JOURNAL OF MODERN MANUFACTURING SYSTEMS AND TECHNOLOGY (JMMST)
e-ISSN: 2636-9575
VOL. 4, ISSUE 2, 61 – 65
DOI: https://doi.org/10.15282/jmmst.v4i2.5263

ORIGINAL ARTICLE

Mini review of carbon based additive in machining lubricant

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ABSTRACT – Milling process is a major machining process used in various type of industries. This process is used to manufacture components such as impellers and structural parts in aerospace industry. Several problems can be arising during the machining operation because 99% of work done produces heat to the chip, the tool and also the workpiece . The temperature of the tool may rise up to 1000°C and this could lead to accelerate the tool wear rate and also the finishing of the surface of the workpiece. In order to improvise this phenomenon, various type of cutting fluid is used in milling operation to use to reduce the temperature of the workpiece. In general, the fluids are used when cutting the workpiece to lower the heat generated at the interface of the tool chip and also the friction on the workpiece. There are four main types of cutting fluid when commonly found in the market which is straight oils, synthetic fluids, soluble oils and the semi-synthetic fluids. This paper is reviewing on the additive for lubricant and their tribology properties.

ARTICLE HISTORY
Revised: 30th September 2020
Accepted: 30th September 2020

KEYWORDS
Carbon based additive
Machining lubricant
Milling

INTRODUCTION

Carbon (C) is a nonmetallic element grouped in Group 14 in the periodic table. Carbon is distributed wide in the nature, but it is not particular plentiful. It only contains 0.032 percent in the Earth's crust yet more compounds are formed than all the other. The isotope of carbon, carbon-12 is the standard relative to measure the atomic weights of the other elements. Carbon itself can form a strong single bond that is stable enough to withstand chemical attack in ambient conditions.

As a free element, carbon has a lot of uses in the market, including jewelry such as diamonds or black fume pigment in automobile's rims and the printer's ink. Carbon itself can appear in another form as graphite. Graphite is use as crucible that can withstand high temperature, electrodes in dry cell and light arch, and the pencil lead. Carbon can also appear in amorphous form that called as vegetal carbon, used as gas absorbent and bleaching agent.

Carbon can be activated using a various type of activation agent. Activated carbons are among the most used adsorbents[1]. They possess a great variety of modified surface groups, making them useful in water purification, as gas removers, and in the recovery of materials, etc. [1]The global consumption of activated carbons was 750,000 t in 2002. The estimated growth of worldwide demand is 4–5% per year, with higher growth rates of 5–6% per year projected for the U.S. between 2002 and 2005[1].

Currently, activated carbon are manufactured by different kind of raw material such as agriculture residue[2], coconut shell, waste sugarcane bagasse[3], corn cob[4], different types of wood, nutshell and coal. With the additive of activated carbon into the base lubricant, it can help to make an improvement on the life of the machine elements and reduce the energy losses while performing machining operation[5].

REVIEW ON CARBON BASED ADDITIVE IN LUBRICANT

Additive in lubricant

Basically, adding additive into lubricant is one of the method to reduce the frictional resistance in machining application [6]. There are several types of additive which are currently using in the industry to improve the lubricant performance of the bas oil [5]. The nanoparticles that usually use ad additive are Al_2O_3, CuO, TiO_2, ZnO, graphene and others. These nanoparticles have the following characteristic such as low wear scar diameter, high viscosity, high pressure distribution, high load carrying capacity and low friction coefficient [5]. According to Xie, additive play an important role in improving lubricants behaviour during cutting process [7]. Activated carbon can also be use as additive in lubricant to improve the properties of the lubricant and improve the surface roughness of the cutting fluid [7], [8].

