ADVANCEMENT ON SELF-ASCENDING PANTADOME SYSTEM USING PLASTIC BOARD MODEL WITH ELECTRIC MOTOR

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Introduction

The principle of the Pantadome system, which was conceived by one of the authors and has been applied to many long-span roof structures, is to make a dome structure foldable during erection by temporarily removing several elements [1], [2]. The "self-ascending" Pantadome system [2], [3], an innovative variation of the original Pantadome system, was first applied to the roof structure of a bullring in Xàtiva, Spain [2], [3]. The fundamental mechanisms of the Pantadome system and the self-ascending Pantadome system are shown in Figure 1. In the Pantadome system, hinge points A and D are pushed up by support columns, often hydraulic jacks, as shown in Figure 1(a). In the self-ascending Pantadome system, a roof is lifted by shortening the distance between A (the lower vertex of a girder) and B (the lower chord of inner ring) as shown in Figure 1(b).

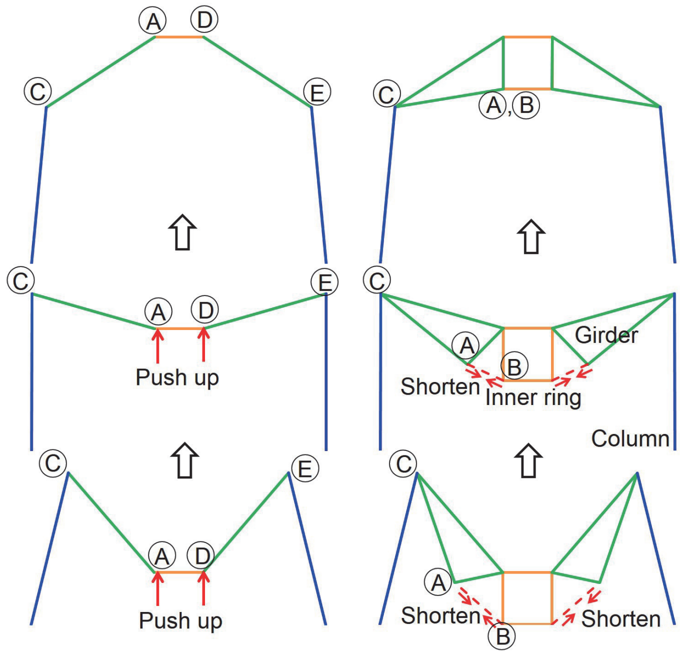
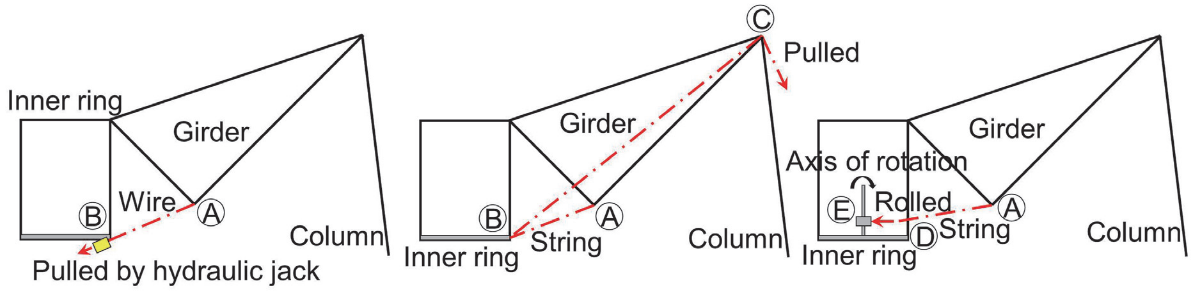


Fig. 1: Mechanism of the Pantadome system (in plane)

In the self-ascending Pantadome system, several methods of shortening the distance between A and B in Figure 1(b) may be used for various situations as shown in Figure 2. The first method involves pulling a wire installed between A and B using hydraulic jack as shown in Figure 2(a). This method was adopted for the reconstruction of the bullring in Xàtiva, Spain [2], [3]. The second method involves pulling a string, which is fixed at A and passes through a pulley at B and C (the head of a column), using human power as shown in Figure 2(b). The third method is to wind a string, which is fixed at A and passes through a pulley at D, using an electric motor located at E (axis of rotation) as shown in Figure 2(c). When the rotational direction of the electric motor is reversed with a switch, the wound strings begin to unwind, thereby increasing the distance between A and D and lowering the roof. Therefore, using an electric motor and reversing switch enables the roof to be lifted or lowered automatically, changing the configuration of the whole structure.



