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Co-Pyrolysis of Disposable Mask with Sugarcane Bagasse

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Keywords: Co-Pyrolysis, Disposable Mask, Sugarcane Bagasse, Yield, Bio-oil.

Abstract. Using disposable masks to protect against coronavirus 19 (COVID-19) has become a habit during the pandemic. However, the emergence of contaminated mask waste causes environmental problems because recycling is difficult. This research carried out the co-pyrolysis of disposable masks waste with sugarcane bagasse in a tubular reactor. The temperature and blend ratio of sugarcane bagasse to disposable mask was varied to investigate the product distribution. The maximum liquid product yield was obtained at 54.3% at 400 °C using a blend ratio of sugarcane bagasse to disposable mask 1/2. Based on the Gas Chromatography Mass Spectrophotometry (GS-MS) analysis, the liquid products consists of alkanes, alkenes, acids, alcohols, ketones, and aromatic compounds.

Introduction

Using disposable masks to protect against coronavirus 19 (COVID-19) during this pandemic has become commonplace. However, contaminated face mask waste causes environmental problems because it requires unique handling processes to release toxic chemicals. Disposable masks are made of different compounds, making them difficult to recycle. In addition, disposal masks will risk infection to sanitation workers involved in waste management. Recycling waste masks cannot be done because of the difficulty of proper separation and the high potential for health hazards. Therefore, it is essential to develop an appropriate method of handling mask waste. Around 129 billion masks are thrown away worldwide due to COVID-19 [1]. Used masks that are disposed of carelessly will cause environmental and health problems such as the spread of disease and microplastic waste that is harmful to the ecosystem [2]. In addition, disposal of used masks will risk infection to sanitation workers involved in waste management. Recycling waste masks cannot be done because of the difficulty in the proper separation process and the high potential for health hazards. Therefore, it is essential to develop an appropriate method of handling mask waste.

One way to handle mask waste is to carry out the pyrolysis process. Pyrolysis is a thermochemical decomposition carried out at a temperature of 400 to 1200 C under atmospheric conditions without the existence of oxygen. The pyrolysis products are gas, liquid (bio-oil) and solid (charcoal). Using raw material from disposable mask waste in the pyrolysis process is a solution for handling waste to produce energy. Global population and technological development are rapidly growing will drive the energy demand. Therefore, the search for new energy reserves is needed to ensure energy availability [3]. In the next 100 years, the fossil fuel reserves estimated will be reduced drastically if not the intensive effort to find new energy sources due to the increase of energy demand by 60% by 2040 [4]. Numerous studies have been conducted to explore energy resources that are more sustainable than renewable resources [5]. Biomass has contributed to more than 50% of supplying renewable energy sources since 1990 [6].

Pyrolysis is a thermochemical conversion method to convert biomass into valuable products, such as fuel or chemicals. The use of biomass pyrolysis has advantages compared to gasification and liquefaction at high pressure, especially in terms of the process condition parameters, which are easier to control and economical advantages [7]. Therefore, bio-oil from biomass pyrolysis has high acidity, low calorific value, and is more viscous than other bio-oil products. Therefore, it will reduce bio-oil quality and need to upgrade if applied as engine fuel properties directly [8]. Biomass co-pyrolysis with a disposable mask is an alternative technique to upgrade the bio-oil quality. Generally, a disposable mask was made from a polymer consisting of many hydrogen atoms and almost no oxygen atoms. The polymer has a low oxygen to carbon (O/C) ratio and a high hydrogen to carbon (H/C) ratio, allowing for an increase in the ratios of O/C and H/C. The hydrogen atom from polymer causes a positive synergistic effect on improving the bio-oil quality during the co-pyrolysis process because it balances the percentage ratio with oxygen and carbon atoms [9]. In addition, the co-pyrolysis of biomass and polymer can give alternative waste treatment and solve the environmental problems [10]. The common polymers that use as a mixture for co-pyrolysis with biomass are polyethylene, polypropylene and polystyrene [11].

The oil yield obtained is higher by adding plastics than biomass alone. The calorific value obtained is also higher due to hydrocarbon compounds consisting of olefins, paraffin, isoparaffins, aromatics, naphthenes, and non-condensing gases [12]. The bio-oil formed from the co-pyrolysis process is a homogeneous substance. During the co-pyrolysis process, the interaction of radical components can form stable bio-oils to avoid phase separation [13]. Several radical reactions during co-pyrolysis can be formed according to the following steps: initiation, formation of secondary radicals, and termination. Several reactions occur during the secondary radical formation process, such as depolymerization, monomer formation, and isomerization intermolecular hydrogen transfer reactions (formation of olefins and paraffin) [14]. The synergy of various radical atoms that interact during the reaction determines the success of the co-pyrolysis process. In this research, the co-pyrolysis of disposable masks waste with sugarcane bagasse was studied to increase bio-oil yield with improved quality. The temperature and blend ratio of sugarcane bagasse to disposable mask was varied to investigate the product distribution.

