Rocket principle: conservation of momentum and reaction

Object of the experiment

- Determine the correlation between jet cross-sectional area and acceleration force of jet slider

Fig. 1: Jet slider including connector pin with magnet and mountable jet nozzles

Fig. 2: Dynamometric device on linear air track

Principles

The rocket principle can be explained by means of the law of conservation of momentum and thrust:

According to the law of conservation of momentum, the propulsion produced by the fuel combusted is of equal magnitude and opposite sign to the thrust of the rocket.

The rocket is propelled forward by the repulsive force generated by the combusted fuel.

This experiment illustrates the principle by means of a model jet on a linear air track.

The jet slider is shaped in such a way as to allow the jets of air streaming onto the linear track to collect in the dome of the slider, from where it is subsequently discharged. This propels the jet slider and ensures a uniform acceleration force. Jets of different sizes can be attached, resulting in different degrees of acceleration.

The acceleration force F_0 is defined by the mass *m* of the jet slider multiplied by the acceleration *a*.

$$F_0 = m \cdot a \qquad \text{(I)}$$

The acceleration a is dependent on the size of the jet and on the air stream emitted onto the linear track. However, the latter is kept constant throughout the experiment. Therefore, there is a dependence between the acceleration force and the cross-sectional area of the jet:

$$F_0 \propto A \qquad \text{(II)}$$

The acceleration force is measured using a dynamometric device

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Equipment list

1 Air track..337 501
1 Jet slider with dynamometric device 337 561
1 Precision dynamometer 0.01 N......................314 081

1 Air supply...337 512
Or
1 Air supply...337 53
1 Power controller..667 823

Additionally required:
Fishing line...309 48ET2

Setup

Set up the air track as shown in Fig. 3. Mount the dynamometric device on the air track. Secure the precision dynamometer to the stand and clamp (s. Fig. 2). using a piece of fishing line to secure the dynamometer to the winding spindle. Using silk yarn, secure the precision dynamometer to the first point of action of the weighing system.

Note: For further information on the points of action and other components of the dynamometric device, refer to instruction manual 337 59.

By turning the winding spindle, tighten the dynamometer until the weighing system is in equilibrium. If necessary, adjust the offset of the dynamometer to zero.

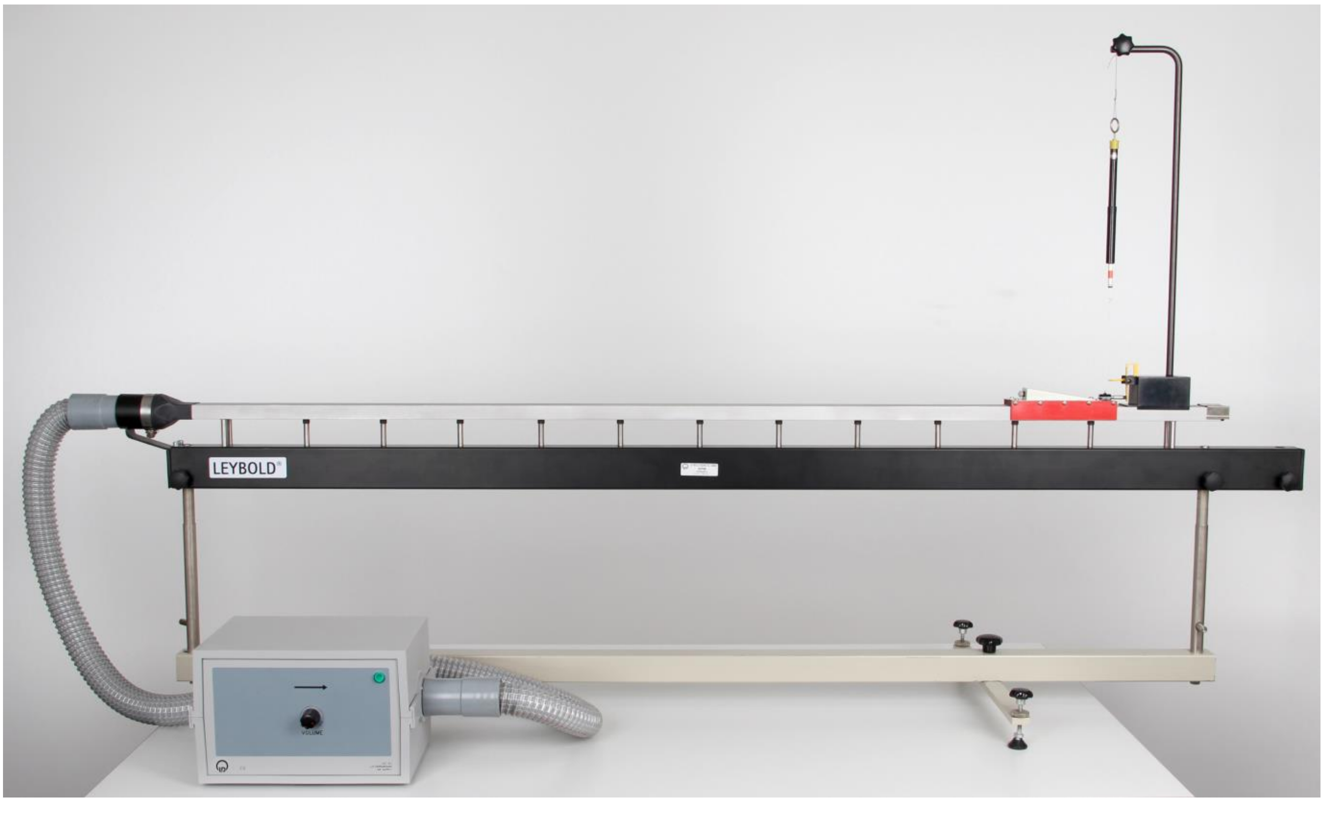
Attach the connector pin with magnet to the jet slider.