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Nanofluid used in lubricant application

Nanoparticle	Base fluid	Size (nm)	Wear reduction (%)	Friction reduction (%)	Concentration
CuO	GO, PAO	40		45	0.005-2 vol%
Graphene	LO	500	20-68	40-70	0.001-30 wt%
Graphite	LO	500			1-30 wt%
CNT MWNT, fullerene, diamond	EO, GO	200	40-50	10-55	0.001-30 wt%
BN h-BN	PAO, GO	150	15	20	1 wt%
TiO_2, Al_2O_3, SiO_2, MoO_2	LO, EO	40-100			0.01-10 wt%

GO=gear oil; LO=lubricant oil; EO=engine oil; PAO=polyalphaolefine
Source: [9]

Activated carbon based lubricant

Activated carbon is an organic matter that is highly porous which can be applied in plenty of industries. For examples, they often being used as catalysts, adsorbents and catalyst support[2]. According to International Union of Pure and Applied Chemistry (IUPAC), activated carbon is defined as a porous carbon material which can react with gases and chemical before, during or after the activation process in order to improve the adsorptive properties [10]. The well-structured porous structure and surface chemical functionalities strengthen the interaction between polar and non-polar adhesion [10]. Normally, the pore size volume is range from 0.20-0.60 cm^3/g, surface area range from 800-1500 m^2/g and the pore diameter is smaller than 2nm (Leimkuehler, 2010). Due to its large surface area, high total pore volume, strong mechanical strength and stability in chemical properties, the demand over the world is estimated to rise around 6% per year and the figure will reach 2.0 million metric tons by the year 2025 [12]. The application of the activated carbon can be applied in water purification, VOC recovery, garbage incineration, catalytic deodorizer, removal of siloxane in digestive gas and acid rain protection [13].

The porous structure of activated carbon is one of the major reasons that researchers use it as additive in lubricant. According to the research from Meiling, additive off activated carbon in lubricant for 1 wt% shows a remarkable improvement during the experiment. The friction coefficient decreased by 25.7% and the wear resistance increased by 3.21 times when the weight ration of activated carbon additive is 10% [14]. The carbon additive is working out like a spacer. This is to prevent the asperities of two metal surface from mating each other [15].

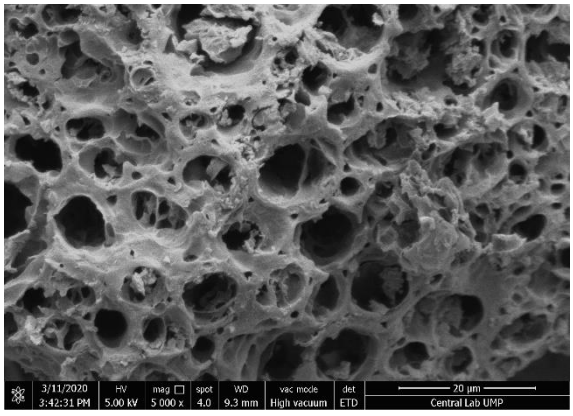

Figure 1. Activated carbon

Preparation of activated carbon

Basically, the main purpose of activation process is to increase the pore volume, enhance the pore volume and enlarge the pore diameter [16]. Any material with high carbon content and low inorganic, can be used as the raw material such as forest, agriculture and municipal wastes, lignite, petroleum pitch, coal and lignocellulosic biomass to produce activated carbon [10]. Besides, different precursors of vegetables type such as oils, husks, pits and seeds from plants and fruits and polymeric materials can be used to produce activated carbon. Because of the low cost and renewable source, agricultural

residues have the advantages to be chosen as the precursors for production of activated carbon[17]. A general method for preparing activated carbon has been proposed by Thomas with the use of natural resources.