(a) Pull wire by hydraulic jack (b) Pull string by human power (c) Roll string by electric motor

Fig. 2: Methods for self-ascending of a Pantadome system

A round ger and an oval ger utilizing the Pantadome system, which corresponds to Figure 1(a), were designed and fabricated in 2013 and 2014, respectively, as shown in Figure 3(a) and Figure 3(b) [4]. When the roofs were lifted, support columns were used as shown in Figure 3(a). A ger utilizing the self-ascending Pantadome system, corresponding to Figure 1(b) and Figure 2(b), was designed and fabricated in 2015 as shown in Figure 3(b) [4], [5]. Here, students outside the ger pulled strings through a pulley mechanism to lift the roof. In this study, further development of the self-ascending Pantadome system was attempted using a plastic board model with an electric motor, corresponding to the method shown in Figure 1(b) and Figure 2(c), to lift and lower the roof automatically.

(a) Pantadome ger in 2013 (b) Pantadome ger in 2014 (c) Self-ascending ger in 2015

Fig. 3: Ger utilizing Pantadome, self-ascending Pantadome system

Simulation of Self-ascending Pantadome System

The deployment process of the self-ascending Pantadome system was simulated using Microsoft Excel as shown in Figure 4. Here, the ceiling height between the ground level and the level of the lower chord of inner ring, *H*, is shown. The calculation assumed constant lengths of the girder, column, and inner ring, and the coordinates of each node were computed as a function of *H*. This model configuration was applied to the plastic board with an electric motor model designed and fabricated in this study. The column height was set to 1.8 m and the distance between the bottoms of paired columns was set to 3.6 m. When *H* was 2.0 m, the model was approximately fully deployed. The distance between A (the lower vertex of a girder) and B (the lower chord of the inner ring) was 0.761 m initially (H = 0 m) and reduced to a value of zero at the fully deployed stage (H = 2.0 m).

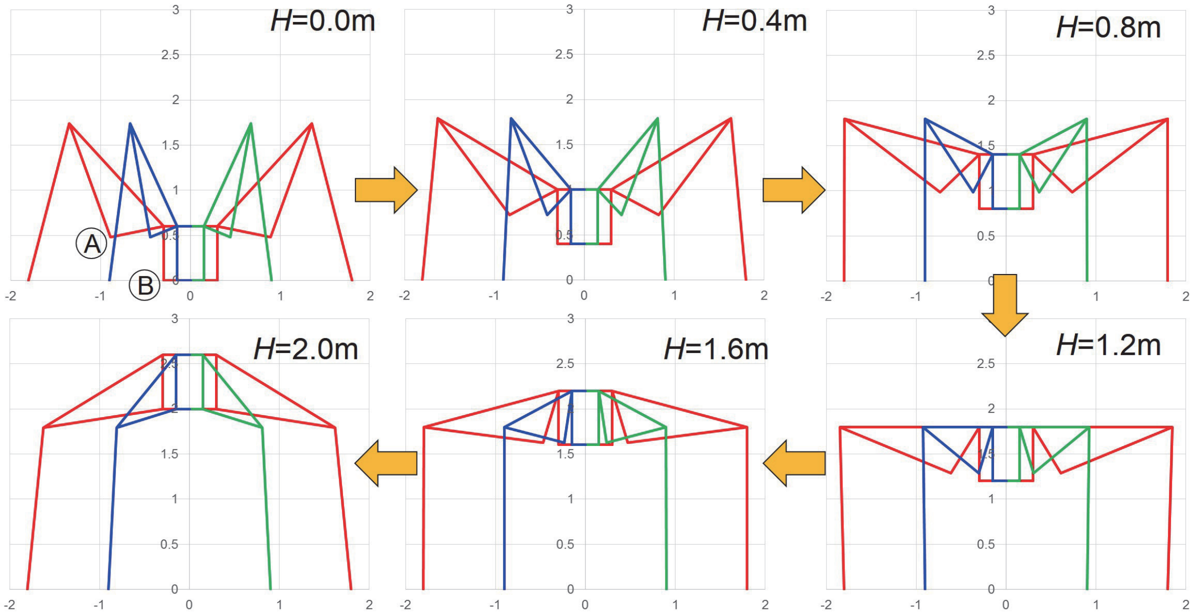


Fig. 4: Simulation for deployment process of self-ascending Pantadome system

Plastic Board Model with Electric Motor

Fig. 5: Plastic board model

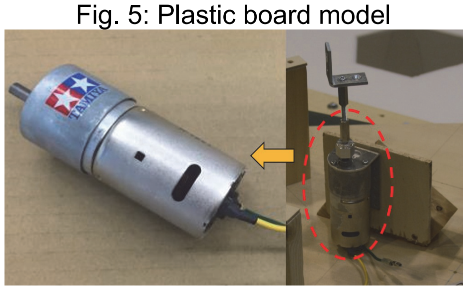
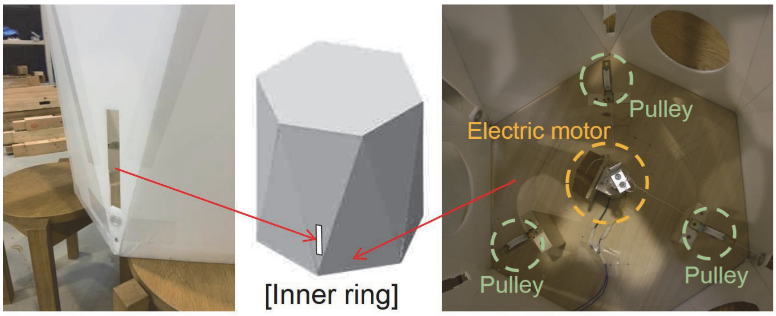


