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<td>Title (English)</td>
<td>Strength of Synthetic Fiber Ropes Degraded by Repetitive Bending</td>
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A synthetic fiber rope has lightweight, high tensile strength and flexibility, making it a suitable replacement for a stainless steel wire rope. This paper focuses on durability against repetitive bending. We performed an experiment with two synthetic fiber ropes and one stainless steel wire rope to investigate the tensile strength reduction caused by frictional wear. The experiment was conducted over 343 mm with repetitive bending, and the results showed that the tensile strength degradation varied among the ropes.

### 1 Introduction

Recently, synthetic fiber ropes with high performance have been developed for various applications. These ropes are particularly lightweight compared to stainless steel wire ropes, making them suitable for applications requiring flexibility. Synthetic fiber ropes can be used as tendon-driven mechanisms, which are commonly used in robotics and aerial vehicles.

In case of designing tendon-driven mechanisms, metal wire ropes are typically used because of their high tensile strength. However, stainless steel wire ropes may not be the best choice due to their weight and brittleness. Synthetic fiber ropes offer a lightweight alternative with high tensile strength, making them suitable for robots and aerial vehicles.

In this research, we evaluate the durability of synthetic fiber ropes under repetitive bending. The Japanese Industrial Standards (JIS) provide guidelines for testing wire ropes for tensile strength, but there is no specific regulation for synthetic fiber ropes. In this experiment, we used a linear actuator instead of a cylinder provided by JIS to simulate the repetitive bending motion.

### 3 Experiment Device and Samples

In order to make the experiment result generic, we carried out the experiment in accordance with JIS. Fig. 1 shows the experimental device we developed. We can get four samples per experiment because this device has four testing pulleys. The device has two experiment devices, which is provided by JIS as shown in Fig. 2, on both sides of the linear actuator (T6L-20-600-3L-SR1-X05N-B, YAMAHA). Two testing ropes in each device are drawn as red and blue lines in Fig. 1.

In the experiment, the testing rope which is set to the device performs reciprocating motion over 343 mm and gets repetitive bending. After specific number of reciprocating motion, we evaluate durability by measuring tensile strength. We use a linear actuator instead of a cylinder JIS provided because we can set the distance and the speed of the reciprocating motion and count repeated number easily and precisely. We also changed a cylinder as a driving source in JIS to a sheave.

The ultimate goal of this research is developing a design methodology with a synthetic fiber rope. As one step of the research, in this paper, we clarify the influence of repetitive bending on tensile strength.
of 300 mm diameter.

We carried out the experiments with three types of ropes of 2.0 mm diameter, (1) Dyneema (ultra high molecular weight polyethylene fiber rope, DB-60, Hayami Industry Co., Ltd.), (2) Zylon-Dyneema (Zylon, PBO fiber rope, covered with Dyneema, DY-20ZL, Hayami Industry Co., Ltd.) and (3) Stainless (stainless steel wire rope, $7 \times 19$, Asahi Intecc Co., Ltd). Table 1 shows experiment conditions. This conditions are calculated by linear interpolation with conditions of 1.59 mm and 2.38 mm rope diameter provided by JIS. In this research we performed 70,000 repetitive motion and it requires around 9 hours and 43 minutes per one experiment.

4 Experiment Results

We measure tensile strength of the ropes with tensile testing device (AG-I, Shimadzu co., 100 kN maximum load) and calculate strength efficiency by the following equation:

\[
\text{Strength efficiency} = \frac{\text{Tensile strength after repetitive bending}}{\text{Tensile strength before repetitive bending}} \times 100 \%
\]

Now, the tensile strength before repetitive bending of (1), (2) and (3) ropes are 2.14 kN, 2.99 kN and 3.50 kN respectively. Fig. 3 shows strength efficiency of three types of ropes with four samples respectively. Since (1) and (3) show over 95 % strength efficiency, they don’t get strength reduction from repetitive bending. On the other hand, the strength efficiency of (2) is around 30 %. This is because the friction occurs in the rubbing of fibers when a rope get bended and stretched, and Zylon which is weak at friction gets degradation.

5 Conclusion

We paid attention to the strength reduction by repetitive bending of a synthetic fiber rope and measured durability with the experiment JIS provided. We disclosed that Dyneema which is strong at friction didn’t cause strength reduction, however, Zylon which is weak at friction causes large strength reduction by repetitive bending experiment. In our future works, we will perform the same experiment with the other synthetic fiber ropes, moreover, get generic data by changing the experiment conditions to the one close to the real tendon-driven mechanism.

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References


