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Investigation of the wear rate of materials under different design conditions

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Abstract

In industries,the wear of material is a topic of great concern, as it directly as well as on a large scale, affects product life cycle and cost estimation. Here, the approach for the study is to study the wear rate of material depending on various experiments performed. These experiments are done using various fillers, reinforcement, and changing process parameters. Results explain improvements and variations in properties. However, alteration leads to various mechanical changes, and this paper mainly focused on the effect on the wear rate of material under different design conditions. Materials for studying wear rate are mainly PLA and ABS polymer used in the fused deposition method of 3D printing. This paper is explained using various images and results, and conclusions are drawn by integrating them all.

Keywords: FDM(Fused deposition Method), PLA,ABS, wear rate, 3D Printing

1. Introduction

Industrial progress plays an important role in the development of a nation[1],i.e., with the current scenario, everyone is trying to use advanced technologies and resources optimally so that industrial output gets maximized. In the scenario where profit maximization is the primary objective in industries, using methods that help reduce time and cost is a system perspective [2]. Researchers are also trying to make a material composition for production that helps reduce material waste and increase its life cycle, contributing to industrial development.This paper reviews a significant problem in industries,i.e. - wear and material composition, to reduce the wear rate of materials.

The selection of material is a crucial step while making a product, as most of the properties (can be desired or undesired) and the product's cost depends on it. While selecting, design limiting properties also needed to be considered, one such property is wear. Wear is simply the removal of material from surface, which can be due to rubbing action between two surfaces, corrosion etc. It can also be said that, as it is a surface phenomenon, volume of material that is

been lost while rubbing or sliding from surface per unit distance slide is calculated as wear rate[3].

During interaction between surface, or while transfer of motion, force etc., a huge part of mechanical energy which is been supplied gets wasted in form of alteration of surface topography of material and their physical and chemical properties due to low wear resistance of materials. Various tribological studies are being carried out to utilize or prevent that wastage of power [4].

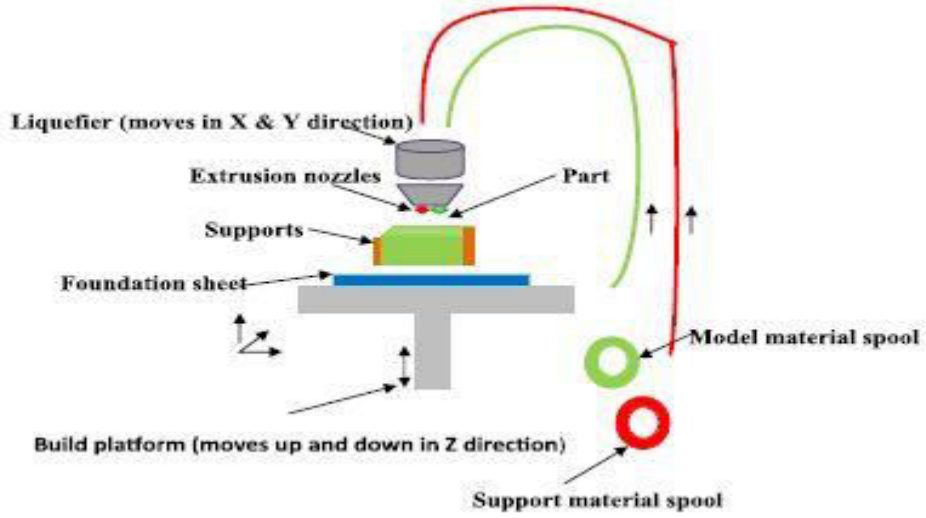

Figure 1. Schematic Diagramof FDM

From the last decades, interest in the field of materials goes on increasing because of the development of new composite materials and polymers with required physical and mechanical properties(Chang et al., 2005). Various combinations of materials such as polymers with organic fillers or inorganic fillers are been tried to test them for different properties such as tensile strength, fatigue strength, thermal diffusivity, wear resistance, corrosion resistance etc. and results are also competently(Wang et al., 2008)[5].

