Membrane Deployment de-orbit System by convex tapes

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1. Deorbit Device

For the purpose of re-entering a 3U size(10cm×10cm×30cm) Nano-satellite into the atmosphere, we have developed a deorbit device using a convex tape (metal tapes that have consistent curvature, represented by commercially available, steel measure tapes). The deorbit device contains a folded membrane, which is deployed by the convex tape. The deorbit device and deployment image of it are shown in Figure1 and Figure2 respectively. The various elements of the deorbit device is shown in Table1.

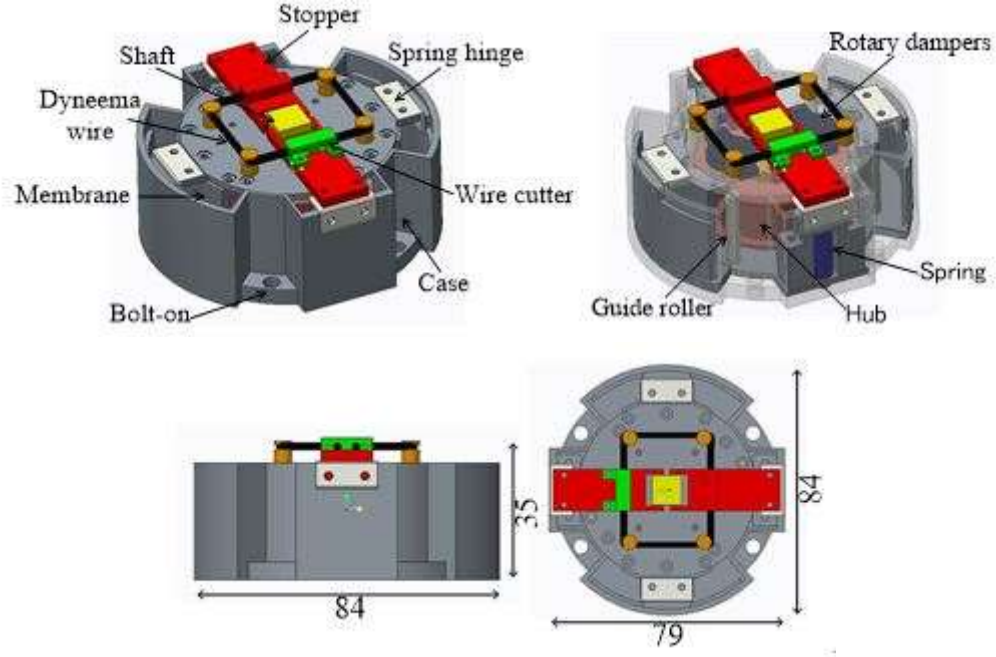

Figure 1　deorbit device

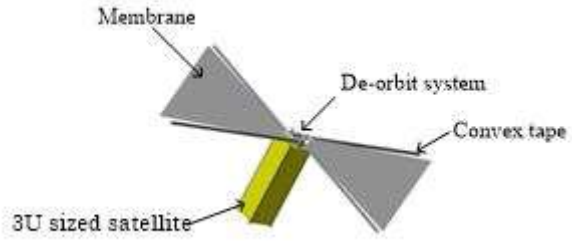

Figure 2　deployment image of deorbit device

Table 1 various elements of the deorbit device

Width	84[mm]	Weight	0.177[kg]
depth	79[mm]	Membrane area	0.3[m^2]
height	35[mm]	Effective sectional area	0.0137[m^2]

This deployment method uses the elastic force of the convex tape, wrapped around a cylindrical hub[1]. By setting the hub in a 1 axial free state with guide rollers around it, the convex tapes can be extended towards the desired directions.