Material and Methods

Materials. Sugarcane bagasse (SCB) was collected from Madukismo Sugar Mill, Kasihan, Bantul, Yogyakarta, Indonesia. Disposable faces mask (DFM) waste was purchased from a local drug store in Yogyakarta, Indonesia. Prior to use, SCB was naturally under light sun for several days and ground to fine powder by using a grinder whereas the average SCB grain size was 1 mm. Meanwhile, DFM was cut into small pieces and dried in the oven at 40 °C for 24 h to reduce moisture content.

Methods. Co-pyrolysis experiments of DFM and SCB was conducted in a tubular reactor which was placed in an electric cylindrical furnace equipped with a thermocouple. Then, the feed (SCB, DFM or a mixture of both) was inserted inside the reactor. Prior to the co-pyrolysis process, the reactor was fed with nitrogen gas for 30 minutes to remove oxygen. The thermocouple is inserted into the reactor. The co-pyrolysis process was carried out for 45 minutes with a heating rate of 30 °C/minute. The pyrolytic vapor is condensed through a glass condenser. At the bottom of the condenser is connected to the erlenmeyer to collect the liquid product. At the end of the co-pyrolysis process, the electric cylindrical furnace is turned off, and the reactor is cooled to room temperature. The liquid product was measured and the char was weighted. The effect of temperature and blend ratio of sugarcane bagasse to disposable mask on product distribution was investigated. The temperature was varied (400, 500, and 600 °C). A mixture of DFM and SCB with blend ratio of 2:1; 1:1; and 1:2 was also pyrolyzed. The Fourier-transform Infrared Spectroscopy (FT-IR) and Gas Chromatography Mass Spectrophotometry (GS-MS) was employed to analyze the liquid products.

Results and Discussions

Effect of Temperature on Product Distribution

The effect of temperature on the product distribution of co-pyrolysis DFM and SCB were study at different temperatures (400, 500, and 600 °C) with constant a heating rate of 30 °C/min. In Figure 1, it can be seen that the liquid product increased from 50.4 to 52.1% when the temperature decrease from 600 to 500 °C. The contrary results were obtained on the percentage of gas product, where the increasing temperature increased the percentage of gas product. The percentage of gas product increased from 29.6 to 36.8% when the temperature increase from 400 to 600 °C. At high temperature, the compounds with high molecular weight were cracked into small molecules due to the increasing reactivity of pyrolysis vapors. Meanwhile, The percentage of solid product decreased from 16.1 to 14.5% when the temperature increase from 400 to 500 °C. At the temperature of 600 °C, the percentage of solid product was at 12.9%. The secondary tar also destruct at high temperatures which may cause the decreasing in the solid yield.