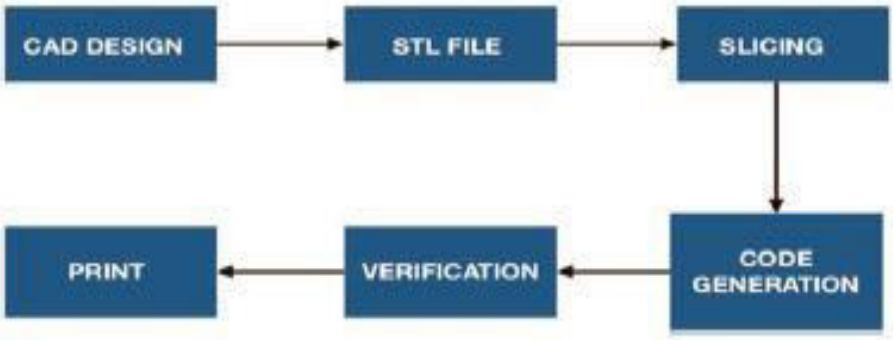

Figure 2. Product File Generation

3D printing, a rapidly growing development technology, due to its much flexible operations as well as its more satisfactorily results. This technique helps in presenting imaginative drawing from pictorial form to physical form in live world[6]. This comes up as a boon for both industrialist as well as researchers and gave new hopes for work. It is a bottom-up approach i.e manufacturing from small to large size, for fabrication of a three dimensional object[7]. An additional benefit of this technique is its layer by layer live visualization during manufacturing of product. It is a topic, which after that much of work, still a lot left for research. This involves similar technology as in 2D printing on papers, and also it is not wrong to say that it is doing 2D printing again and again, whatsoever the method is[8].

As Science is all about doing experiments and experiments is all about doing trials. Some of those trials gave positive results and they become desired output,can be discovery also while some may also give negative results and become experiences, but ultimately both called as research. Various materials are being used to manufacture a product using fused deposition method in 3d printing such as PLA, ABS, and Nylon etc. [9]. Here,the criteria for research is about manufactured material wear.

2. Literature Review

J. Sudeepan et al.In this experiment,ABS(Acrylonitrile-butadiene-styrene),as base material,is been tested for wear as tribological property by using micron(10^{-6}) ZnO as filler. This test is performed using wear testing machine block-on-roller multi-tribotester(DUCOM) at temperature of 27 °C, in dry condition using Taguchi method.Here,parameters considered for design are wt% of filler content, applied normal load and speed of sliding in rpm whereas response considered as coefficient of friction and specific wear rate.Number of optimal combination is find using Taguchi technique. Resulting combination comes out to be filler at 5% by weight , load at 35 N and speed to be 120 rpm giving minimal response for coefficient of friction(μ) and for wear rate(specific)response offiller at 15% by weight , load at 35 N and speed to be 120 rpmis been least.

$$Ws = \frac{W_1 - W_2}{\rho * P * \upsilon * t}$$

Later stages analysis for analysing effect of design parameters on coefficient of friction(μ) and wear rate(specific) is done using ANOVA(analysis of variance). Coclusion comes out to be, significant influence of fillers on both coefficient of friction(μ) and wear rate(specific) but are most been effected by normal load. In other way,it is also said that,If ABS is been added with micron sized ZnO filler and at correct combination of parameters tribological properties can be improved[10].**T.D. Ngo et al.**:This paper signifies the need to work on polymer materials for 3D printing. This explains that multifunctional materials can easily be printed using additive manufacturing technique. For 3D printing of materials filaments can be used in various forms such as in wire form ,as powder, can be paste or in sheets form and as inks also,shows its flexibility for manufacturing component. The most common material which is been preferred for military automotives parts, aerospace, in sports equipments, medical ,architectural and other industries is Polymer.They are used mostly in filament form in FDM(Fused deposition

method),which is most general method of 3D printing. Some such polymers are ABS,PLA(Polylactic acid), PA(Polyamide),Nylon are the mosty used polymers.But due to lack of mechanical properties polymers are mainly used for fast prototyping.

Table 1. Detailed classification of Additive Manufacturing Processes

Methods	Materials	Applications	Benefits	Drawbacks
Fused deposition modelling	Continues filaments of thermoplastic polymers Continuous fibre-reinforced polymers	Rapid prototyping Toys advanced composite parts	Low cost High speed Simplicity	Weak mechanical properties Limited materials (only thermoplastics) Layer-by-layer finish
Powder bed fusion (SLS, SLM, 3DP)	Compacted fine powders Metals, alloys and limited polymers (SLS or SLM) ceramic and polymers (3DP)	Biomedical Electronics Aerospace Lightweight structures (lattices) Heat exchangers	Fine resolution High quality	Slow printing Expensive High porosity in the binder method (3DP)
Inkjet printing and contour crafting	A concentrated dispersion of particles in a liquid (ink or paste) Ceramic, concrete and soil	Biomedical Large structures Buildings	Ability to print large structures Quick printing	Maintaining workability Coarse resolution Lack of adhesion between layers Layer-by-layer finish
Stereolithography	A resin with photo-active monomers Hybrid polymer-ceramics	Biomedical Prototyping	Fine resolution High quality	Very limited materials Slow printing Expensive
Direct energy deposition	Metals and alloys in the form of powder or wire Ceramics and polymers	Aerospace Retrofitting Repair Cladding Biomedical	Reduced manufacturing time and cost Excellent mechanical properties Controlled microstructure Accurate composition control Excellent for repair and retrofitting	Low accuracy Low surface quality Need for a dense support structure Limitation in printing complex shapes with fine details
Laminated object manufacturing	Polymer composites Ceramics Paper Metal-filled tapes Metal rolls	Paper manufacturing Foundry industries Electronics Smart structures	Reduced tooling and manufacturing time A vast range of materials Low cost Excellent for manufacturing of larger structures	Inferior surface quality and dimensional accuracy Limitation in manufacturing of complex shapes

