The Best Aircraft

Group 7

PURPOSE

To find **the best shape of a model airplane** which can fly a long distance.

EXPERIMENT 1

Keywords

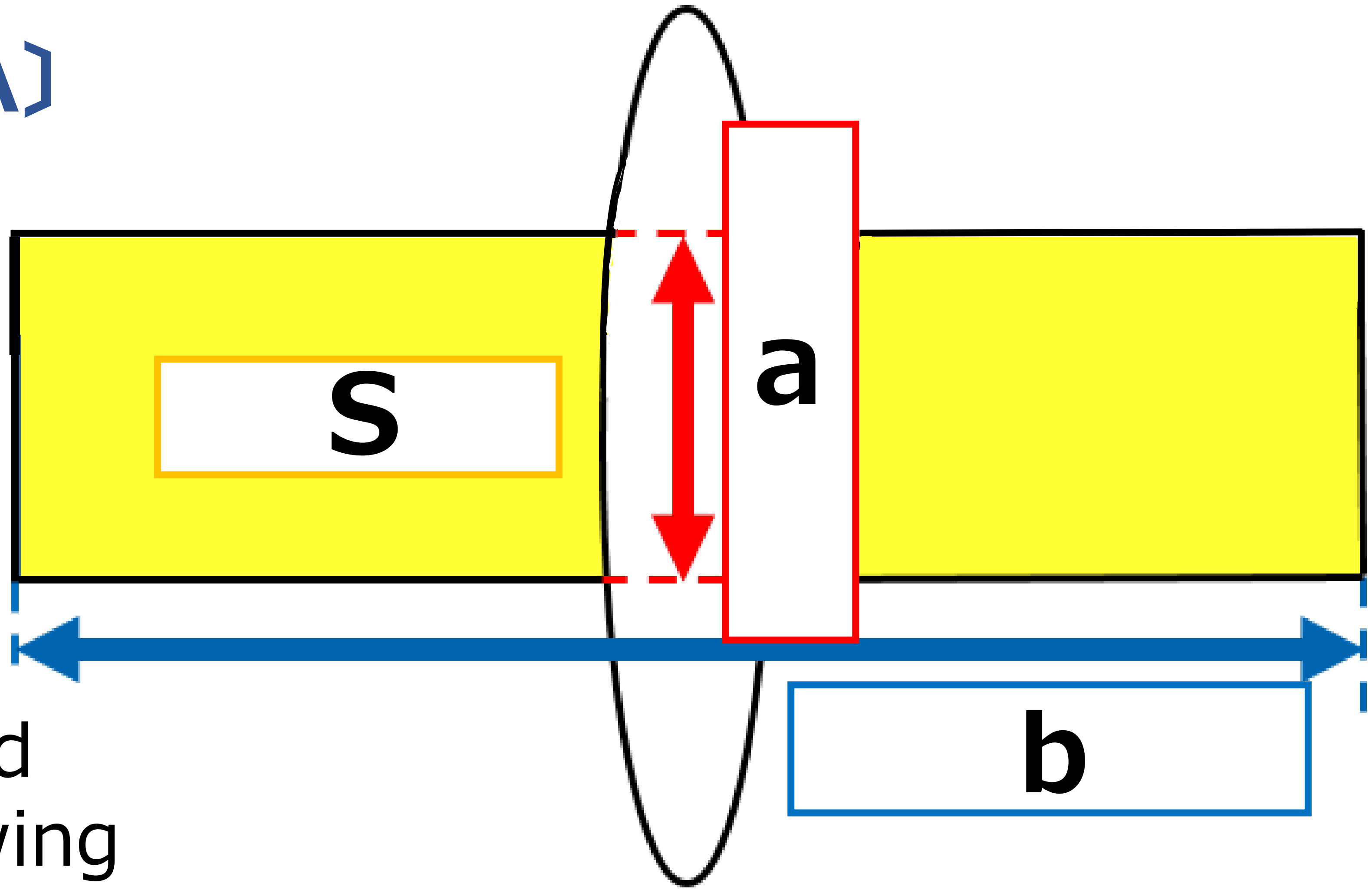
・Aspect ratio〔A〕

$$A=\frac{b}{a} \quad S=ab$$

$$A=\frac{b^2}{S}$$

⇓

Degree of length and narrowness of the wing



EXPERIMENT 1

Keywords

- **Lift〔L〕** The force which moves a body up.
- **Drag〔D〕** The force which prevents a body from moving.

