

WIRE REINFORCED COMPOSITE MATERIAL FOR ADDITIVE MANUFACTURING

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1. Introduction

Fused Filament Manufacturing (FFM) is one method of Additive Manufacturing (AM) called 3D printing. This method is expected as an innovative manufacturing technology to create materials by composing several materials and fabricate an object by allocating several materials. Additionally, the composition and allocation of different materials can be operated by a computer program. In conventional FFM, the fabricated parts were difficult to be used as mechanical parts because the material was limited in thermoplastics. However, currently, some FFM machines that treat Carbon Fiber Reinforced Plastics (CFRP) using long carbon fiber have been commercialized. The strength of the fabricated parts by these machines has similar strength with Aluminium. Therefore, FFM has high potential to treat high performance materials. In this study, a new FFM method, in which wire is extruded together with plastic, is proposed. This method can treat any kinds of materials for reinforcement. The mechanical property of the composite material fabricated by this method are tested.

2. Wire reinforced material extrusion

FFM is a method to extrude fused plastic and deposit it appropriate place according to computer program. Then, the material used in FFM must be based on thermoplastics. However, if the thermoplastic is used as a composite material with a reinforcement material, the strength can be reinforced. Carbon Fiber Reinforced Plastics (CFRP) is a famous composite material, which has similar tensile strength with metal parts. Some FFM machines for using CFRP are commercialized. There are two methods to use carbon fiber in FFM. One is to use a filament containing carbon fiber like pellets used in injection molding [1]. Another one is use carbon cloth or string laid on the thermoplastics [2].

In the proposed method, the latter type is expanded to use arbitral materials. Figure 1 shows the concept of the method. The reinforcement material is prepared as string shape, and it is supplied with fused thermoplastics in FFM process. The extruded thermoplastic is condensed with the reinforcement wire.

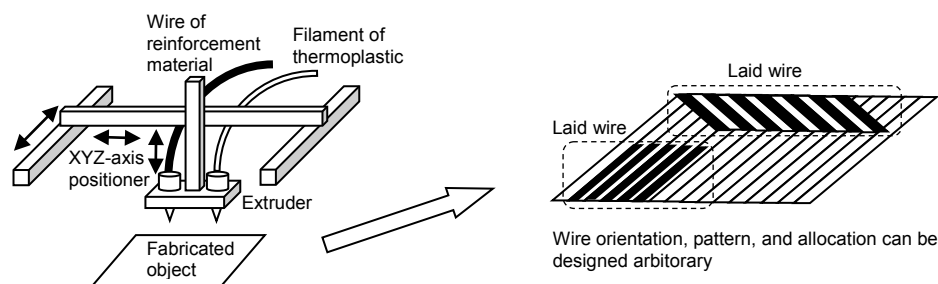


Figure 1 Concept of FFM machine that can extrude a wire reinforced composite material

There are two important merits of this method.

- *Arbitral material can be used as reinforcement material if it can be shaped as string*
- *Arbitral wire alignment and allocation can be designed and controlled by computer program*

3. Reinforcement materials

The most considerable material for reinforcement is carbon fiber string, which is similar with the commercialized machine. Beside the CFRP, a metal wire can be used. Most metal AM machines currently used in industry are the powder-bed fusion type, which uses metal powder as material and a laser or electron beam power is used to melt it and form an object. In general, it takes high costs. If FFM can fabricate a high strength object with low costs, it will become a competitive method with the powder-bed fusion type AM.

4. Wire alignment and allocation design

The proposed method enables us to design the wire alignment and allocation by programming FFM process. As well as carbon fiber orientation is important factor of the strength, the design of wire orientation decides the mechanical property of the object fabricated by the proposed method. However, the design method has not been established. The authors are working on the development of design method. The design problem is categorized into following two issues.

- *Wire alignment: How the wire should be set with orientation and pattern.*
- *Wire allocation: Where and what kind of wire should be supplied.*

5. Test of the wire reinforced composite material

A prototype machine was developed and one line deposition using a carbon string with nylon was realized. The machine will be improved to deposit multi layers and fabricate test specimens. The wire reinforced composite will have strong anisotropic property in strength. Through the tests using many kinds of specimens that have different orientation and pattern, the mechanical properties of the wire reinforced composite material are discussed.

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