Recent studies been conducting over improving mechanical properties with reinforcement of fibersand nano-materials to make them useful for more functional components[11].

3. Advances in Tribology

This section gives idea about biocarbon reinforced PLA and its effect.Firstly, printablity of fused deposition modeling(FDM) is affected by biocarbon,more specifically by 30% vol of biocarbon particles. The working nozzle got clogged often as carbon particles were not molten nor plasticized like PLA while passing through nozzle.The object prepared are read using SEM(Scanning Electron Microscopy), which shows close contact between the PLA matrix and biocarbon particlesalso no such visibility of micro-cracks at the interface. Mechanical interlocking between the PLA as surrounding material and biocarbon particles is much better.

After testing morphology of the worn out surfaces was obtained for PLA without biocarbon, with 5% vol, 15% vol and 30% vol of biocarbon from Confocal Laser Scanning Microscopy(CLSM). Results shows that unreinforced PLA has highest wear dimension while best wear resistance obtained for PLA with 30% vol of biocarbon[12].**Muhammad Arif Mahmood et al:**This paper explains about variation in wear resistance with changing of various manufacturing parameter through cura software.

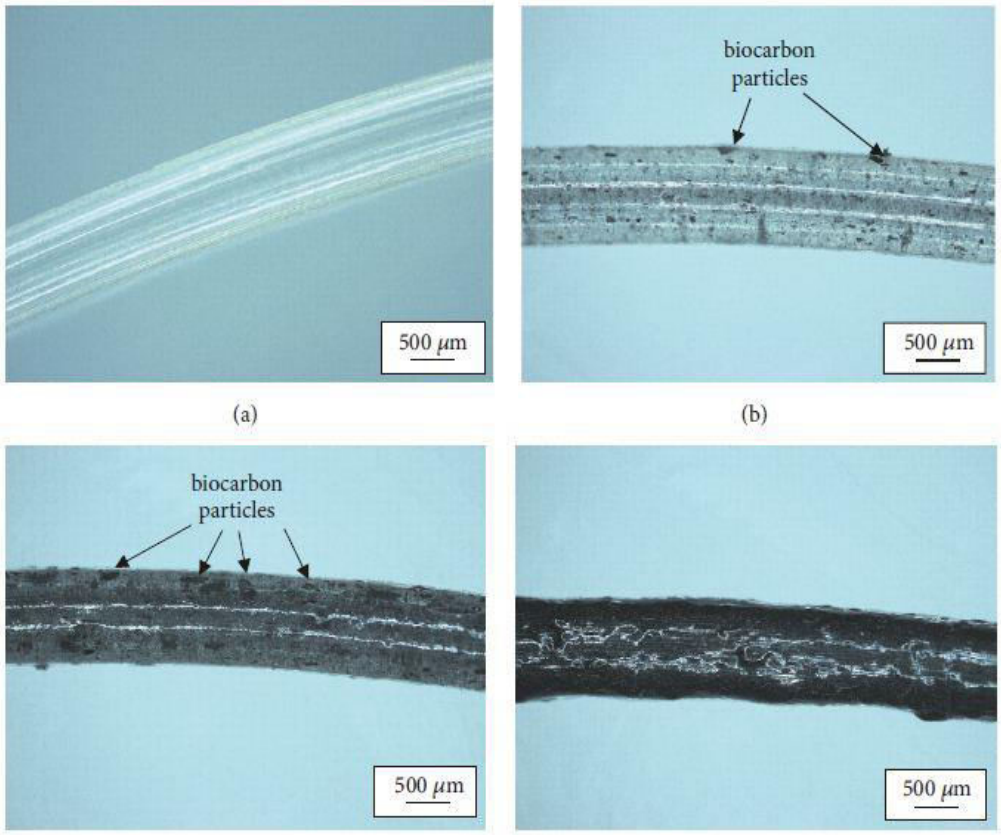

