UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2002/2003
Second Semester Examination
2002/2003 Academic Session

Februari/Mac 2003
February/March 2003

ESA 362/3 – Kawalan Penerbangan Pesawat
(Aircraft Flight Control)

Masa : [3 Jam]
Time : [3 hours]

ARAHAN KEPADA CALON :
INSTRUCTION TO CANDIDATES:

1. Sila pastikan bahawa kertas peperiksaan ini mengandungi **(18) LAPAN BELAS** mukasurat bercetak **termasuk lampiran** dan **(6) ENAM** soalan.
Please ensure that this paper contains (18) EIGHTEEN printed pages including attachments and (6) SIX questions.

2. Anda dikehendaki menjawab **(5) LIMA** soalan
Please answer (5) FIVE questions.

3. Agihan markah bagi setiap soalan diberikan di sut sebelah kanan.
The marks allocated for each questions is shown on the right hand side.

4. Soalan boleh dijawab Bahasa Inggeris kecuali satu soalan wajib dijawab dalam Bahasa Melayu.
The questions can be answered in English but one question must be answered in Bahasa Melayu

5. Mesin kira bukan yang boleh diprogram boleh digunakan.
Non programmable calculator can be used.

1. Pesawat penumpang jenis A 300 sedang membuat penerbangan di dalam keadaan atmosfera tidak terganggu (udara tetap dan tiada angin). Keadaan penerbangan yang pegun dan secara simetri diberi sebagai

Jisim pesawat	m = 130,000 kg
Kelajuan angin	V = 108 m/s
Kedudukan pusat graviti	(Xs- 0.25) = 0.05
Kedudukan menegah tujahan enjin	$Z_E = 2.65$ m
Sudut kecondongan enjin	$\sigma = 2.2$ degree

Selepas mendapatkan persamaan gerakan bagi penerbangan secara membujur dan penentuan keadaan mantap penerbangan trim, data penerbangan dalam keadaan ini diberi seperti yang berikut:

$$\alpha_0 = 0.0925 = 5.3^0$$
$$C_{L,0} = 0.74$$
$$C_{D,0} = 0.045$$
$$C_{m,0} = -0.0182$$
$$C_{\mu,0} = 0.0455(thrust\, coefficient)$$
$$i_{H,0} = -0.0068 = 0.39^0$$

Kiralah terbitan dimensi aerodinamik yang berikut:
$M_q, M_\alpha, M_u, Z_\alpha, Z_u, X_\alpha, X_u$.

A passenger aircraft of Type A 300 is performing level flight in the undisturbed atmosphere (still air , no wind). The stationary, symmetrical flight condition is given below

Mass of the aircraft	*m = 130,000.00 kg*
Airspeed	*V = 108 m/s*
Position of the centre of gravity	*(Xs- 0.25) = 0.05*
Vertical position of engine thrust	$Z_E = 2.65$ *m*
The inclination angle of engine	$\sigma = 2.2$ *degree*

After setting up equation of motion for longitudinal flight and determining the steady-state trimmed flight condition, the data of that trim flight condition is provided as follows:

$$\alpha_0 = 0.0925 = 5.3^0$$
$$C_{L,0} = 0.74$$
$$C_{D,0} = 0.045$$
$$C_{m,0} = -0.0182$$
$$C_{\mu,0} = 0.0455(\textit{thrust coefficient})$$
$$i_{H,0} = -0.0068 = 0.39^0$$

Calculate the following dimensional aerodynamic derivatives :
$M_q, M_\alpha, M_u, Z_\alpha, Z_u, X_\alpha, X_u$.

(100 markah/*marks*)

2. Bagi keadaan penerbangan pesawat sama seperti Soalan 1, di atas,

Tentukan terbitan dimensi kawalan yang berikut:
$M_\eta, M_f, Z_\eta, Z_f, X_\eta, X_f$.

