

# Aerodynamik

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V 0.2.1

### **Prolog**

Aerodynamik ist ein hochkomplexes Fach, das man aus gutem Grunde als Fach an den technischen Universitäten findet. Das vorliegende Skript kratzt hier nur an der Oberfläche. Es wird nur erklärt, was zu wissen für den sicheren Betrieb von Luftfahrzeugen notwendig ist.

## Die Atmosphäre

Zusammensetzung und Aufbau

ICAO-Standardatmosphäre

Atmosphärischer Druck

Umströmung eines Körpers,  
Unterschallbereich

Luftwiderstand und Luftdichte

Grenzschicht

# Reibungskräfte

## Laminare und turbulente Strömung

## Bernoulliesche Gleichung – Venturi-Effekt

Entscheidend für das Verständnis des Auftriebs ist es, den Venturi-Effekt zu kennen und zu verstehen.

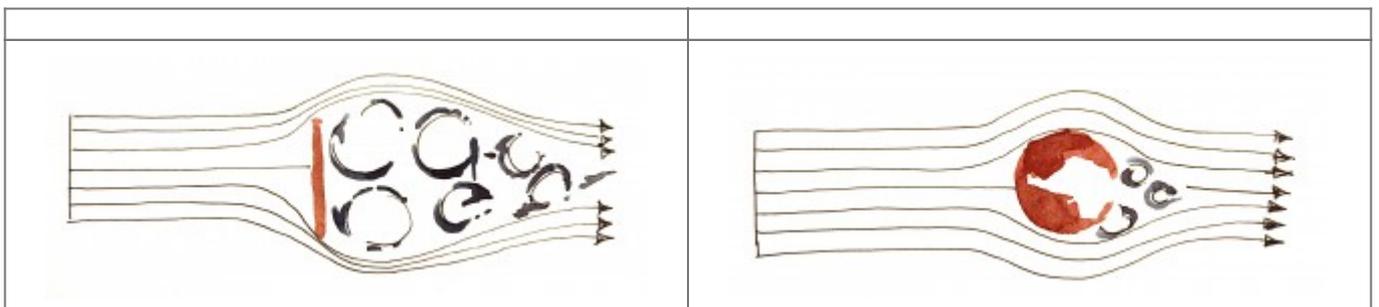
Betrachten wir zunächst ein Stück Schlauch. Pumpt man nun in diesen Schlauch an einem Ende eine bestimmte Menge Flüssigkeit (oder Gas) pro Zeiteinheit hinein, so wird an dessen anderem Ende die selbe Menge in der selben Zeit wieder hinausbefördert. Soweit ist die Betrachtung trivial. Verjüngt man nun den Schlauch zwischen den beiden Enden, so macht man die selbe Beobachtung. Was bedeutet dies nun für die Stelle, an der der Schlauch dünner wird? Hier muss pro Zeiteinheit mehr Flüssigkeit hindurch. Das führt dazu, dass sich die Strömungsgeschwindigkeit der Flüssigkeit erhöht und damit gleichzeitig ihr Druck abnimmt.