Figure 3. Variation in filling: a) without; b)5%; c)15%; d)30%

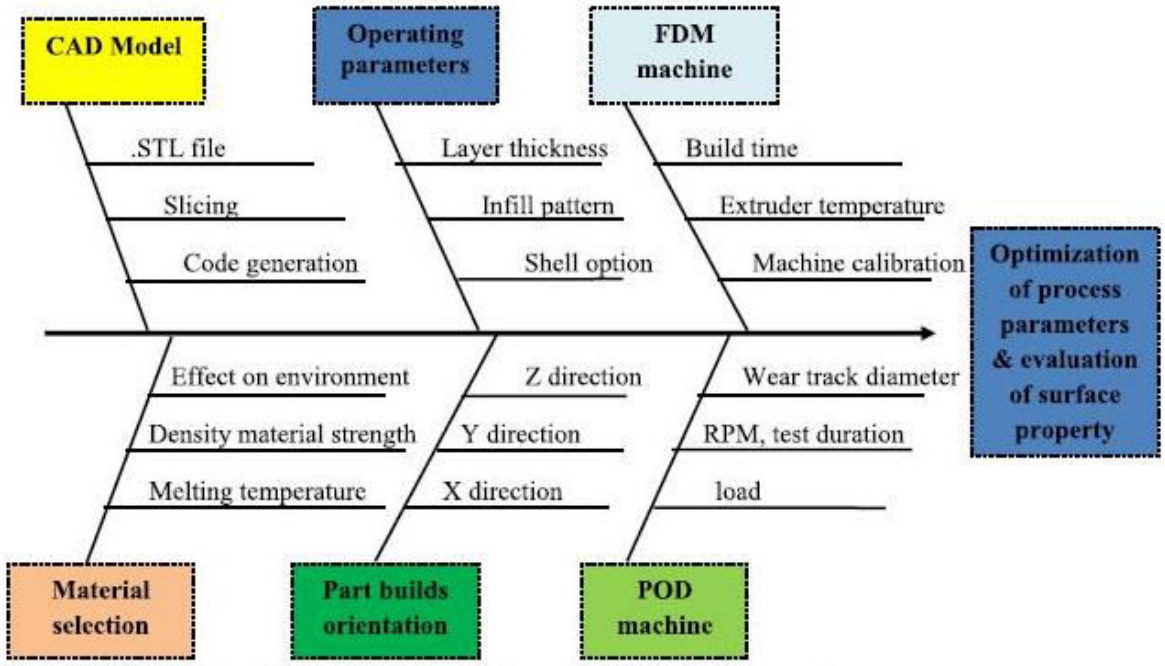

Figure 4. Different parameters for design

Optimal combination for specimen prepration is obtained using Taguchi technique and also been optimized using ANOVA and ANN(Artificial neural network) .Resulting optimal combination for these parameter is been selected for wear resistance.

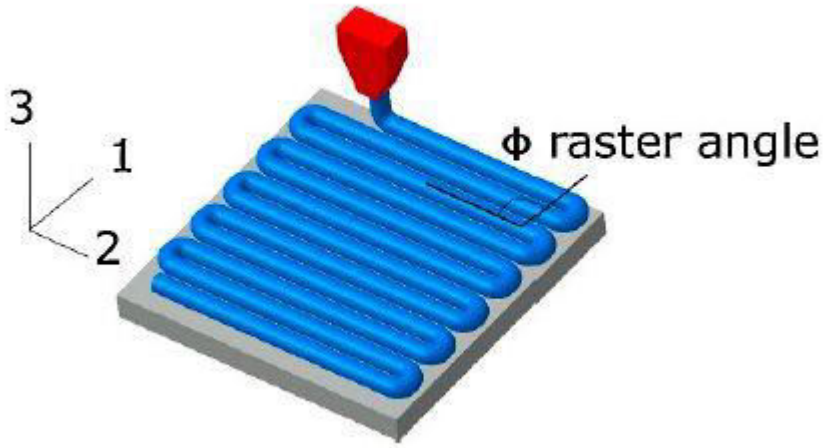

Figure 5. Raster angle

Process parameters included to design various pin specimen are layer thickness, orientation and extruder temperature. Printing of specimen is done using FDM process of 3D Printing. Based on the different values for parameters specimen are prepared and been investigated for wear testing and other properties using Pin on wear disc testing machine.Concluding results shows that build orientation parameter have major influence on the wear performance of polymer specimen[13].

4. Conclusion

Depending upon various studies on materials,it has been concluded that the addition of external fillers, varying in material manufacturing parameters, will change the mechanical properties of the material. The work shows that many more such combinations can also be tested to obtain more output regarding various properties, and this topic also needs more work.

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