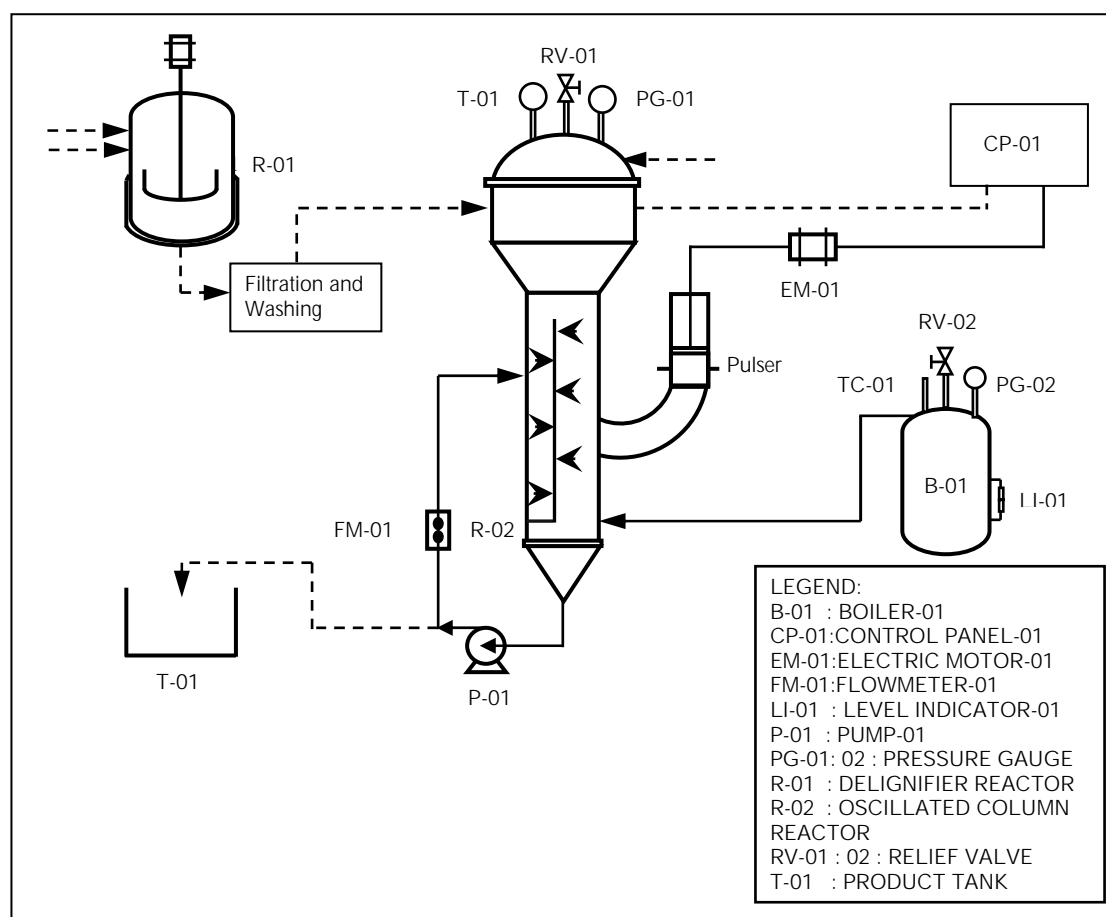
Figure 1. Flowsheet of *A. mangium* Cellulose Hydrolysis into Glucose Solution

The process of converting α-Cellulose hydrolysis to D-glucose in acid condition was developed in two steps as shown in Figure1. Those were prepared to decrease lignin so the feed would be free of lignin, relatively. Second step, hydrolyses of delignified α-Cellulose feed in Oscillated Reactor Column (hydrolyses reactor with oscillation flow). *A. mangium* as raw material was mixed with NaOH and Na_2S solution in the delignifier reactor. Its products, α-cellulose solid and the residues were filtered to separate α-cellulose from the residues. It was then mixed with sulfic acid and entered in the reactor. The mixture of raw materials was circulated continuously using the circulation pump and set up the flowrate. D-glucose content from the hydrolysis process was taken every 20min to be analyzed.