Fig. 6: Electric motor

The plastic board model used in the self-ascending Pantadome system is shown in Figure 5. This shows the final model, in which many circle holes were cut on the surface of the girders and inner ring to reduce the self-weight without reducing the stiffness and strength substantially. The upper and lower surfaces of the inner ring were hexagons having edge lengths of 0.3 m and 0.26 m for the upper and lower surfaces, respectively. The height of the inner ring is 0.6 m. The height of the trapezoidal upper surface of the girder was 1.55 m and the height of the triangular lower surface of the girder was 1.34 m. The electric motor shown in Figure 6, often used for miniature cars or robots, was utilized to wind up the strings installed between A, D, and E in Figure 2(c). Since the location at which the string passes through the surface of the inner ring changes, a slit was made on the surface of the inner ring as shown in Figure 7. The arrangement of the electric motor and pulleys at the bottom of inner ring is shown in Figure 8. Here, the pulleys were installed so that the location at which the string was wound about the axis of rotation maintained an almost constant position. The upper chord of inner ring was connected to the upper vertex of a girder by hinges as shown in Figure 9. The deployment process of the plastic board with an electric motor is shown in Figure 10. As the strings were wound by the electric motor, the inner ring ascended automatically. When the direction of rotation was reversed, the strings were loosened, and the inner ring descended. Such a deployment process can change the configuration of the entire structure drastically.



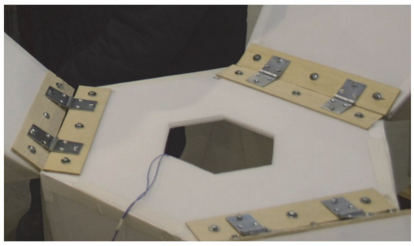


Fig. 7: Slit for string   Fig. 8: Arrangement of bottom of inner ring   Fig. 9: Hinge connections

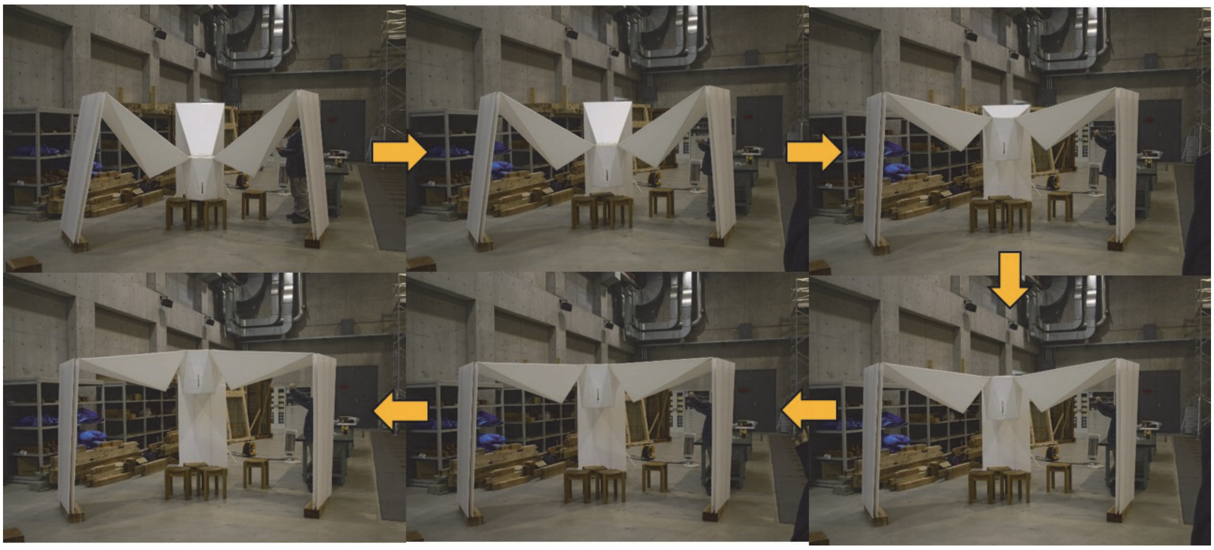


Fig. 10: Deployment process of plastic board with electric motor

Conclusions

The advancement on the self-ascending Pantadome system was attempted using a plastic board model with an electric motor. The electric motor enabled the roof to automatically ascend or descend, changing the configuration of the whole structure drastically.

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