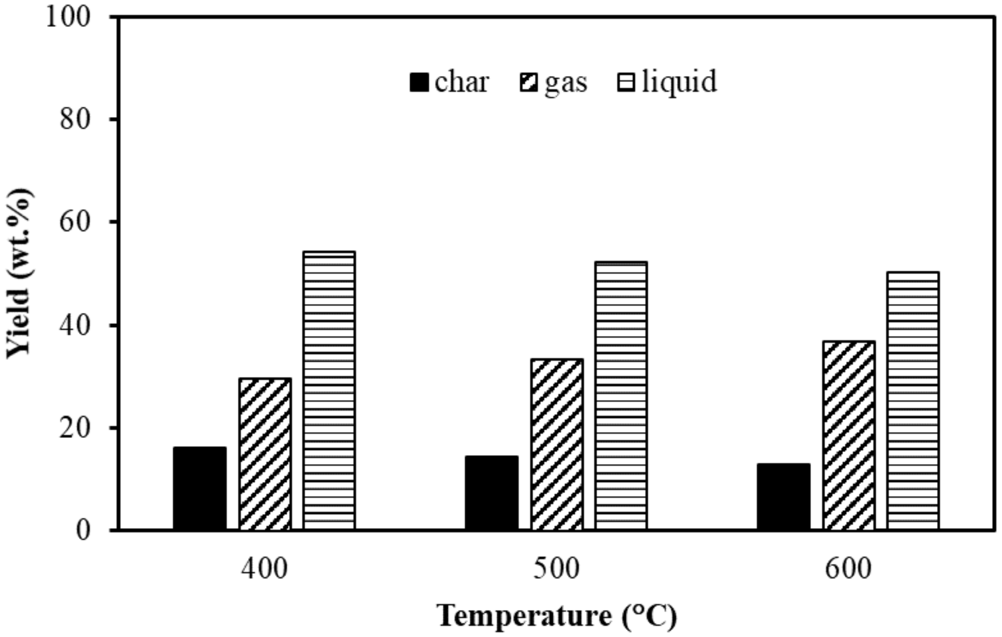

Fig. 1 Effect of Temperature on Product Distribution of Co-pyrolysis of Disposable Masks Waste With Sugarcane Bagasse.

Effect of Blend Ratio of Feed on Product Distribution

Figure 2 showed the effect of blend ratio of SCB and DFM on product distribution. Co-pyrolysis of DFM and SCB was conducted at 600 °C with different blends of 2 : 1, 1 : 1, and 1 : 2. The addition of DFM is aimed to improve the percentage of liquid product and also to upgrade the quantity of liquid product. The solid product decreased from 27.8 to `12.9% when the blend ratio of SCB to DFM decreased from 2:1 to 1:1. At the the blend ratio of SCB to DFM of 1:2, the solid product was achieved at 10.5%. Meanwhile, the percentage of gas product increased with the addition of DFM portion. The percentage increased from 32.6 to 36.8% when the SCB to DFM was decreased from 2:1 to 1:1, respectively. The highest percentage of gas product was achieved at SCB to DFM of 1:2 at 39.3%. The percentage of gas product increased due to the secondary cracking of the vapours. However, the secondary decomposition of heavy molecules at high temperatures also can be form non-condensable gas (Horne and Williams, 1996). At high temperature, the lignocellulosic material on biomass encourages the depolymerization of primary volatiles more fast to form more stable anhydrocellulose.

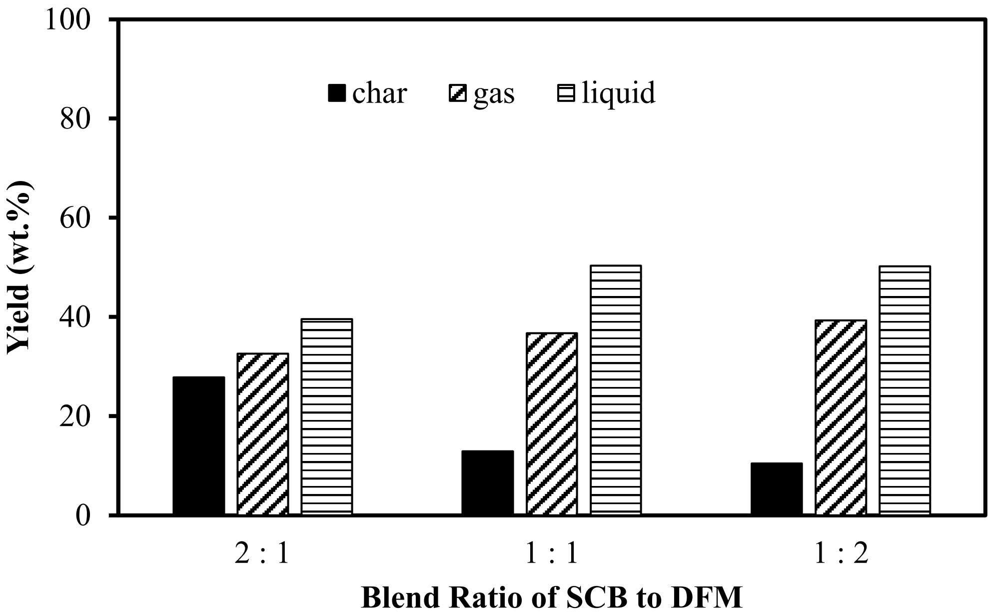

Fig. 2 Effect of Blend Ratio of Feed on Product Distribution of Co-pyrolysis of Disposable Masks Waste With Sugarcane Bagasse.

The results also confirmed that the liquid products increase with the reducing of SCB mass on the mixture. Enhancing of the liquid products at a high DFM/SCB mixture was due to the presence of hydrogen atom donors from DFM. DFM which is made from polymers such as polypropylene or polyethylene contains hydrogen atoms. During co-pyrolysis at high temperatures, the presence of hydrogen atoms can lead to enhancing the liquid products. The enhancing of the liquid products during co-pyrolysis of DFM/SCB indicated that the positive synergistic effect the addition of DFM.