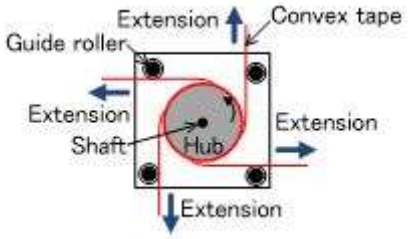

Figure 3　deployment principle

Also, the hold and release of the deorbit device is done by using stoppers, a dyneema wire, and a nichrome wire. The rotation of the central axis is prevented by stoppers, which are again, retained by the dyneema wire. The deployment starts by heating the nichrome wire inside the wire cutter, which then cuts the dyneema wire. After the stoppers are lifted by a spring hinge, the membrane surface and the convex tapes are pushed out by the force of a spring to start their deployment. Furthermore, by making the membrane surface and the central axis retention release device all-in-one, the device's maintainability is raised, and can be easily used. The attachment to the satellites are done by bolts. By using bolts, large scale processing is unnecessary, and will simplify the attachment. There are 4 places where the bolts will be used, which are shown if Figure1.

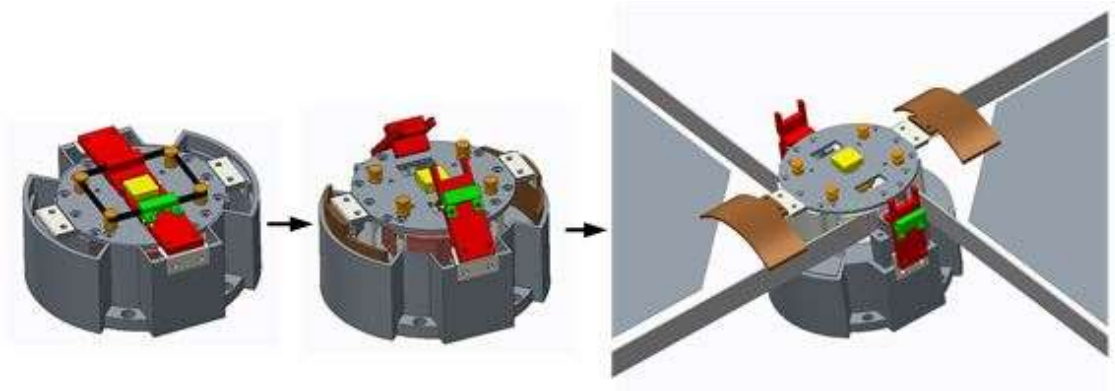

Figure 4　appearance of deployment

2. Effectiveness

The deorbit device using convex tape consists of few equipment which leads to its lightweight, and against the ensured surface area after deployment, it is space-saving and is compact. Also, because expensive parts are not used, it can be made inexpensively, and because it is rigid to some extent, the membrane shape can be maintained against some disturbance. Due to these advantages, the deorbit device using convex tapes are suited for nano-satelites. We have calculated the orbit of a satellite with the deorbit device attached, after deployment of the membrane using orbital elements specified in the orbit calculation software DAS[2], shown in Table2. From the calculation result, the re-entry into the atmosphere occurs 5.1 years after the membrane deployment.

Table 2 orbital elements

Semi-major axis	6930[km]
Orbital inclination	97.6[deg]
eccentricity	0.002[-]
R.A.A.N	30[deg]
Angument of perigee	210[deg]
Mean Anomaly	190[deg]

3. Cost

The parts that are mainly used, and its price are shown in Table3.

Table 3 price of parts(exchange rate：1USD＝113.09JPY)

Parts	Price($)
Convex tape	0.88
Spring hinge	5.08
Gear	3.54
Rotary damper	2.65
Roller	3.54
Bearing	2.83
Spacer	1.77
Rotation axis	1.77
Aluminum plate	44.2
Processing cost	630
Margin	105.51
	Total 800

As shown in Table3, there are no expensive parts in the deorbit device. Also, the processing fee is not included, but it is thought to be suppressed under 800$, which is reasonable for university satellites.