For the aircraft flight condition same as in Question 1 , above

Determine the following dimensional control derivatives:
$M_\eta, M_f, Z_\eta, Z_f, X_\eta, X_f$

(100 markah/*marks*)

3. Bagi keadaan penerbangan pesawat yang sama, gunakan data dimensi aerodinamik dan kawalan yang berikut bagi Soalan 3, 4, 5, dan 6.

$$M_q = -1.03, M_\alpha = -1.0, M_u = -0.003, Z_\alpha = -0.66, Z_u = -0.003,$$
$$X_\alpha = 11.00, X_u = 0.007$$
$$M_\eta = -1.70, M_f = -0.004, Z_\eta = -0.050, Z_f = -0.004, X_\eta = 0.110, X_f = 3.10$$

Dapatkan persamaan gerakan linear bagi penerbangan membujur:

(a) dalam bentuk ruang keadaan diwakili oleh $\dot{\underline{X}} = \underline{\underline{A}}\underline{X} + \underline{\underline{B}}\underline{U}$; dan

(b) gambarajah blok isyarat.

For the same flight condition, please use following dimensional data aerodynamics derivatives and control derivatives for Question 3, 4, 5 and 6.

$$M_q = -1.03, M_\alpha = -1.0, M_u = -0.003, Z_\alpha = -0.66, Z_u = -0.003,$$
$$X_\alpha = 11.00, X_u = 0.007$$
$$M_\eta = -1.70, M_f = -0.004, Z_\eta = -0.050, Z_f = -0.004, X_\eta = 0.110, X_f = 3.10$$

Represent the linear equation of motion for longitudinal flight

(a) in form of the state – space representation $\dot{\underline{X}} = \underline{\underline{A}}\underline{X} + \underline{\underline{B}}\underline{U}$;

(b) signal block diagram

(100 markah/*marks*)

4. Dengan menggunakan persamaan keadaan dan gambarajah blok isyarat, tunjukkan bahawa pergerakan membujur boleh dipisahkan kepada mod kalaan pendek (SP-mode) dan mod mengelak (PH-mode).

By using the state –equation and the signal block diagram, please show that the longitudinal motion can be split into short-period mode (SP-mode) and phugoid-mode (PH-mode).

(100 markah/*marks*)

5. Berdasarkan penghampiran persamaan bagi mod kalaan pendek, tentukan yang berikut:

(a) fungsi pindah $f_{q\eta}$;

(b) redaman ζ dan frekuensi tabii ω_0 kalaan pendek; dan

(c) ciri-ciri awalan dan kepegunan q yang disebabkan oleh input langkah η.

Based on the approximate equation for short-period mode, determine the following

(a) the transfer function $f_{q\eta}$*;*

(b) the damping ζ *and natural frequency* ω_0 *of short period ; and*

(c) initial – and stationary characteristics of q *due to step input of* η

(100 markah/*marks*)

6. Berdasarkan penghampiran persamaan bagi mod kalaan mengelak, tentukan yang berikut:

(a) fungsi pindah f_{uf}

(b) redaman ζ dan frekuensi tabii ω_0 kalaan mengelak; dan

(c) ciri-ciri awalan dan kepegunan q yang disebabkan oleh input langkah η.