RESULTS AND DISCUSSION

The kinetic variables as the object of this research were the ratio between feed and H_2SO_4, the reaction time, and the concentration of catalyst (H_2SO_4). The highest conversion was 50–55% at 10% sulfic acid concentration. The differences between the conversion, which were reached at 6% of H_2SO_4 and 10% of H_2SO_4 were low. The results are shown in figures 2, 3, and 4. In this case, the acid degrees affected the process of α-cellulose hydrolyses that converted to D-glucose. The total H^+ ion from the acid solution influenced the depolymerization process.

Those phenomena were due to the high concentration of ion H^+ in the solutions. The higher the concentration, the easier the formation of unstable molecule structures of α-cellulose.
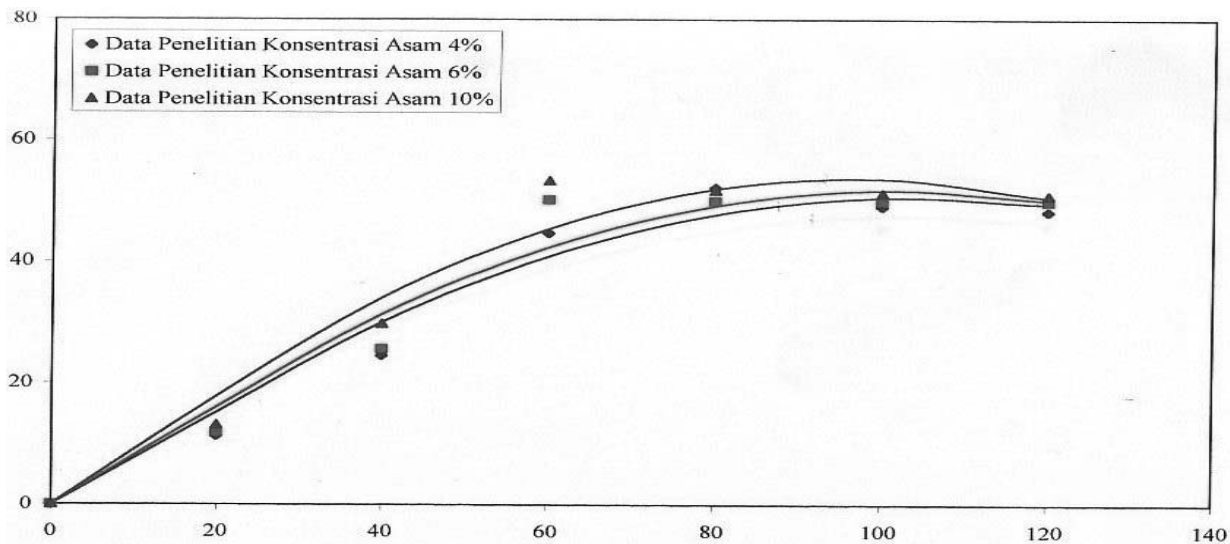
Figure 2. Effect of Time on α-Cellulose Conversion at 1:50 Ratio, Non-Oscillation Condition
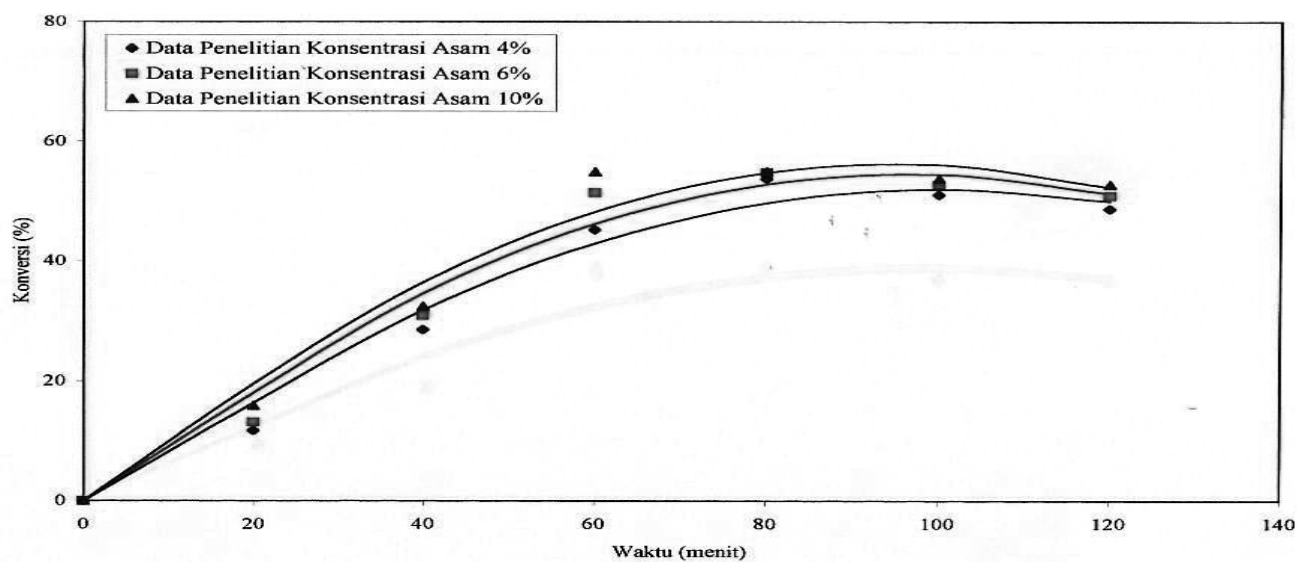