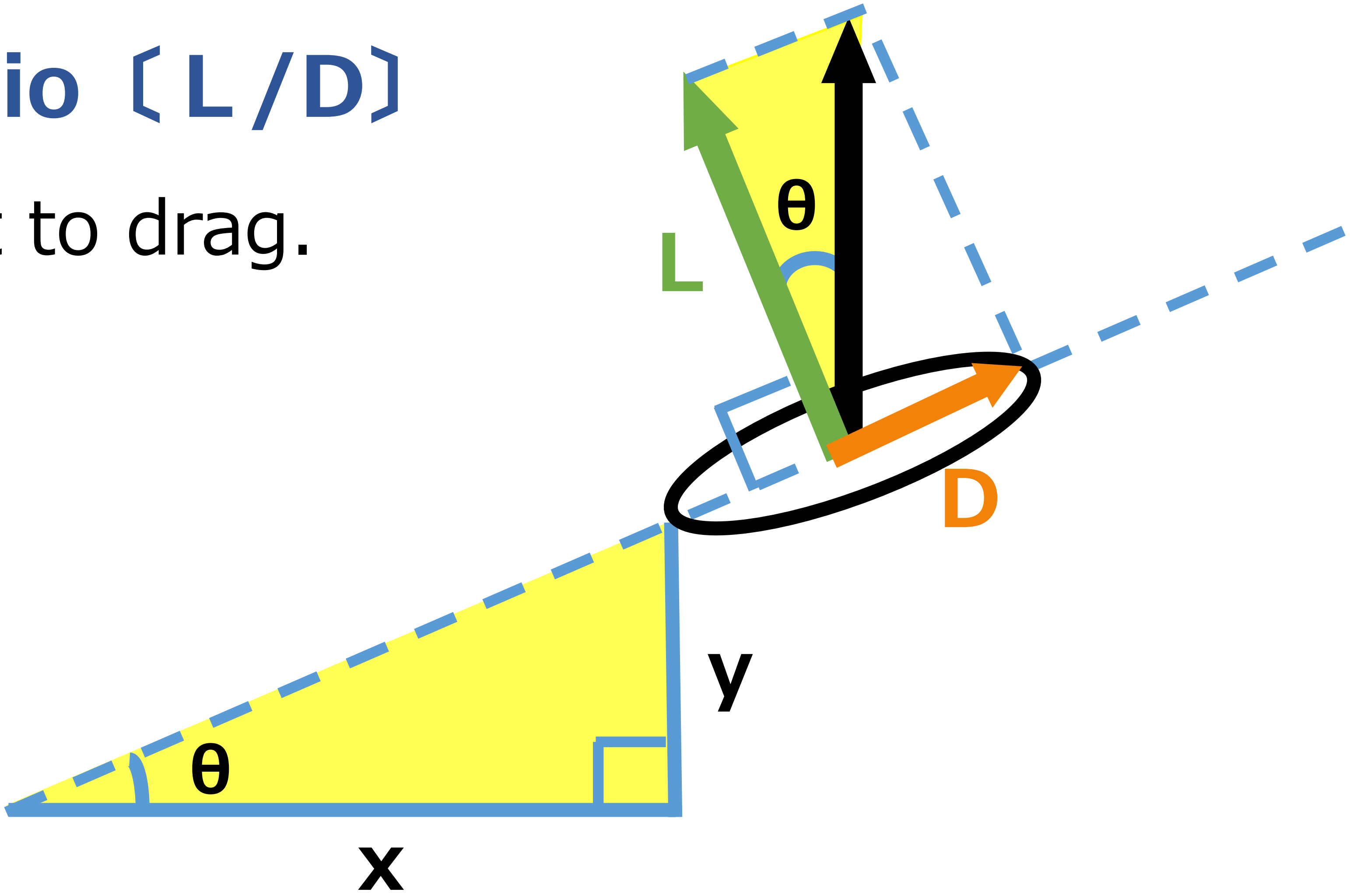
EXPERIMENT 1

Keywords

・**Lift-drag ratio〔L/D〕**

The ratio to lift to drag.