FT-IR Analysis of the Liquids Products of Co-pyrolysis of Disposable Masks Waste with Sugarcane Bagasse

The functional groups in liquid products were identified using FT-IR analysis. The FT-IR spectra of liquid products from co-pyrolysis of DFM and SCB at different blend ratio are tabulated in Table 1. The main functional groups present in liquid products The main functional groups present in liquid products are alcohols, aromatics, phenols, alkanes, ketones, aldehydes, and carboxylic acids.

Table 1. FTIR analysis of Liquids Products from the Co-Pyrolysis.

Wavelength (cm^{-1})	Functional group	Compound	SCB	DFM	DFM : SCB = 1 : 1
3438	O – H stretch	phenols and alcohols	o	x	o
3072	= C – H stretch	alkene group	x	o	o
2854	C – H stretch	alkane	x	o	o
1710	C = O stretch	aldehydes, ketones	o	x	x
1639	– C = C – stretch	alkenes, aromatics	x	o	o
1272	C – O stretch	esters and ethers	x	o	o
1084	C – O stretch	alcohol	x	x	o
1051	C – O stretch	carboxylic acids	o	x	x
990	= C – H bend	alkene	x	o	o

From Figure 3 it can be observed that the majority of co-pyrolysis liquids contain aliphatic and aromatic compounds, including phenols, alkanes, alkenes, alcohols, acids, and ketones. DFM pyrolysis produced a high percentage of alkanes and alkenes meanwhile, the amounts of acids, alcohols, ketones, and benzene were low. The presence of phenolic compounds was not found from

DFM pyrolysis. Increasing the percentage of DFM in the co-prolysis process will cause an increase in the composition of aliphatic compounds. The liquid products of DFM and SCB co-pyrolysis contain more alkane and alkene compounds than the liquid acquired by the pyrolysis of SCB alone. The cellulose and hemicellulose contained in biomass converted to esters, aldehydes, acids, carboxylic acid, alcohols and ketons. Meanwhile, phenols and derivatives were formed from the decomposition of lignin are primarily form by unit of biomass and the are formed by fraction of biomass.

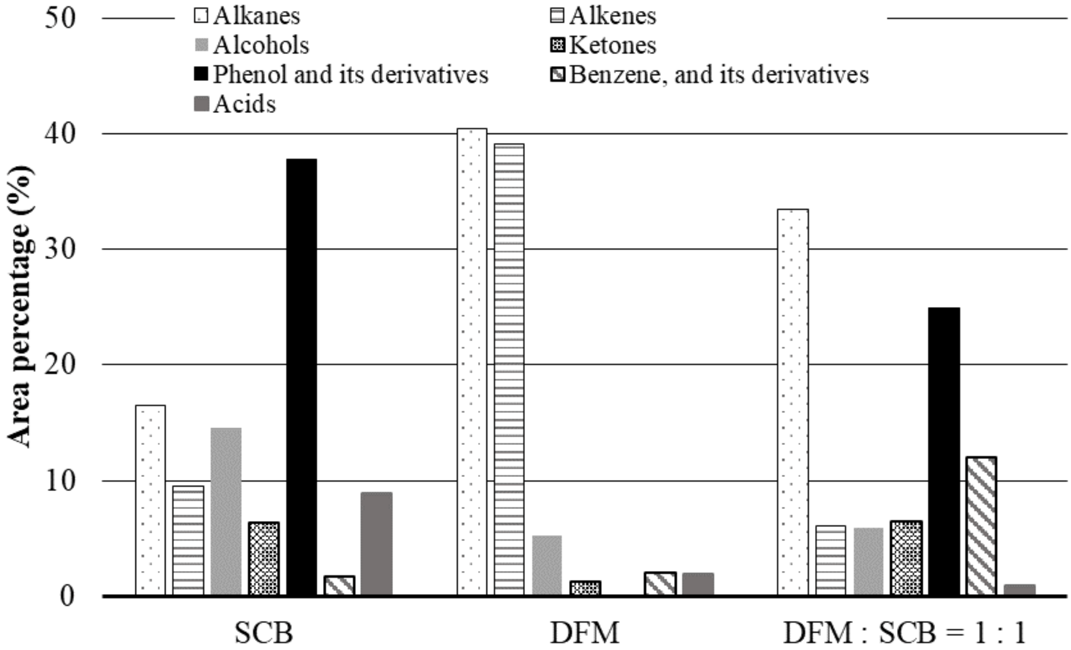

Fig. 3 Chemical Composition of Liquid Products from the Co-Pyrolysis of Disposable Face Mask (DFM) and Sugarcane Bagasse (SCB)

Conclusions

The temperature and blend ratio of sugarcane bagasse to disposable mask was varied to investigate the product distribution. The maximum yield of liquid product was obtained at 54.3% at 400 °C using blend ratio of sugarcane bagasse to disposable face mask 1 : 2. The FT-IR spectra and GC_MS analysis of the liquid products from the co-pyrolysis of disposable face masks and sugarcane bagasse exhibited the presence of alkanes, alkenes, acids, alcohols, ketones, and aromatics.

