Origami Structure: Kinematics and Applications

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Contents

• Origami: Art, Mathematics, Engineering
• Kinematics of rigid origami
• Engineering applications of origami structures
• Future development
Origami
Origami: Art

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Origami: Mathematics
Origami: Engineering


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Rigid Origami

Rigid origami pattern: $\alpha + \beta + \gamma + \delta = 2\pi$
Rigid Origami Patterns

The deformable polygons in discrete differential geometry
Rigid Origami: Planar structures
Rigid Origami: Tubular structures
Square-twist pattern

Conditions for square-twist pattern:

\[
\begin{align*}
\alpha_{12} + \alpha_{34} &= \pi, \\
\alpha_{23} &= \alpha_{41} = \frac{\pi}{2}.
\end{align*}
\]

\[
\theta'_1 = -\theta_4, \theta'_4 = \theta_1.
\]

four-fold rotational symmetry.
Square-twist pattern

Corresponding mechanism network of square twist pattern

Compatibility condition:

\[
\begin{align*}
( \theta_1^a ) & \rightarrow ( \theta_4^a ) = ( \theta_1^b ) \rightarrow ( \theta_4^b ) = ( \theta_1^c ) \rightarrow ( \theta_4^c ) = ( \theta_1^d ) \rightarrow ( \theta_4^d ) \\
( \theta_1^a ) &= ( \theta_4^d )
\end{align*}
\]
Square-twist Pattern

\[0 \leq \theta_M \leq \pi, -\pi \leq \theta_V \leq 0.\]

Maekawa-Justin theorem: \( M - V = \pm 2 \)

Big-Little-Big Angle theorem

Different arrangement of Mountain-Valley fold lines

Type 1  
Type 2  
Type 3  
Type 4
Square-t twist Pattern

Type 1  Type 2  Type 3  Type 4
Square-twist Pattern: Type 1
Square -twist Pattern: Type 3
Square-twist Tessellation Crease Pattern
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Metamaterial with negative Poisson’s ratio
Medical devices based on origami structures

Medical devices based on origami structures

NOTES: Natural Orifice Translumenal Endoscopic Surgery
Origami structures for absorbing energy and carrying load

- Conventional square tube
- Origami crash box

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Origami structures for absorbing energy and carrying load
Large-scale deployable structures
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Future development

Rigid origami:
- **Tessellation** is a powerful tool in synthesis;
- **Kinematics** of the linkages is the fundamental;
- To find more **new** rigid origami patterns, especially with **large deployable ratio**.

Engineering applications:
- **Compliant** structures are the bridge;
- To **widen** the application areas;
- To **enhance** the **advantages** of origami structures.

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