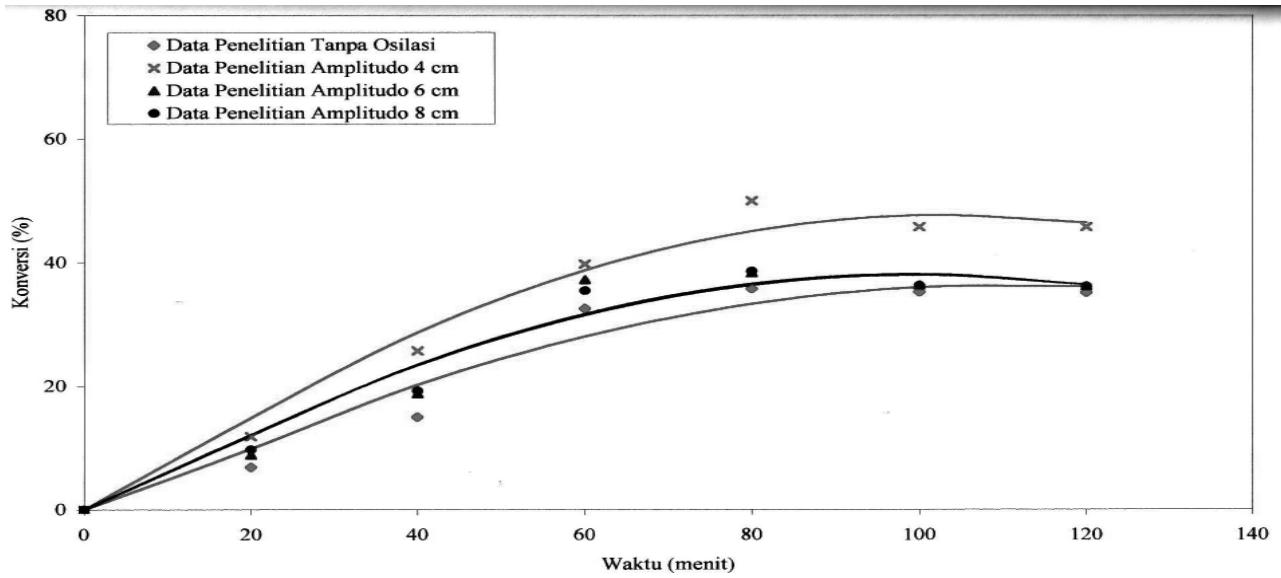Figure 3. Effect of Time on α-Cellulose Conversion at 1:50 Ratio, Amplitude 4cm