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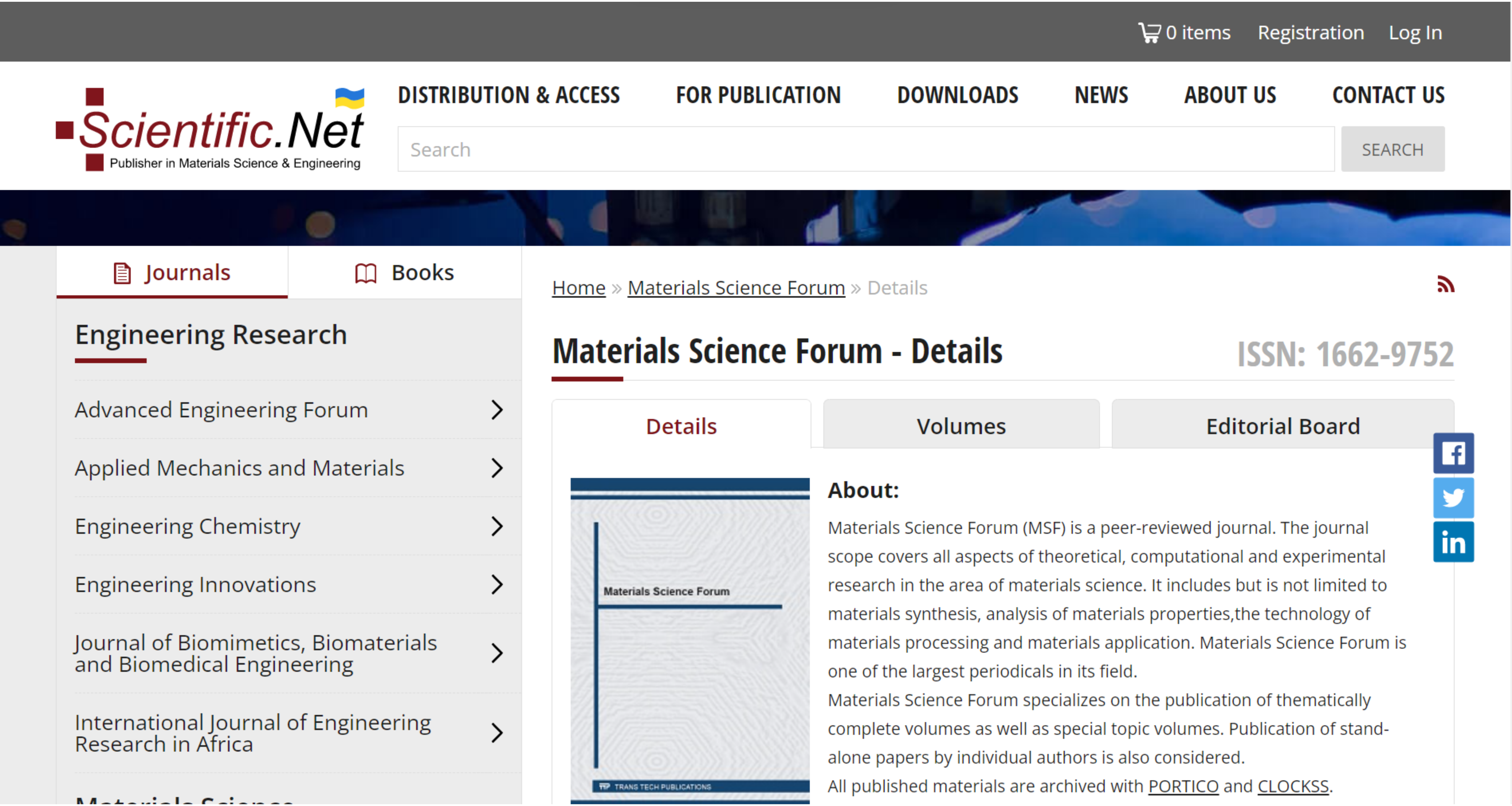

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