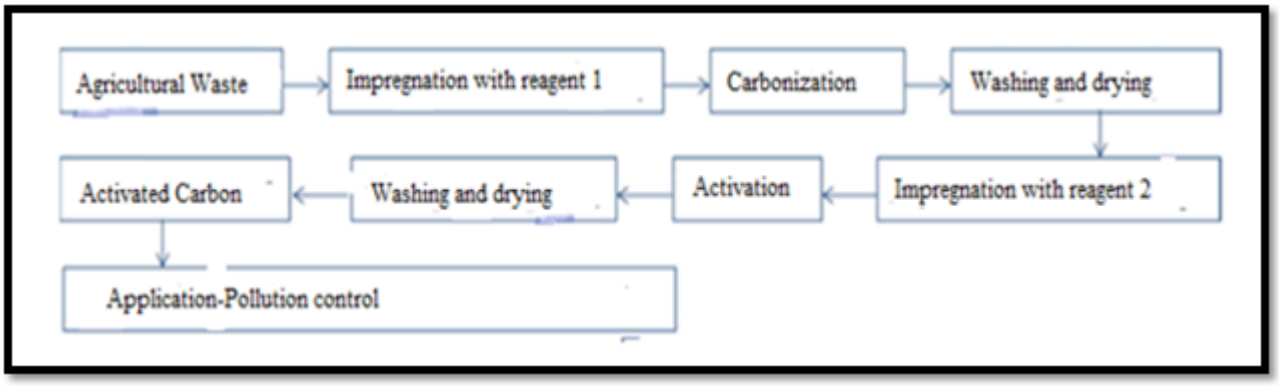

Figure 2. A general method of preparation of activated carbon from natural resources [13].

Graphene based lubricant

Graphene is a six-carbon atom lied in a layer showing a honeycomb lattice in hexagonal shape. Graphene present itself as a two-dimensional(2D) structure in a single layer [18].Besides, graphene shows a good mechanical strength, smooth atomic surface, excellent thermal stability and low surface energy. With promising the low surface energy, adhesion and friction on different substrate can be reduced [18]. Furthermore, due to its low interlayer shear strength and the layer structure, graphene were actively being used in research for the tribology properties [19]. According to the research, the nanoparticles from graphene family able to make a separation from the contact and form a protective film on the interface of the frictional and possess a special antiwear function. This results in improving the lubricating performance for the base lubricant [19].

Properties of graphene [18]

Properties	**Values**
Thermal conductivity	~5000 W m^{-1} K^{-1}
Specific surface area	~2600 m^2 g^{-1}
Melting point	~4125 K (predicted)
C-C bond strength	0.142nm
Interplanar spacing between graphene sheets	0.335
Young's modulus	~1 TPa (1.5 x 10^8 psi)
Tensile strength	~130 Gpa
Fracture toughness	~4 Mpa $m^{1/2}$
Electron mobility	~200,000 cm^2 V^{-1} s^{-1}
Electron density	2 x 10^{11} cm^{-2}

Additive of graphene into base lubricant can improve the anti-friction and anti-wear properties. Graphene can improve the lubricating condition by providing a nano-bearing effect that form a protective tribolayer. In the hole of the textured surface, graphene nanoparticle can be stored and released [18]. According to the research carried out by Mohamed, the tribological result shows that graphene nanolubricant had improve the anti-friction properties by 29-35% and the anti-wear properties by 22-29% during a boundary lubricating system[20]. For solid lubricant, graphene nanosheet also shows a compromising result. For a tribological test carried out in air, a stable and compact sliding interface between graphene nanosheet is observed [21].

Carbon nanotube based lubricant

Carbon nanotube is a single layer of carbon atom (graphene) rolled up in the form of sheet. It can be categorised into 2 groups which is single-walled (SWCNT) with the diameter less than 1 nanometre and multi-walled (MWCNT) which contain of few interlinked nanotubes concentrically. The size is in micrometres or millimetres. According to Leander's research, MWCNT shows its ability in reducing friction and wear for various type of operations. For instances, environmental roughness, surface pressure, temperature and humidity [22]. Besides, the viscosity index of CNT is investigated by Hadi. The researchers found out that the viscosity index of the lubricant increase by adding CNT into the base lubricant [23].

