Lift off from the take-off trolley - uplift force without side effects

– Aeromodelling and School Physics –

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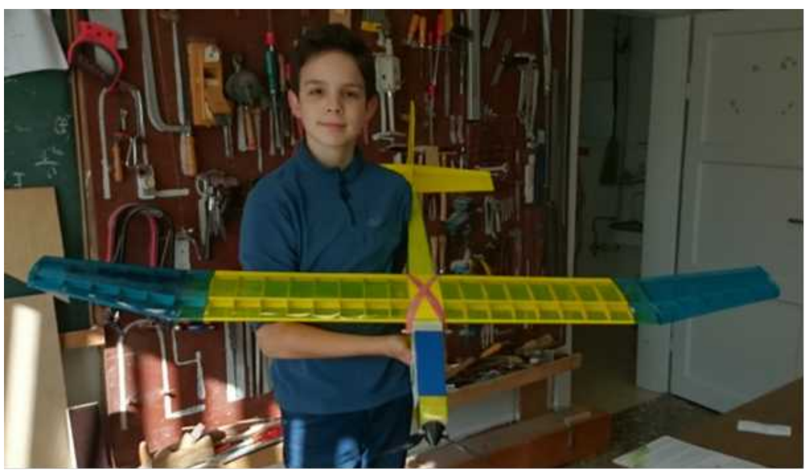
start trolley for a motor glider

- Our club has long-standing relations with a high school: → work group *aeromodelling*
- In this respect, students build a simple motor glider

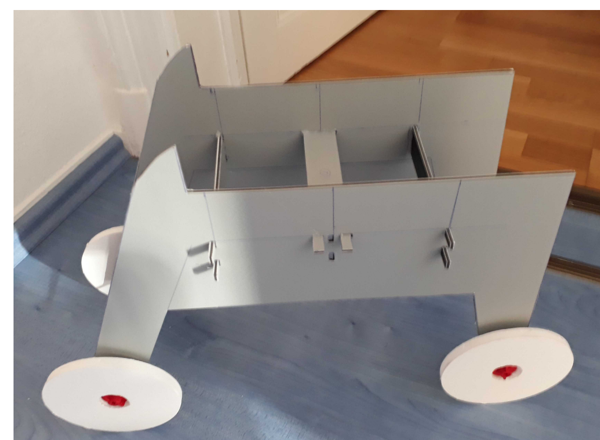


Keno with motor glider *Luxx* – a model kit of the German company Aeronaut

start trolley: which attributes?

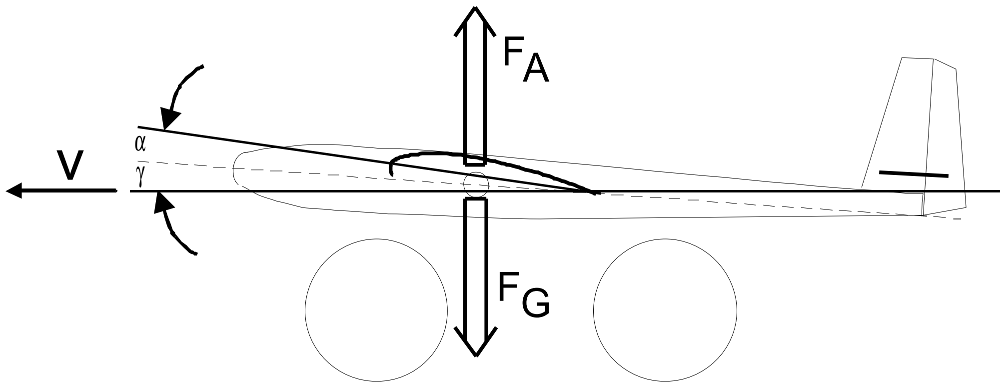
Keno is in the 8th grade. As a work project, he wanted to built a start trolley → required attributes?

- grass runway → large wheels
- low axis friction → ball bearings
- light and robust → reinforcements
- angle of attack → calculate



start trolley: which angle of attack?

For a given speed the model should get airborne. Which value should be the sum of angle $\gamma + \alpha$?