$$\frac{x}{y} = \frac{L}{D}$$

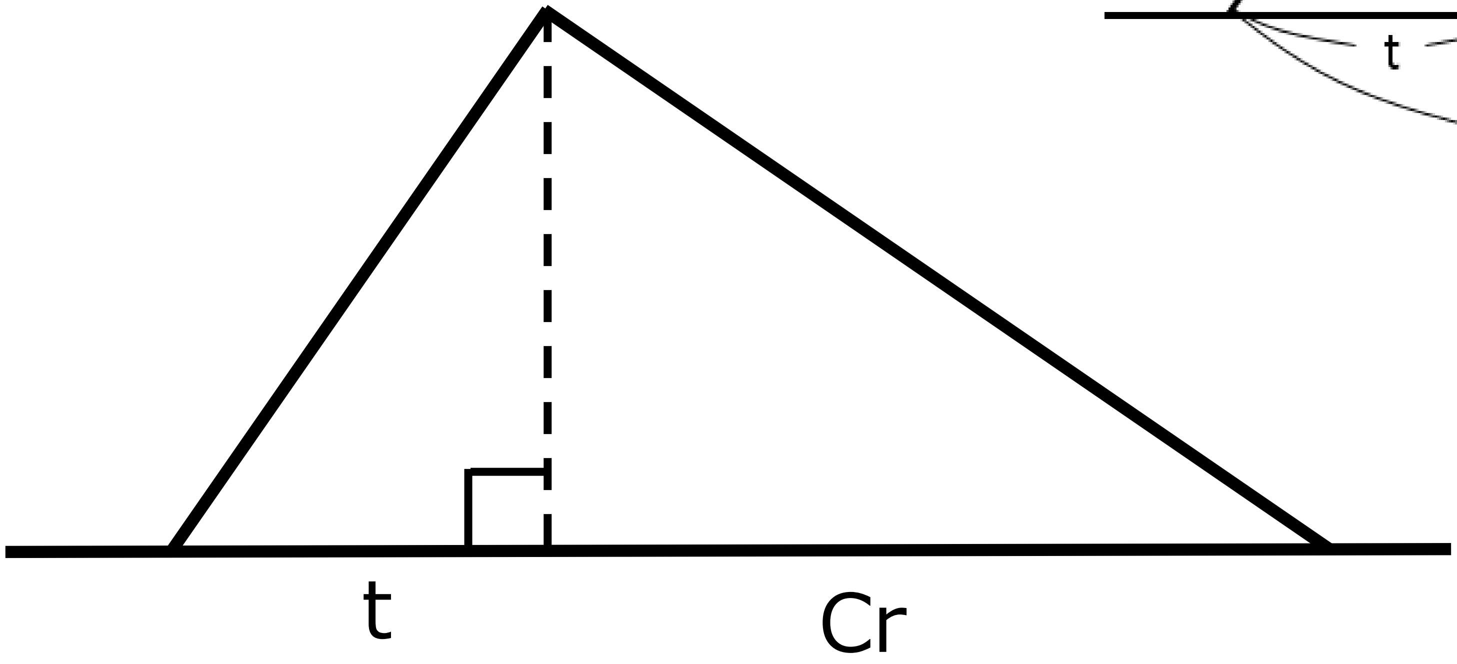


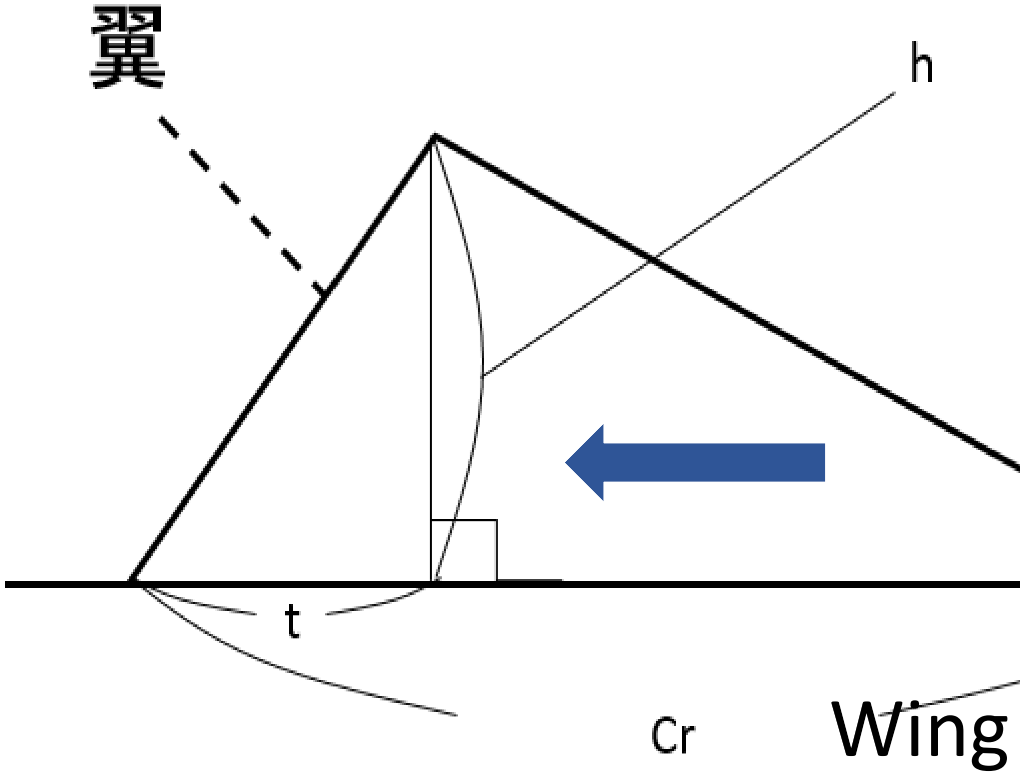
EXPERIMENT 1

Keywords

- **Camber**

  The puff of the wing.





EXPERIMENT 1

Hypothesis

$$L = C_L \times \frac{1}{2}\rho V^2 \times S$$

$$D = \frac{L^2}{\frac{1}{2}\rho V^2 \times \pi \times b^2 \times e} + C_{D0} \times \frac{1}{2}\rho V^2 \times S$$

$$\frac{L}{D} = \frac{C_L \times \frac{1}{2}\rho V^2 \times S}{\frac{L^2}{\frac{1}{2}\rho V^2 \times \pi \times b^2 \times e} + C_{D0} \times \frac{1}{2}\rho V^2 \times S} = \frac{C_L}{\frac{C_L^2}{\pi e A} + C_{D0}}$$

EXPERIMENT 1

Hypothesis

By relationship between
arithmetical mean and geometrical mean

$$\frac{L}{D} = \frac{1}{\frac{C_{Do}}{C_L} + \frac{C_L}{\pi e A}} \leqq \frac{1}{2\sqrt{\frac{C_{DO}}{C_L} \times \frac{C_L}{\pi e A}}} = \frac{\sqrt{\pi e A}}{2\sqrt{C_{DO}}}$$

EXPERIMENT 1

Hypothesis

▼

The bigger aspect ratio is,
the longer the model airplane flies.