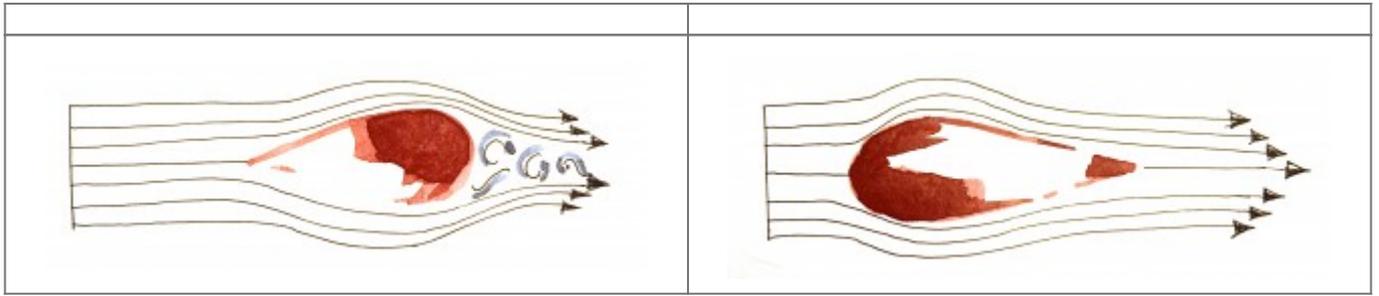


Bernoulli formulierte die zugehörige Gleichung, die besagt, dass bei einem strömenden Fluid der Druck abnimmt, wenn die Geschwindigkeit zunimmt.

## Umströmung eines zweidimensionalen Flügelprofils

### Umströmung einer ebenen Platte





Umströmung eines gekrümmten Flügelprofils

Beschreibung des Tragflügelquerschnitts

Auftrieb und Widerstand

Beziehung zwischen Auftriebsbeiwert ( $C_l$ ),  
Widerstandsbeiwert ( $C_d$ ) und  
Anstellwinkel

## Dreidimensionale Umströmung eines Tragflügels

### Tragflügelprofile und Flügelformen

Bei der Formgebung einer Tragfläche wird das Prinzip aus dem Venturi-Effekt aufgegriffen. Sie wird so geformt, dass Luft, die von vorne gegen die Tragfläche strömt, über die Oberseite der Tragfläche einen längeren Weg hat, als über die Unterseite. Nun passiert das selbe, wie in der Versuchsanordnung von oben. Die Luft, die über die Tragfläche strömt wird beschleunigt. Diese Beschleunigung sorgt für einen Unterdruck auf der Oberseite der Tragfläche. Die Tragfläche wird also nach oben gesogen.

### Induzierter Widerstand

Abwindwinkel (downwash angle),  
Wirbelwiderstand, Bodeneffekt

### Flügelstreckung

### Schädlicher (Flügelprofil-)widerstand

Formwiderstand, Reibungswiderstand und Interferenzwiderstand

Verhältnis Auftrieb/Widerstand

## Kräfteverteilung am Flugzeug

Gleichgewicht und Kräftepaare

Während des Fluges wirken vier Kräfte auf das Flugzeug: Der Auftrieb, die Schwerkraft, der Widerstand und der Schub. Im unbeschleunigten Horizontalflug sind diese Kräfte alle gleichgroß. Der Schwerkraft unterliegen alle Körper auf der Erde, der Widerstand entsteht durch das Bewegen eines Körpers durch die Luft, diese beiden Komponenten sind uns also durch die Natur vorgegeben. Schub und Auftrieb werden künstlich erzeugt. Den Schub erzeugt der Motor mittels seines Propellers, den Auftrieb erzeugen die Tragflächen aufgrund ihrer Form.

	Auftrieb	
Schub	Flugzeug	Widerstand
	Schwerkraft	

Auftrieb und Masse

Schub und Luftwiderstand

Kräftwirkungen in gleichförmigen Flugzuständen (Horizontal-, Steig-, Gleit- und Kurvenflug)

## Steuerungsanlagen

Die drei Hauptachsen

Nicken um die Querachse

Rollen um die Längsachse

Gieren um die Hochachse

Wirkung des Höhen- und Seitenruders und der Querruder

Steuerung bei Nick-, Roll- und Gierbewegungen

Zusammenhang von Rollen und Gieren (z.B. Seitengleitflug, Seitenwindsteuertechnik für die Landung)