4. Technical feasibility - Mechanical and electrical design

The deorbit device using convex tape (Nano-sail-D2[3]) has already accomplished many ground level experiments on membrane deployment, and is becoming practical. Also, deployment by burning down dyneema wire by heating a nichrome wire has already undergone space demonstration. This deployment system used in many Cube Sat is used SEEDS and SPROUT in Nihon University. The designed deorbit device is planned to have a battery and a micro-computer onboard, and will allow the deployment of membrane surface upon its own judgement, when the satellite malfunctions.

5. Reliability

We have summed up troubles that may happen during the deployment of the deorbit device along with its cause, and by evaluating them based on experimental results, we have raised the reliability of membrane deployment. Among them, the detachment of the convex tape from the hub during its extension, has large effect on the deployment behavior[4]. Separation of the boom from the hub during deployment motion (detachment) has been often observed. If the detachment occurs, a smooth deployment

becomes difficult because of the irregular motion of bent booms inside the guides, and the reliability of the deployment will not be obtained. So, revealing detachment conditions is important for developing deorbit devices.

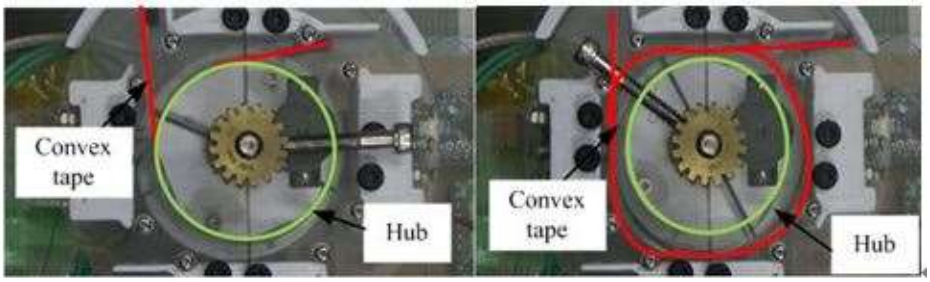

Figure 8　separation phenomenon(left：no separation,　right：separation)

Excessive rotation of the hub, caused by the hub rotating faster against the speed of boom extension, is thought to be the cause of detachment. For that reason, we have suppressed the angular velocity of the hub, using a rotary damper. By using a rotary damper, the extension speed of the convex tape converges. We have confirmed that the separation phenomenon does not occur by experiment, and the deorbit device we have designed, has accomplished deployment under microgravity environment without detachment.

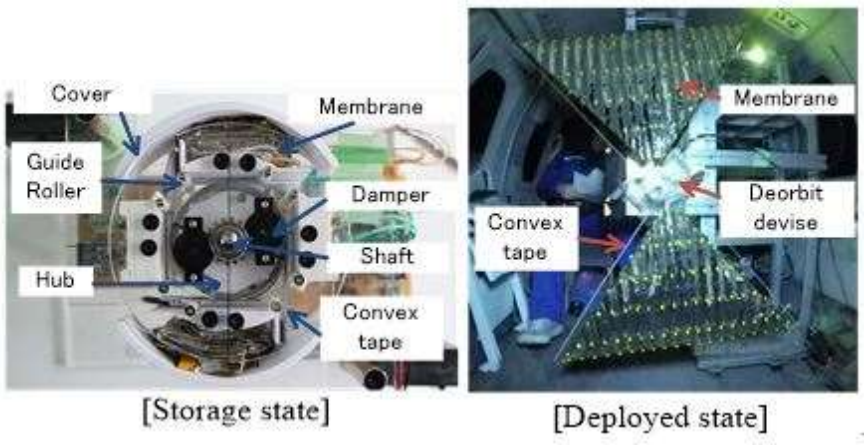

Figure 9　deployment experiment under microgravity environment

References

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[4] Shota INOUE, Akihiro TAMURA, Noboru TADA and Yasuyuki MIYAZAKI : Dynamic Characteristics of Self-Deployable Structure Consisting of Tape Springs,30th