EXPERIMENT 1

Method

1. Make three types of model airplanes.
   (Aspect ratio…3.23/6.11/8.91)

2. Put catapult on a chair horizontally.
   (Height…38cm)

3. Release each airplane 5 times.

EXPERIMENT 1

Result

Aspect ratio	Lift coefficient	Drag coefficient	Flight distance (cm)
3.23	0.0590	0.0046	486
6.11	0.0607	0.0043	542
8.91	We have omitted these results due to unstable flight.		440
8.91 (+piano wire)	0.2501	0.0149	640

EXPERIMENT 1

Study

1. The biggest wings without piano wire didn't fly well because they bent.

⇒ **The strength of the wings decreased very much because the wingspan was too long.**

2. **The flight distance increases when we make the aspect ratio larger.**

EXPERIMENT 2

Hypothesis

When the wings bend ...

⇒ **Elastic buckling** is happening.

EXPERIMENT 2

Hypothesis

Elastic buckling

A phenomenon in which an object changes its shape when under pressure.

EXPERIMENT 2

Hypothesis

P_K Buckling load
n Terminal coefficient
E Young's modulus
π Circular constant
I Geometrical moment of inertia
b Wingspan

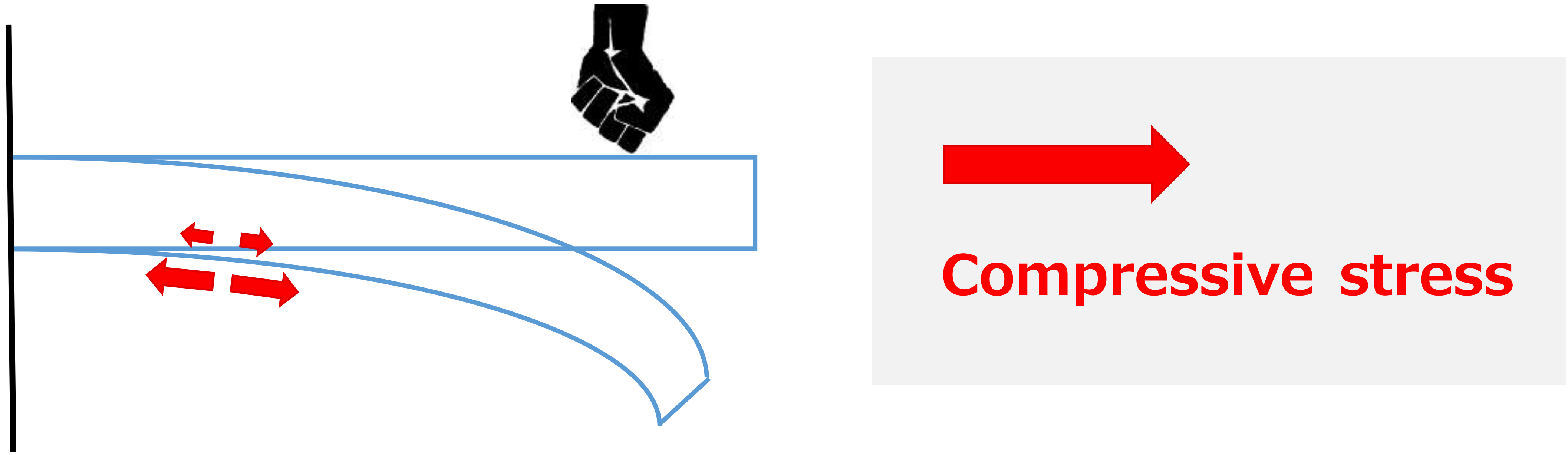
$$P_k = \frac{nEI\pi^2}{l^2}$$

EXPERIMENT 2

Hypothesis

Compressive stress

When an object bends, this force arises from inside the object to maintain balance.



EXPERIMENT 2

Hypothesis

δ Compressive stress

M bending moment

y_{MAX} Distance from neutral axis to the end of the compression side

I Geometrical moment of Inertia

$$\delta_{MAX} = \frac{M \times y_{max}}{I}$$

EXPERIMENT 2

Hypothesis

Conditions for the wing not buckling.

$$\delta_{MAX} \leqq \frac{P_K}{S_S}$$

⇒ Max compressive stress is less than the buckling stress.

EXPERIMENT 2

Method

1. Fix a wing base to 2 stands horizontally.
2. Connect the wing to a spring balance and gradually increase the load.
3. Measure the force at the moment that the wing buckles.

