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INVESTIGATION ON TRIBOLOGICAL BEHAVIOR OF FDM PRINTED ABS POLYMER

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Abstract **— – Fused Deposition Modeling (FDM) widely uses Acrylonitrile butadiene styrene (ABS) to print various Mechanical components like Gears, Rack and pinion, Power Screw and Mechanical Links etc. But their properties change with the method of printing, working temperature, printing temperature and layer flow direction. In this particular study ABS SPECIMEN printed by FDM is used to study its Abrasive wear properties. The test has been carried out on a custom made pin disc wear testing apparatus.**

Index Terms **— Acrylonitrile butadiene styrene (ABS), Fused Deposition Modeling (FDM), Abrasive Wear, Mass Loss, Load.**

I. INTRODUCTION

Mechanical components are conventionally made from metals like steels, copper alloys, aluminium alloys etc. Although many exotic alloys and metals like titanium and aircraft grade aluminium alloys have significantly improved the performance of these parts, but still these parts fail to compete with the parts made out of modern polymers in terms of light weight, self lubrication properties and specially ease in manufacturing. Research in this field has shown that the polymers have enough ability to dampen shock and impact resistance, fabricability, self lubrication properties and low noise operation to be used in manufacturing mechanical components such as lead screws, mechanical links and gears etc [7]. It has been found that gears and lead screws made-up of ABS polymer performed well under dry condition and their performance can be significantly improved by the use of lubricants [3]. One advantage of using polymers like ABS is that the rapid prototyping techniques like fused deposition modelling (FDM) can be used, these processes are quick and cost effective in case of custom jobs and low batch size production. Although parts made up of ABS do not posses enough strength to work under high end machines still they find there applicability in robotics, Xerox machines, printers and other components that work under low load operations. Blend of PC and ABS have been found to poses superior mechanical properties especially in gear application . The abrasive properties of ABS (polymers) can be increased by addition of graphite powder [5].Another way of increasing surface property of ABS is by introduction of reinforcements like glass fibre or carbon fibre[6]. The ABS is material of choice for making components that work under higher speed and low load. Some thermosetting polymers like polyethylene and polyester are also used in making of plastic gears [7]. Polymers generally fail by either fatigue or sudden melting [8].different modes of failure observed in polymers are wear, cracking at root, cracking at pitch circle, and pitting[9]. Tests have shown that the gears fabricated of ABS show decreased wear rate as the rotational speed increases, but as the working load increases the specific wear rate also increases [2].ABS components has good strength and impact resistance[10]. It is also found that the wear-load graph has lower slope initially but it increases rapidly on further load increment [4]. Other mechanical parts like lead screws and mechanical links are also made by FDM with ABS as material this is because of reason that ABS has very good frictional properties. Coefficient of friction is found to be minimum under lubricating condition and it remains constant at higher loads [3]. The coefficient of friction of ABS depends upon the time and applied load [4].The side effect of lubricating ABS parts is that it increases plasticization promoting wear in parts [3].

II. WORK METHODOLOGY

A. Material and specifications of test specimen

Test specimen made up of Acrylonitrile butadiene styrene (ABS).

Properties	Values
Bulk Density (g/cm^3)	1.13
Infill (%)	100
Printing method	FDM
Printing firm	Think3D (Hyderabad)
Grain flow	Longitudinal
Colour	White
Extruder temperature	210^o - 250^{o}C

B. Preparation of specimen

Test specimen made up of Acrylonitrile butadiene styrene (ABS) by using fused deposition modelling process. The specimen was printed with 100% infill. Specimen was printed by Think3D at Hyderabad. There was no colour additive and all the specimens were white ABS.

C. Wear test apparatus specification

The apparatus used for the testing, is a custom made arrangement fabricated at Integral University (Lucknow). This setup consist of a DC motor to connected to a abrasive disc, an acrylic disc serves as specimen holder, screw jack is used to apply the required load while a load cell is used to measure input load. A regulator unit is also employed to control the input current and voltage. Brief overview of the apparatus specimen is given in the table below:

APPARATUS:

COMPONENT	SPECIFICATION
Motor	1 H.P.
Rotational range	1 rpm – 3000 rpm
Holding radius	8cm, 16cm, 24cm
Abrasive wheel	
Screw jack	
Load cell	

REGULATOR UNIT:

Parameter	Value
Regulated voltage	0 – 260 V
Least count (voltage regulation)	2V
Current range	0 – 10 amp
Least count (current)	0.4 amp
Voltage range	0 – 300 V
Least count (voltage)	20

D. Wear test

The total of 5 specimens was used. Each specimen was subjected to 5 tests at each selected RPM value. The RPM selected was 200, 400, 600 RPM. This provided total of 75 results and the mean of each result set was taken. The experimental procedure was as follows:

- Hold the specimen in specimen holder which is attached with acrylic sheet
- Bring the sanding wheel in contact with the specimen and find zero position of load cell
- Apply load by using load cell provided in the experimental setup
- Motor is activated and shaft starts rotation with selected RPM
- The process is continued for 5 minutes
- The experimental setup is switched off and the specimen is removed from setup
- The specimen is placed on electronic balance machine and mass loss in obtained.

