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A review on tribological performance of natural fibre polymeric composites

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ABSTRACT

The incessant research into green substitutes for engineering applications since the turn of this century, has labelled this century as a 'cellulosic century'. The current work attempts to dedicate a compilation of developments of research in tribological performance of natural fibre polymeric composites from year 2000 to June 2014. Information on natural fibres, polymers and their composites, and research on tribology developments will be presented. Typical adhesive wear mechanism for different types of composites and their performance on operating and test parameters will be discussed. Attempts are made to address the shortcomings from previous works as to pave the way for future research on science of tribology of polymeric composites.

1. Introduction

Despite the fact that the production of crude oil is bound by some crucial factors such as the world economy performance, policies and regulations, consumer choices and technology advancement, world's demand on crude oil is projected to increase at a rate of 22% from year 2010 until 2035 [1]. The main factor for the growing demand of crude oil is the increasing number of vehicles. In 2011, fuel consumption by vehicles chalked up 62.3% of world fuel production [2]. The total number of vehicles in the world has now exceeded over one billion and is increasing with an annual rate of 3.4% [2]. China for instance has projected higher forecast of passenger car vehicles from 43 cars per 1000 people in year 2010 to 320 cars per 1000 people in year 2035 [1,3]. As a result of rapid growth of world vehicle population, there is a need of a concerted effort from government and non-government agencies in developing means to improve fuel efficiency of vehicles through policies and regulations implementations, and technological developments contributing to reducing dependence on fossil fuels.

Malaysia is noted to be the second largest producer of fossil fuels in Southeast Asia. Oil and gas production has become the core of Malaysian economy [4–6]. Nearly 40% of Malaysia's primary energy consumption is derived from the oil sector [7]. Fig. 1 shows Malaysia's oil production and consumption for the past 18 years. From the figure, it can be seen that oil production was almost at break-even with oil consumption in year 2009. This was due to the maturing of oil fields particularly larger fields in the shallow waters located offshore Peninsular Malaysia. Despite the narrow gap between total exports (net production) and total imports (net consumption), Malaysia still continues to export half of its crude oil production.

According to the Energy Information Administration (EIA) [9], the world production of oil is expected to decline at a rate of 4% per annum after year 2010. Assuming no new discovery and development of crude oil fields, world oil production rate will decline further until year 2030 [10]. It is a known fact that crude oil is a non-renewable resource. By simple definition, it cannot continuously meet the increasing demands. According to Marion King Hubbert, the production rate of crude oil is said to follow the Hubbert peak theory as depicted in Fig. 2 [11]. The theory states that the production curve of crude oil approximates a bell shaped curve when the peak of crude oil production elapses, following which the next production rates soon enters an exponential declining region. The rapid decline could cause an increase in the price of fuel and petroleum based products.

As a result of immense pressure on declining crude oil reserves and increase in cost of production of fossil fuels, engineers, scientists and researchers are now exploring for alternative sources of renewable energy; energy that comes from natural

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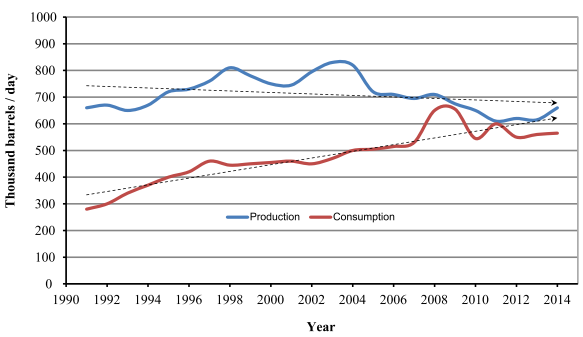

Fig. 1. Malaysia's oil production and consumption for the past 18 years [8].

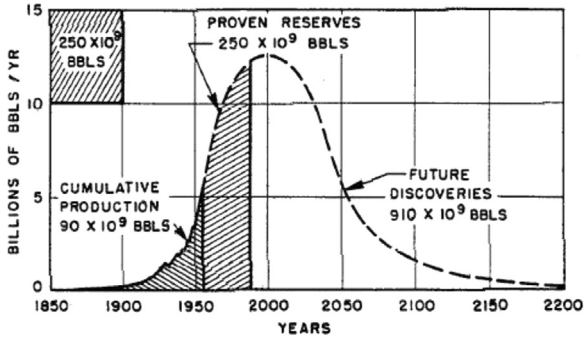

Fig. 2. Hubbert's 1956 forecast for world oil production[12].

and replenishable resources. Renewable energy is closely associated with environment and sustainability. Today, the focus is towards 'green environment'. The spectrum of green environment activities encompasses many areas that include 'green energy', 'green homes', 'green living', 'green solutions', 'green technology' and 'green materials' [13]. In the recent initiatives on 'green materials' for instance, great effort has been made in the policy and promotion in search of engineering sustainable solutions in energy and the environment. The European Union has drawn up a legislation to promote more environmentally friendly and energy-efficient vehicles.