EXPERIMENT 2

Result

	Shape of section(m)			Theoretical value (N・m)	Measured value (N・m)
1	t=0.018	h=0.005	Cr=0.078	0.0018	0.011
2	0.017	0.008	0.076	0.0075	0.016
3	0.016	0.010	0.076	0.0150	0.026
4	0.029	0.008	0.078	0.0075	0.009
5	0.028	0.011	0.077	0.0210	0.022
6	0.025	0.016	0.072	0.0630	0.034
7	0.040	0.010	0.079	0.0150	0.019
8	0.040	0.006	0.080	0.0031	0.0066
9	0.038	0.018	0.074	0.0900	0.031

EXPERIMENT 2

Study

1. The bigger the camber is,
the less wings performs in the buckling test.

2. The bigger the camber is,
the bigger the parasite drag is.

3. Experiment value is smaller
than theoretical value for large cambers.

CONCLUSION

Max aspect ratio

$$A_{MAX} = 2\left\{\frac{\pi^2 E I^2}{S_S m g y_{max}}\right\}^{\frac{1}{3}}$$

CONCLUSION

L/D max and Aspect ratio

Wing type	Aspect ratio	L/D max
Styrene paper	7.4	8.6
Styrene paper (+piano wire)	7.4	8.9
Copper (Young's modulus×700)	105	8.3

CHALLENGES FOR THE FUTURE

1. Consider lift from tail wing.
2. Consider parasite drag coefficient of other parts.

SPECIAL THANKS

Adviser

Mr. Koike, a professor
at Osaka Institute of Technology.

Cooperation in calculation

・Classmate Mr. Kotobuki
・Wolfram Alpha
・Smartphone application
Electronic calculatorEQ7

REFERENCES

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2. *Basic knowledge of the machine design engineer* (2016,RE Co,.Ltd)

3. Kentiku Kouzou,*"the structural mechanics" that a building student learns* (2012,Kentiku kouzou)

4. *The basics of permissible stress degree* (Kindai University, Department of architecture)