It gets airborne if

$$F_A \geq F_G \text{ , with } \quad F_G = m \cdot g$$

Taking the lift-formula

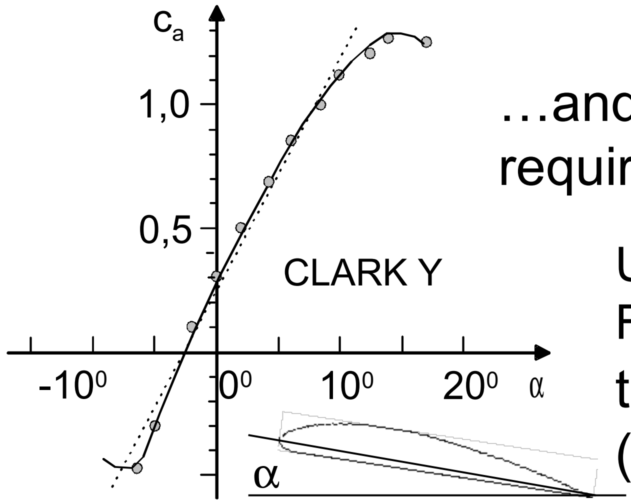
$$F_A = \frac{\rho}{2} \cdot v^2 \cdot A \cdot c_a$$

one can calculate the lift coefficient c_a

$$c_a \geq \frac{2 \cdot F_A}{\rho \cdot v^2 \cdot A}$$

with:
α: angle to fuselage (deg)
γ: angle to trolley (deg)
m: mass (kg)
g: gravitational constant (9.81m/sec^2)
A: airfoil area(m^2)
ρ: density of air (1.25kg/m^3)
v: velocity (m/sec)

start trolley: which angle of attack?



…and from the curve lift coefficient vs angle, the required sum of angles is calculated.

Using the parameters of the model Luxx
$F_A = m*g = 0.47kg*9.81m/sec^2 = 4.58N$, $A = 0.21m^2$,
the sum of angles are given:
(e.g. velocity 6m/sec, 8m/sec,10m/sec)

v = (6 8 10) m/sec;
→ ca = 1.0 0.55 0.36
→ $\gamma + \alpha = 8.2^0$ 3.6^0 1.4^0

→ the <u>practical</u> <u>implementation</u> revealed

$\alpha + \gamma = 7^0$

→ <u>question</u>:
is an accelleration to v = 6 …8 m/sec possible in a gym for testing?

Test with video proof

3 take-offs and 3 videos with position-variation of center of gravity:

-c.g. in front- -c.g. in back- -c.g. middle-

→ test is positive !!

<u>videos showed</u>: the modell gets airborne at the same point always!
→Just as the model gets airborne and started to fly, longitudinal stability is affected by responsible parameters (e.g. *angle difference wing to elevator* and *position of c.g.)*

But: how fast was the model at the moment of take-off?

take-off-time / Video;
t_{ab} = 2.8sec;

take-off-distance / measured:
s_{ab} = 9m

For <u>uniformly</u> <u>accelerated</u> motion:

$$v_{ab} = a \cdot t_{ab}$$

$$s_{ab} = \frac{1}{2} \cdot a \cdot t_{ab}^2$$

Substituting and solving the equations gives

$$\rightarrow \quad v_{ab} = \frac{2 \cdot s_{ab}}{t_{ab}} = 6.43 \frac{m}{\sec}$$

→ c_a = 0.86 und $\gamma+\alpha = 6^0$

- The result confirms the speed range of 6…8m/s estimated before;
- Considering the only approximated airfoil data and the simple measurement method, calculated angle sum ($\gamma+\alpha$ = 6 deg) and installed angle sum ($\gamma+\alpha$ = 7deg) accord very well.

take home message

- With simple measurements during take-off phase students can determine the physical variables *speed* and *accelleration* at the take-off point. This corresponds to 9th grade school physics.

  The lift-off itself illustrates the term *lifting force* F_L.
- The model engine increased the trolley-speed linear up to the point where $F_A > F_G$ and the modell takes off. Using the measured values *take-off-time* and *take-off-distance* students can calculate the angle of attack $\alpha+\gamma$ during take off. They learn how to use the diagram *Lift Coefficient* vs *A*ngle of Attack.
- Besides a link to theory, a trolley is additional fun during RC control training.