Note: For further information on the jet slider, refer to instruction manual 337 56.

Keep jets I, II and III ready at hand.

Connect the air supply to the air track. Alternatively, an air supply can be used in conjunction with the power controller.

Fig. 3: Experiment set-up



Carrying out the experiment

Measuring acceleration force for different jet nozzle sizes

- Switch on the air supply.
- Set the air supply such that the jet slider is set in motion (roughly 9 o'clock position). Allow the current of air to flow for the entire duration of the experiment so that the air stream remains constant.
- Attach nozzle I to the jet slider.
- Position the jet slider on the air track.
- Have the jet slider move towards the dynamometric device.
- Tighten the dynamometer such that the weighing system returns to equilibrium.
- Read off the force and make a note.
- Repeat the measurement in order to rule out any measurement error.
- Repeat the procedure using the two larger nozzles (marked with II and III respectively).

Measuring example

Table 1: Dependence of acceleration force on nozzle diameter and cross-sectional area

Nozzle	$\frac{d}{mm}$	$\frac{A}{mm^2}$	$\frac{F_0}{mN}$
I	2.3	4.2	2.0
II	3.2	8.0	3.2
III	4.2	13.8	4.8

Results

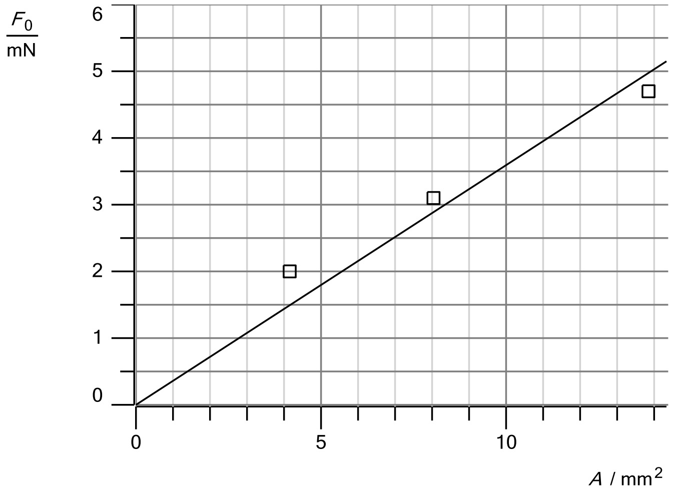


Fig. 4: Acceleration force as a function of cross-sectional area.

Evaluation

Observation shows that the larger the nozzle opening, the greater the acceleration force.

A line fitting the measured values can be drawn to show the acceleration force as a function of the cross-sectional area of the jet nozzle. Fig. 4 confirms that $F_0 \propto A$.