5. JIKO, *Information site for CAE engineers*(2016,JIKO)

EXPERIMENT 1

Keywords

L Lift — D Drag

V Speed — ρ Density

S Wing area — b Wingspan

C_L Lift coefficient

C_D Drag coefficient

A Aspect ratio

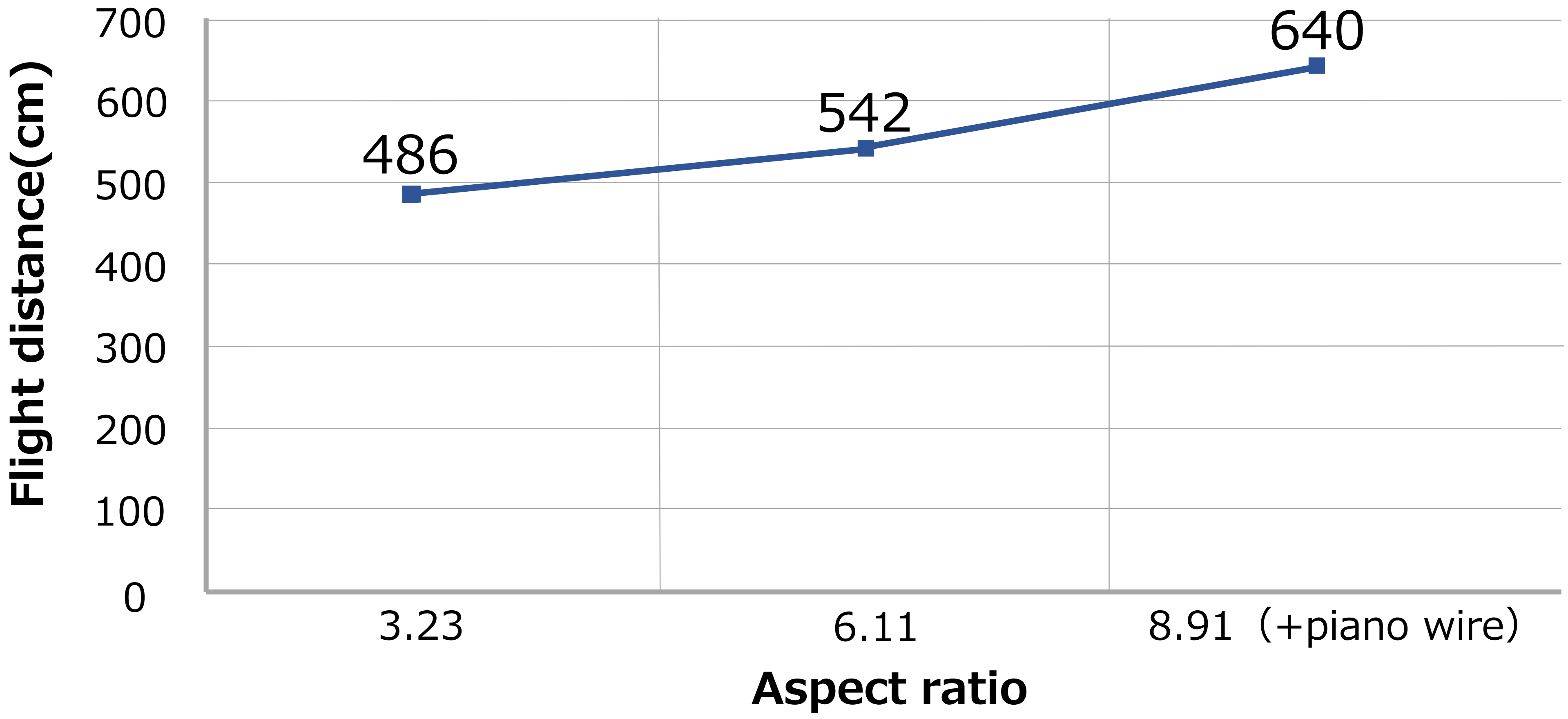
e Span efficiency coefficient

π Circular constant

EXPERIMENT 1

Study

Relations of aspect ratio and the flight distance



EXPERIMENT 2

Complements

The distance from a threshold to a point of action of the power

M	Bending moment	**x**	基準点から力の作用点までの距離	**F**	Force

$$\mathbf{M} = \mathbf{Fx}$$

The power which turns an object

EXPERIMENT 2

Complements

The distance from a threshold to a point of action of the power

曲げモーメント

M Bending moment　　**x** 基準点から力の作用点までの距離　　**F** 力の大きさ

Force

$$M = Fx$$

曲げモーメントあたらしい

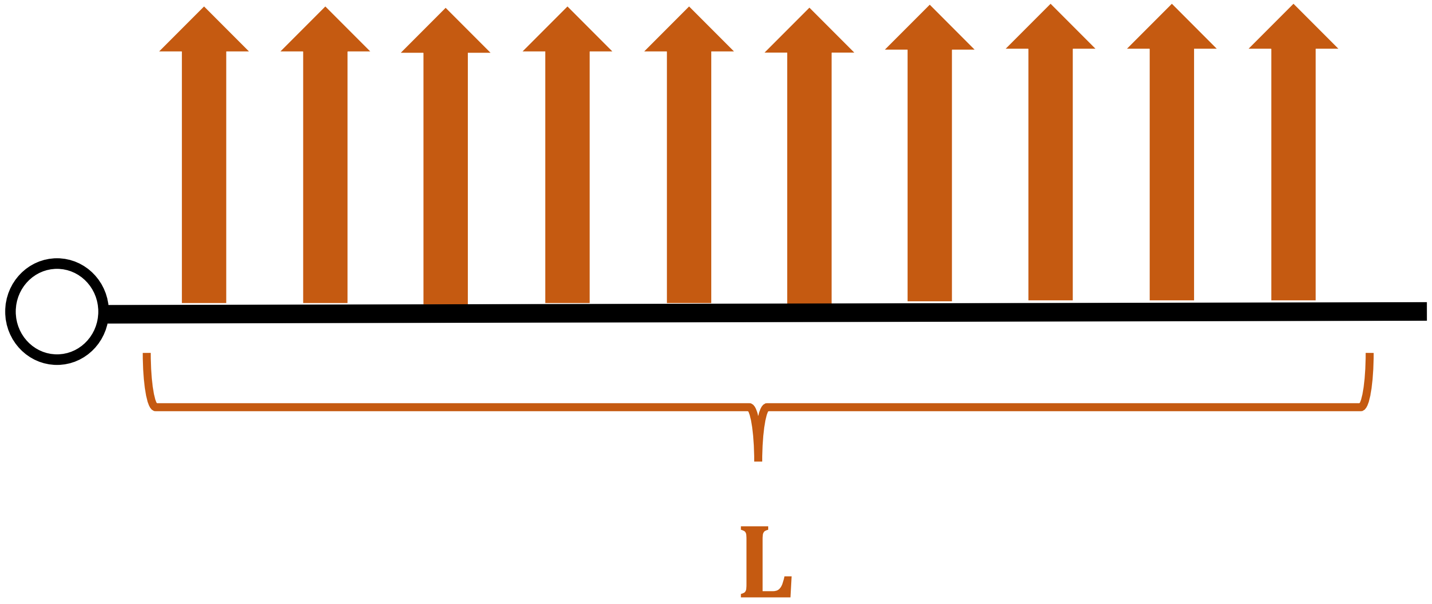
Bending moment

物体を回転させる力

The power which turns an object

EXPERIMENT 2

Complements

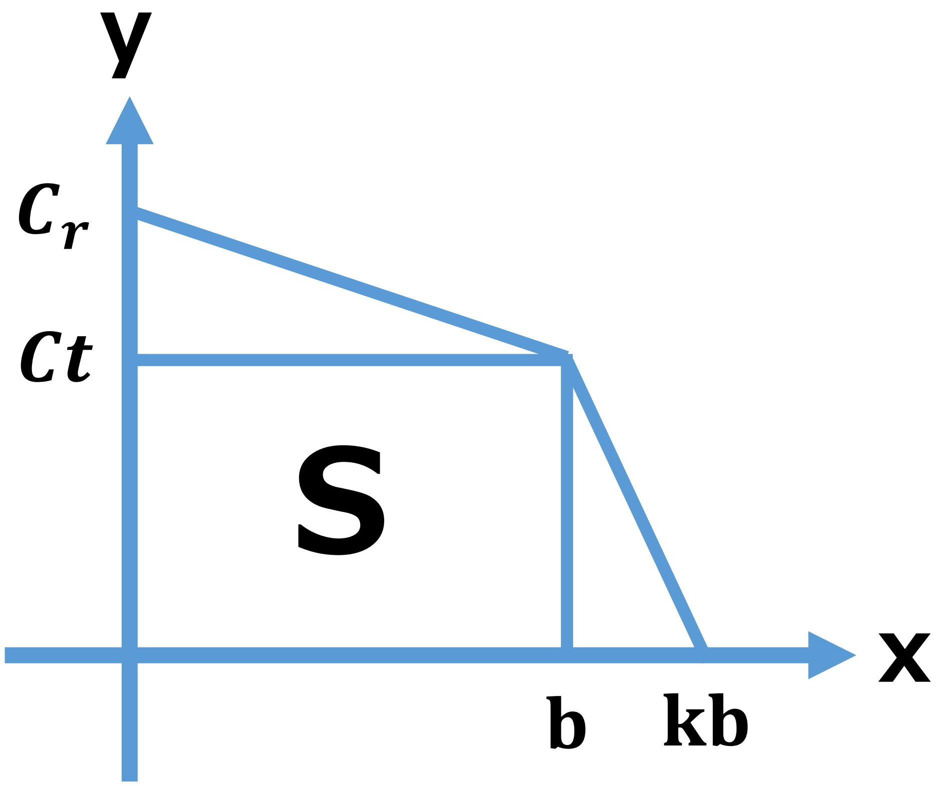


There are many point of applications on wing.