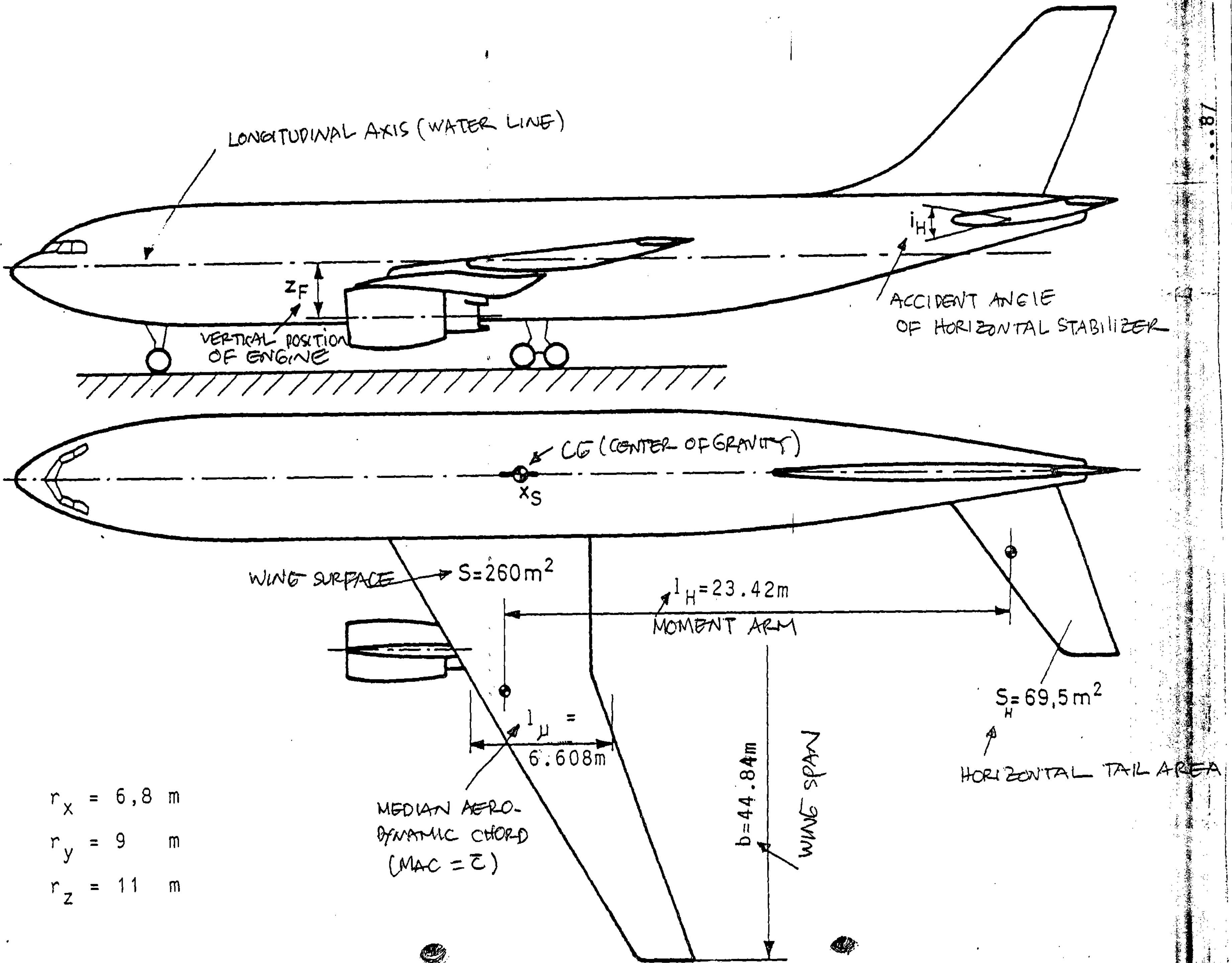
Based on the approximate equation for phugoid mode, determine the following

(a) the transfer function f_{uf};