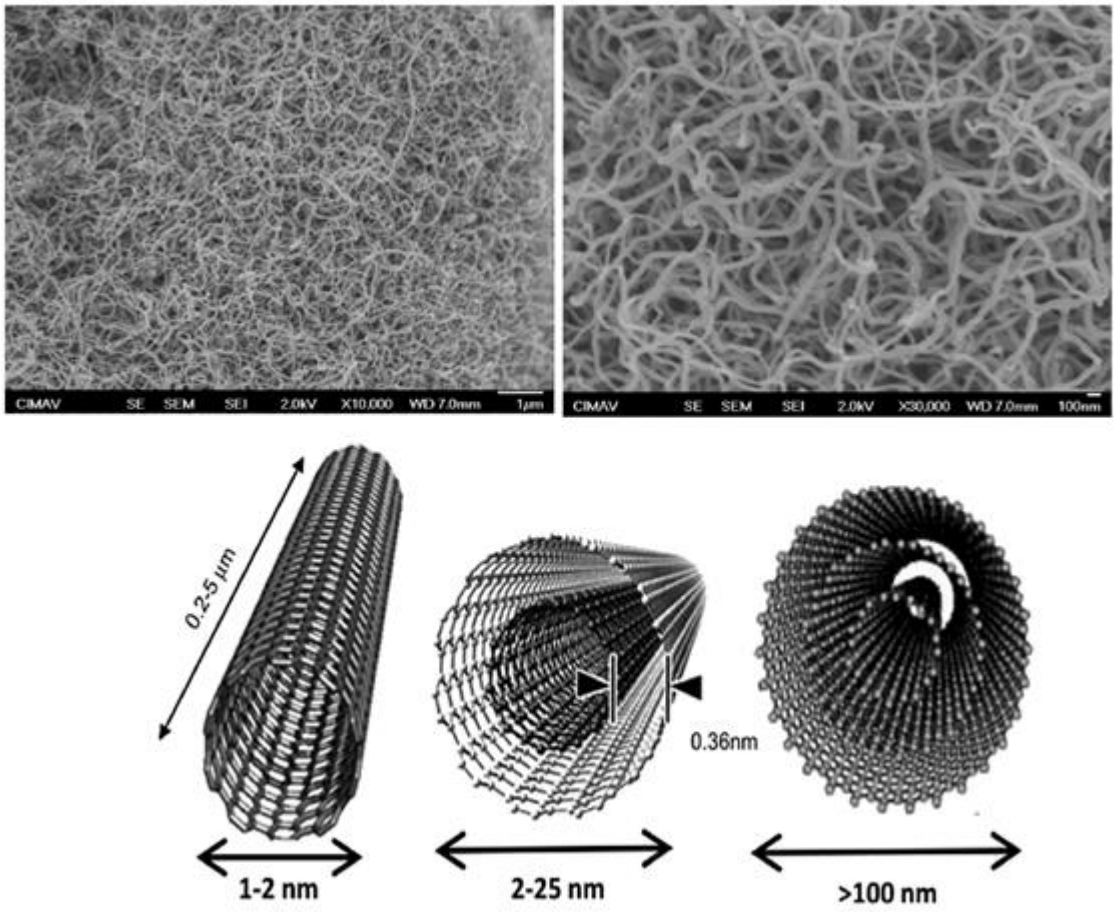

Figure 3. Images of carbon nanotube

Concentration of CNT plays an important role in the tribological result for additive in lubricant. According to a study from Imran, if shows that the friction coefficient was decreased to 0.08 by adding 0.1 wt% of single walled carbon nanotubes (SWCNT) in the polyalphaolefin (PAO) base lubricant. While for multiwalled carbon nanotubes (MWCNT), the friction coefficient drop to 0.15 when the contact pressure is 0.83GPa.[24]. In a twin-disk tests that apply with a contact stress of 1.1 GPa, lubricant added with 0.01 wt% of SWCNTs promising a highest result of wear resistance [25]. As a conclusion, additive of CNT in lubricant oil poses a reduction in the friction coefficient down to 80% as the concentration of 0.5 wt% [24]

CONCLUSION

In the field of machining, friction coefficient and wear resistance if the main concern of the industries. With the help of additive into base lubricant, both of this problem can be solved. By improving the wear resistance of the tool and the surface of the workpiece, a better surface roughness and longer tool life can be achieved. While reduction in friction coefficient can reduce the power consumption of the machine. Carbon based additive is an organic matter. Therefore, with the aid of carbon based additive will not bring harm to the environment.

ACKNOWLEDGEMENT

The authors would like to thank UMP for funding this work under an internal grant RDU1803186.

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