⇒ Sum up moment per unit area from the root of the wing to the top

EXPERIMENT 2

Complements



$$M = \int_0^b x \times \frac{mg\cos\beta}{S}\left(\frac{C_t - C_r}{b}x + C_r\right)dx$$

$$+ \int_b^{b+kb} x \times \frac{mg\cos\beta}{S}\left(\frac{-C_t}{kb} + \frac{C_t k + C_t}{k}\right)dx$$

EXPERIMENT 2

Complements

The bending moment which hangs on the wing

- Rectangle wing

$$\boldsymbol{M = \frac{1}{2} L x}$$

- Trapezoid wing

$$\boldsymbol{M = \frac{b m g \cos\beta \left(C_t k^2 + 3 C_t k + 2 C_t + C_r\right)}{3\left(k C_t + C_t + C_r\right)}}$$

EXPERIMENT 2

Complements

Geometrical moment of inertia

Strength decided by the sectional form of the object

EXPERIMENT 2

Complements

Distance from a middle vertical plane

I_2 Geometrical moment of inertia y 中立面からの距離 dA 微小面積 small area

断面二次モーメント

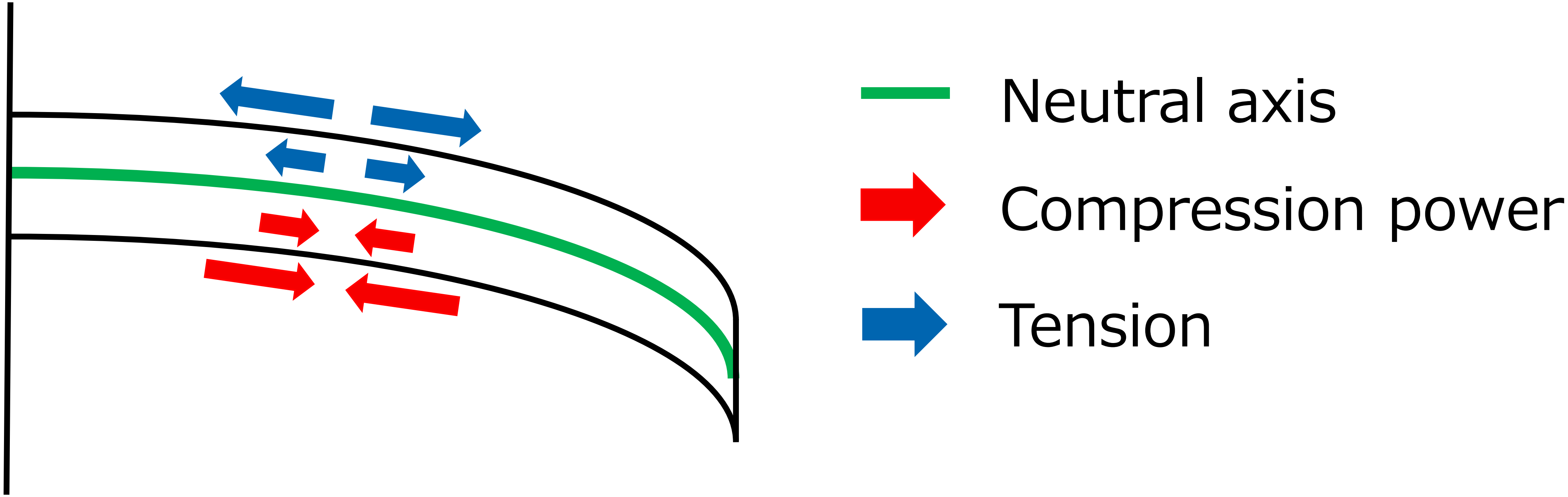
$$I_2 = \int y^2 dA$$

EXPERIMENT 2

Complements

Neutral axis

Neither the compression power nor the tension acts.