Figure 4. Effect of Time, Frequency, and Amplitude on α-Cellulose Conversion at 1:20 Ratio, Acid Concentration 4%
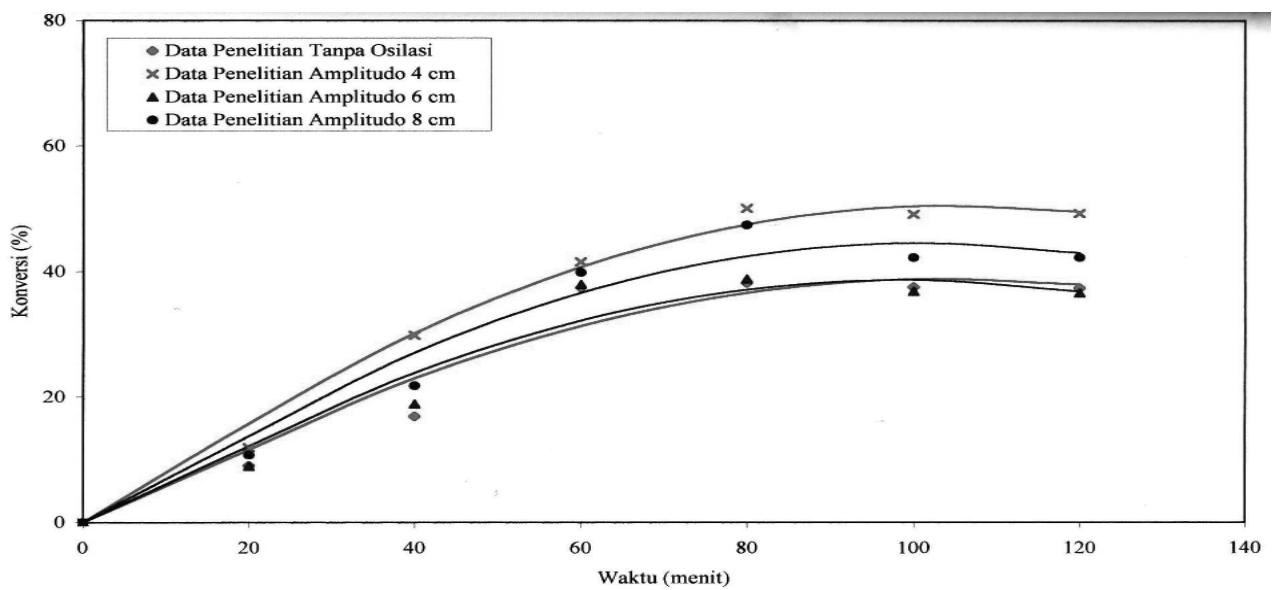

Figure 5. Effect of Time, Frequency, and Amplitude on α-Cellulose Conversion at 1:50 Ratio, Acid Concentration 4%

This concentration was influenced by the strength of acid types and the concentration of acids. For similar acid types, the solution that has a high concentration will give a high concentration of ion H^+.

CONCLUSIONS

Based on the results and discussion, this research obtained the effect of the oscillation flow on the enhancement of α-cellulose conversion become D-glucose with hydrolysis process in acid condition was increasing more than the process without oscillation flow. The highest conversion at 50–55 % was attained at the ratio of wood mass to H_2SO_4 of 1:50.

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