A legislation implemented by the European Union has emphasised that 80% of vehicles must be reused or recycled while Japan has set a target of 95% of its used cars to be recycled and reused [14]. In the reduction of dependence on fossil fuels, natural or plant-based materials are in a better position as potential alternatives over conventional synthetic materials. Natural materials possess excellent properties such as high composite strength, low abrasive effects to processing equipment, easy to manufacture, light weight, low cost, biodegradable, and recyclable [15]. In lieu of the above and in the interest of global sustainability, automotive industries are now shifting their entire research and development initiatives to incorporate the use of plant-based materials, specifically, natural fibre composites in the production of passenger car vehicles. To-date, car components using plant-based fibres and composites have proven to be feasible in a number of automotive parts. For an example, sisal, hemp and flax fibres are commonly used as interior door padding, floor panels and linings for seat-backs. Coconut fibres are used to make head restraints and back cushions while cotton fibres are used as sound proofing materials in the interior of a passenger car vehicle. In addition, natural fibre composites derived from thermoplastic and thermosetting matrices are being used as inner door pocket components and spare wheel wells by the automotive industry [14,16].

The applicability of natural alternatives in automotive components has brought about extensive research on the industrial applications of natural components. One of the main areas of research is the tribological characterisation and applications of natural components. The science of tribology is essential in improving the reliability of any machine components and systems. It is the study of friction, wear, and lubrication between interacting surfaces in relative motion. Any component of a mechanical system is subjected to wear and frictional losses. For any major component of mechanical system, it is estimated that the wear and friction losses can reach to 63% of total cost incurred by the industries around the world [17]. The quest for system and energy efficiency and cost effectiveness had triggered a growing interest in tribology.

The previous decade had witnessed a keen development of tribology of polymeric composites subjected to natural fibres. Intensive research was conducted on both synthetic and natural fibres. Fig. 3 illustrates the number of articles published on research works in tribology of synthetic and natural fibres over the last decade. It indicates the increasing interest of worldwide research on the topic.

While the second half of the 20th century had been dedicated to research in tribology, the early part of the 21st century gave more focus on renewable sources of natural fibres, mainly for tribo-composite applications in response to environmental issues. During this period of time, there are innumerable scientific studies on plants as alternative sources for industrial applications. The phenomenon of interest in plant-based alternative as potential materials for industrial applications has prompted Omar and others [18] to label the current century as the 'cellulosic century'. As a result, the authors find it appropriate to dedicate a compilation of research works in tribological performance of natural plants in polymeric composites. The compilation outlines the research work carried out from the year 2000 to June 2014. Information on natural fibres, polymer composites associated with the history and science of tribology developments will be presented. It is to be noted here that due to the complexity on the different kinds of testing modes available under the science of tribology, this paper will only address on the adhesive wear of plant derived natural fibres reinforced synthetic polymeric composites.

Hence, it is hoped that this review will provide an effective overview on the research works reported for the past 10 years, addressing the types of adhesive wear mechanism for different types of composites and their performance on friction, temperature, surface roughness, contact condition, test parameters and their applications. Following the review process, certain limitations and shortcomings on the research works will be addressed appropriately with the hope that it will pave the way for further

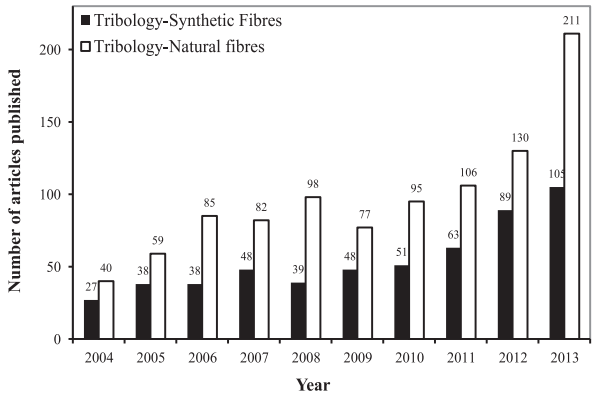

Fig. 3. Number of articles published based on tribology of synthetic and natural fibres.
Source: http://www.ScienceDirect.com. Keywords used: natural fibres, synthetic fibres, tribology.