EXPERIMENT 2

Complements

statical moment of area
I_1 断面一次モーメント

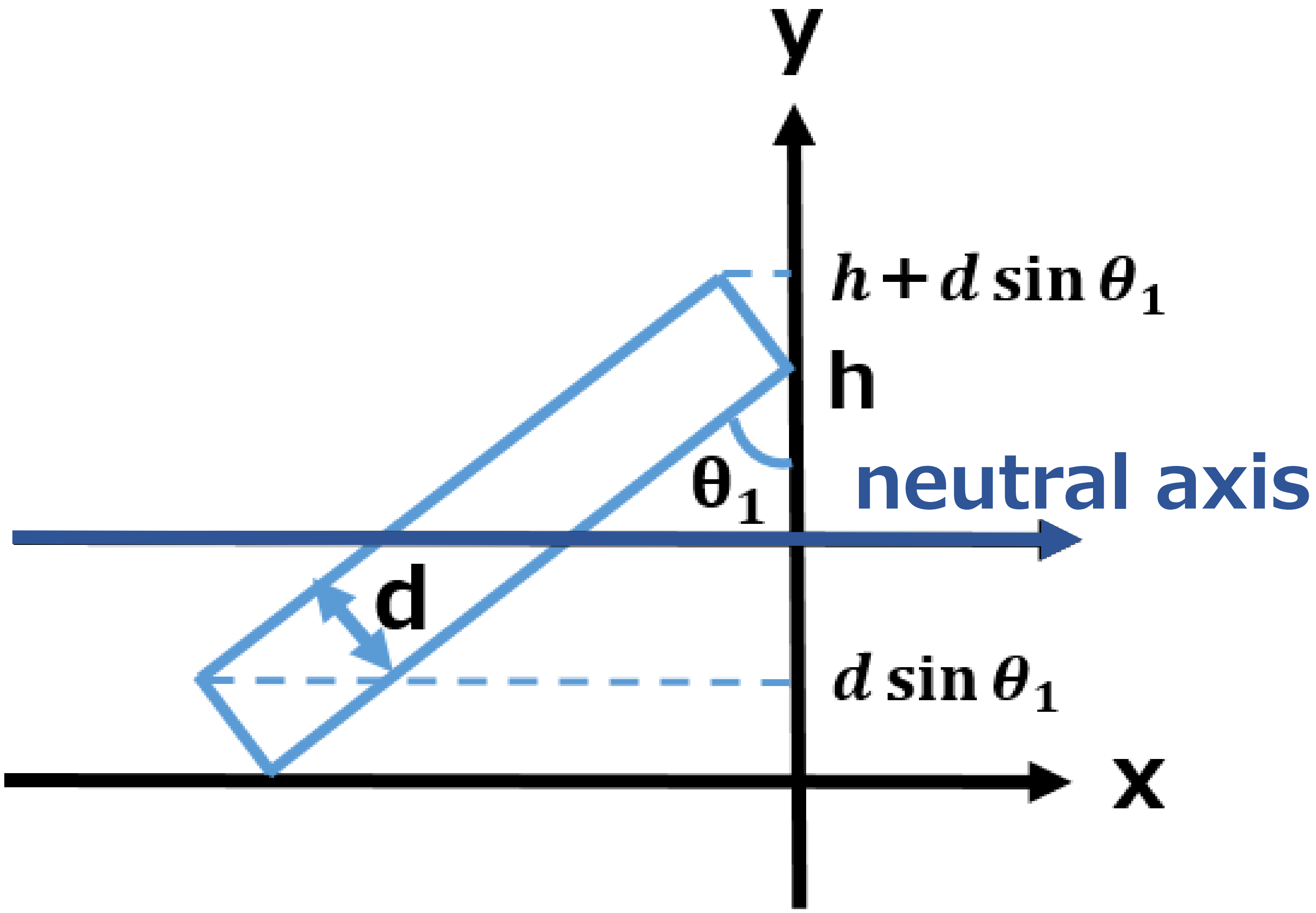
Distance between the bottom line and section of the wing
y 断面の底辺からの距離

dA 微小面積 small area

$$\mathbf{I_1 = \int ydA}$$

EXPERIMENT 2

Complements



Geometrical moment of inertia

Neutral axis is a standard and calculate

EXPERIMENT 2

Complements

The results of geometrical moment inertia of calculations

- Neutral axis

$$y_0 = \sqrt{\frac{2\,\mathrm{d}^2(\sin\theta_1\tan\theta_1+\sin\theta_2\tan\theta_2)+3dh(\tan\theta_1+\tan\theta_2)+3h^2\left(\frac{1}{\cos\theta_1}+\frac{1}{\cos\theta_2}\right)}{6\left(\frac{1}{\cos\theta_1}+\frac{1}{\cos\theta_2}\right)}}$$

EXPERIMENT 2

Complements

The results of geometrical moment inertia of calculations

- Geometrical moment of inertia

$$I_2 = \frac{1}{6} t\,\mathrm{d}\left\{2d^2 \sin\theta_1 + 3d(h - 2y_0) + \frac{2}{\sin\theta_1}\left(h^2 - 3hy_0 + y_0^2\right)\right\}$$
$$+ \frac{1}{6}(a - t)\,\mathrm{d}\left\{2d^2 \sin\theta_2 + 3d(h - 2y_0) + \frac{2}{\sin\theta_2}\left(h^2 - 3hy_0 + y_0^2\right)\right\}$$

EXPERIMENT 2

Complements

The results of geometrical moment inertia of calculations

▼

calculate the moment
when an elastic bucking occurred

The maximum lift-drag ratio