Chapter 07. Conclusion and Future Scope

7.1 Conclusion

In the present study, a composite filament extruder is designed and manufactured indigenously for short fiber reinforcement. The major modifications incorporated for short fiber composite filament extruder as compared to standard filament extruder are:

- Flat nozzles are replaced by converging nozzles for easy flow of fibers without choking.
- The clearance between the extruder screw and barrel is 1.5 mm for the smooth flow and mixing of matrix and reinforcement material.
- Three heaters were provided on the screw and barrel portion like traditional extruders and an additional heater was provided at the nozzle to prevent solidification of the material at the nozzle.
- During initial trials, it was observed that when the extruded filament was passed through a water bath, because of the sudden change in temperature of the filament from melting temperature to room temperature, the filament became brittle due to quenching. To overcome the same a hot water bath with a temperature controller is incorporated.

Biocomposite filament with Chicken feathers as reinforcement and Poly-lactic Acid as matrix material are prepared in the indigenously developed composite filament extruder. The characteristics of the samples developed are investigated. The investigations included tensile testing, visual observations under a Stereo microscope, thermal analysis using DSC and TGA thermograms, spectrometric analysis by FTIR, chemical (alkaline) resistance, and electrical resistance. The observations are as follows.

- The ideal proportion of CFF in filament manufactured is 2% by weight.
- The average ultimate tensile strength of the filament is measured at 44.23 MPa. The tensile strength of the filament was increased by 73% as compared to CFF/PLA samples prepared by the sandwich method. Tensile strength was increased by 34% as compared to 3D-printed PLA parts.
- Visual observation under the stereo microscope shows a milky cloud like substance at the interfaces of CFF and PLA. The milky cloud is the result of interfacial reactions, which can be due to cellulose and keratin crystalline structure interactions or due to chemical bonding/ reactions between the hydrocarbon structure of cellulose (PLA) and the amino acids (Nitrogen bonds) present in the keratin /protein present in the Chicken feathers.

- The glass transition temperature of the sample is around 357 °C
- The chemical bonds at the interfaces result in better properties as the interface exchanges are not just by wetting and absorption as observed with other composite compounds
- No pinholes/voids were present in the filament samples while the samples prepared by sandwich method had many pinholes which resulted in their lower tensile strength.
- The crosslinking at CFF/PLA interfaces resulted in better physical and thermal characteristics as compared to base materials. The presence of air pockets and pinholes in samples prepared by the sandwich method has resulted in insufficient adhesion at the interfaces.
- The filament sample has good alkaline resistance.
- The filament sample is a good electrical insulator
- The crystalline structure stability is better at a higher temperature compared to base materials.

Extruded composite filaments have better physical, mechanical, thermal, and chemical properties compared to base materials. Considering the characteristics observed the composite filaments can be used in the following applications:

- The composites can be used to manufacture components of EVs where tensile strength and electrical insulation are required.
- The filaments can be weaved and prepared to package for electrical components
- Can be weaved into mats and used as a replacement for metallic mesh for working in alkaline environments.
- Filaments can be used as raw material for 3D printing complex shapes.

7.2 Future Scope

The present development and investigation open new fields for future research.

For the extruder

The short fiber filament extruder can be further developed to include long fibers. A mixer can be incorporated in the feed funnel or the screw can be modified for better mixing of fiber and matrix material. More sensors can be incorporated for precise monitoring and controlling of the process through the implementation of IoT.

For the CFF/PLA composite filament developed

- The filament material can be further analyzed chemically using Nuclear magnetic resonance spectroscopy (NMR) to obtain the structure of the polymorph compound formed at the interfaces of CFF/PLA.
- Process parameters can further be optimized to extend the formation of polymorph throughout the filament cross-section.
- The research can be extended for various blend proportions of CFF and PLA and optimize the characteristics of the resulting composite filaments.
- The CFF/PLA composite filaments can be used in 3D printing and the samples prepared can be characterized for future research.

Applications of CFF/PLA filaments.

Future research can be directed to find the suitability of CFF/PLA filaments in applications such as:

- Manufacture components of EVs where tensile strength and electrical insulation are required.
- Creating biodegradable and rigid packing of electrical/ electronic components.
- Weave the filaments into mats and used them as a replacement for metallic mesh for working in alkaline environments.