E. Formulas used:

- Percentage wear = (mass loss * 100) / initial mass
- Specific wear rate = mass loss / (density * time * rubbing speed *load)

III. RESULTS AND DISCUSSION

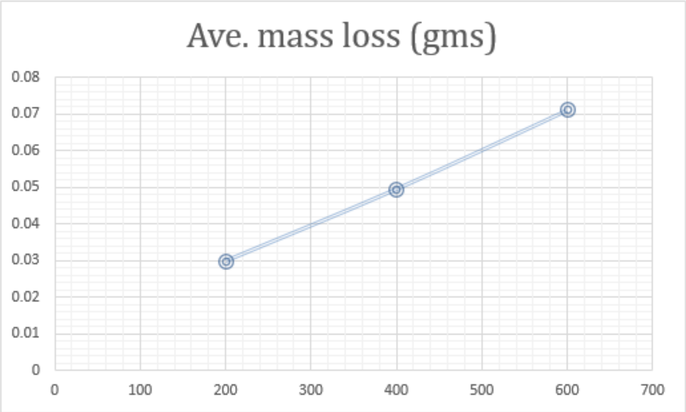
A. Mean result:

After conducting total of 75 experiments regarding our investigation of tribological behaviour of FDM printed ABS polymer following mean result has been obtained. These results are shown in tabular form below:

Final test results			
RPM	Ave. mass loss (gms)	Ave. % wear	Ave. specific wear (10^{-8})
200	0.0299	0.3045	4.2073
400	0.0496	0.5157	3.4935
600	0.0712	0.7635	3.3444

B. Graphical representations:

Average mass loss vs. RPM



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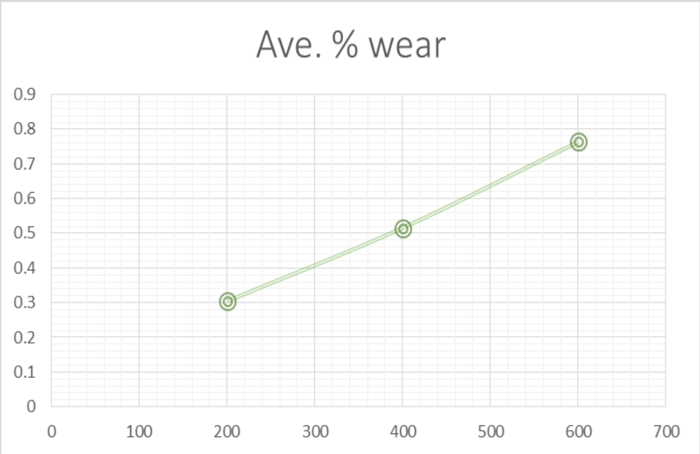
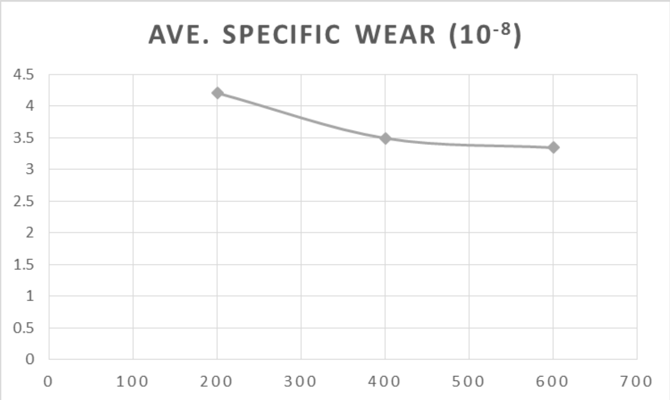
Average percentage wear vs. RPM

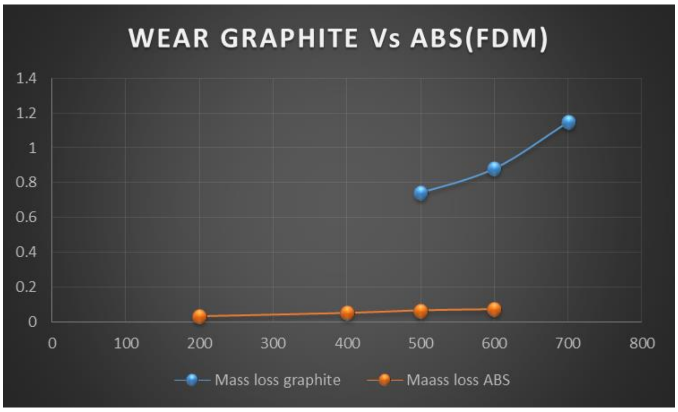


Average specific wear vs. RPM



C. Comparison with other non-metal (Graphite):

Following graph shows a relative comparison between mass loss during wear test at load of 10N and different RPM conditions:



Conclusion

The average mass loss shows following main characteristics:
• There is linear relationship between amount of mass lost due to wear and rotational speed of grinding wheel
• The mass loss in first two minutes is more as compared to last 3 minutes
• The above fact is due to the reason that wheel loading occurs and due to it amount of wear reduces
The average percentage loss:
The average percentage of wear vs. RPM graph is almost same as previous one. This is due to the fact that percentage wear is a function of mass loss and possess a linear relationship.

The specific wear vs. RPM graph shows following highlights:
• This graph is not linear in nature showing that specific wear rate does not follow linear relationship with RPM.
• Unlike previous two graphs, this graph shows decrease in specific wear rate as the rotational speed of grinding wheel increases.

Comparison with graphite:
It is clearly evident that:
• The comparison data was taken from my work and prior work done on graphite by Mr. Majid Khan under the supervision of Dr. Shadab Khan (Integral University)
• Under same load and rotational speed the graphite has much higher amount of mass loss and rate of wear than FDM printed ABS polymer specimen.
• The FDM printed ABS shows linear relationship between mass loss and rpm unlike graphite which seems to exhibit positive exponential relationship between mass loss and rotational speed.
• Above Graph shows that ABS possess better tribological behaviour than graphite in terms of wear rate.
• The Ratio of Wear Vs RPM of Graphite is higher than ABS polymer.

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