Aerodynamischer Ausgleich und Masseausgleich von Steuerflächen

## Trimmsteuerung

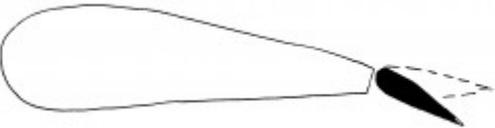
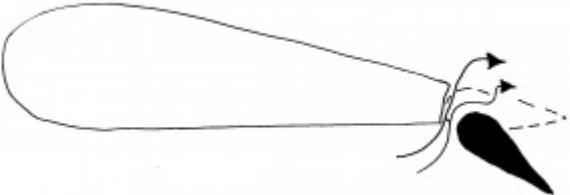
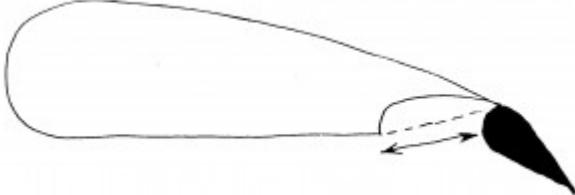
Trimmruder, Ausgleichsruder und Gegenausgleichsruder

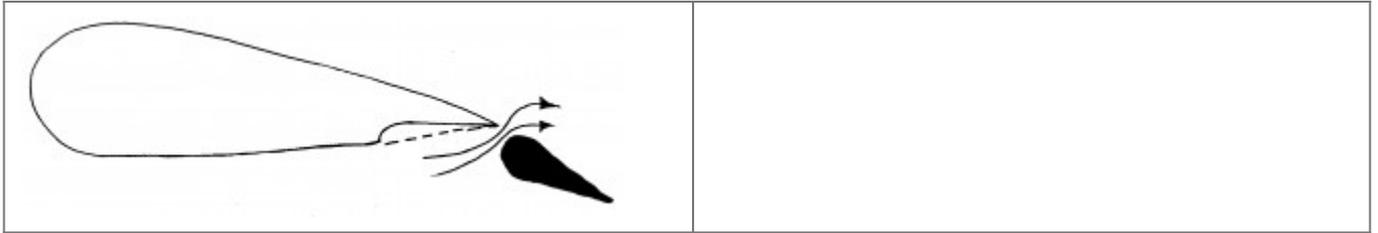
Aufgabe und Funktionsprinzip

Bedienung

## Landeklappen und Vorflügel

Wölbungs-, Spreiz-, Spalt-, Zap- und Fowler-Klappen

Wölbungsklappe	Spreizklappe
	
Spaltklappe	Zapklappe
	
Fowlerklappe	



Aufgabe und Funktionsprinzip

Betrieblicher Einsatz

Vorflügel, Klappen an der Flügelvorderkante

Aufgabe und Funktionsprinzip

Normaler/automatischer Betrieb

## Strömungsabriss

Kritischer Anstellwinkel

Störung der glatten Anströmung

Verringerung des Auftriebs, Erhöhung des Luftwiderstandes

Verschiebung des Druckpunktes

Anzeichen für beginnenden Strömungsabriss

Flugzeugeigenschaften bei Strömungsabriss

Einflussgrößen für die Abreißgeschwindigkeit und das Verhalten des Flugzeugs bei Strömungsabriss

Strömungsabriss bei Horizontal-, Steig-, Sink- und Kurvenflug

Möglichkeiten von Überziehwarnungen und Überziehwarnanlagen

Beenden des überzogenen Flugzustandes

## Vermeiden von Trudeln

Strömungsabriss an den Flügelspitzen

Entstehung einer Rollbewegung

Erkennen von beginnendem Trudeln

Ausleiten des Trudels

## Stabilität

Begriffsbestimmungen der statischen und dynamischen Stabilität

Längsstabilität

Einfluss der Schwerpunktlage auf die Steuerung bei Bewegung um die Querachse

Quer- und Richtungsstabilität

Beziehung zwischen Quer- und Richtungsstabilität

## Lastvielfaches und Abfangmanöver

Festigkeitsüberlegungen

V-n-Diagramm einschließlich Böen

Belastungsgrenzen, mit und ohne Landeklappen

Veränderung des Lastvielfachen im Kurvenflug und beim Hochziehen

Höchstzulässige Geschwindigkeit für vollen

Ruderausschlag

Vorsichtsmaßnahmen während des Fluges

**Belastungen am Boden**

Seitliche Belastungen auf das Fahrwerk

Landung

Rollen, Vorsichtsmaßnahmen bei  
Richtungsänderungen

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