(b) the damping ζ *and natural frequency* ω_0 *of phugoid mode; and*

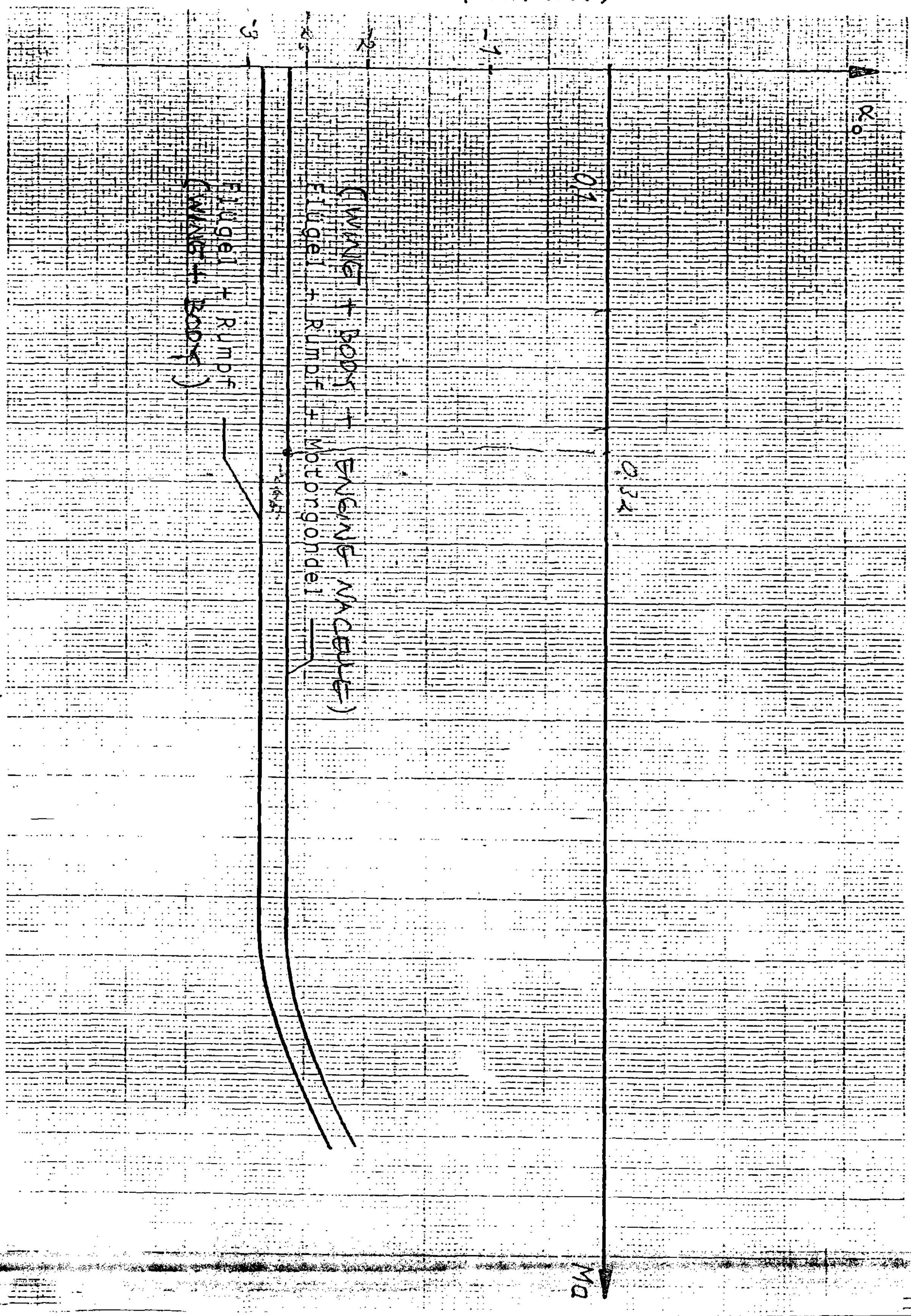
(c) initial – and stationary characteristics of q *due to step input of* η.

(100 markah/*marks*)


LONGITUDINAL AXIS (WATER LINE)
z_F
VERTICAL POSITION OF ENGINE
i_H
ACCIDENT ANGLE OF HORIZONTAL STABILIZER
CG (CENTER OF GRAVITY)
x_S
WING SURFACE
$S=260 m^2$
$l_H=23.42m$
MOMENT ARM
$S_H=69,5 m^2$
HORIZONTAL TAIL AREA
l_μ = 6.608m
MEDIAN AERODYNAMIC CHORD (MAC = $\bar{c}$)
b=44.84m
WING SPAN
r_x = 6,8 m
r_y = 9 m
r_z = 11 m

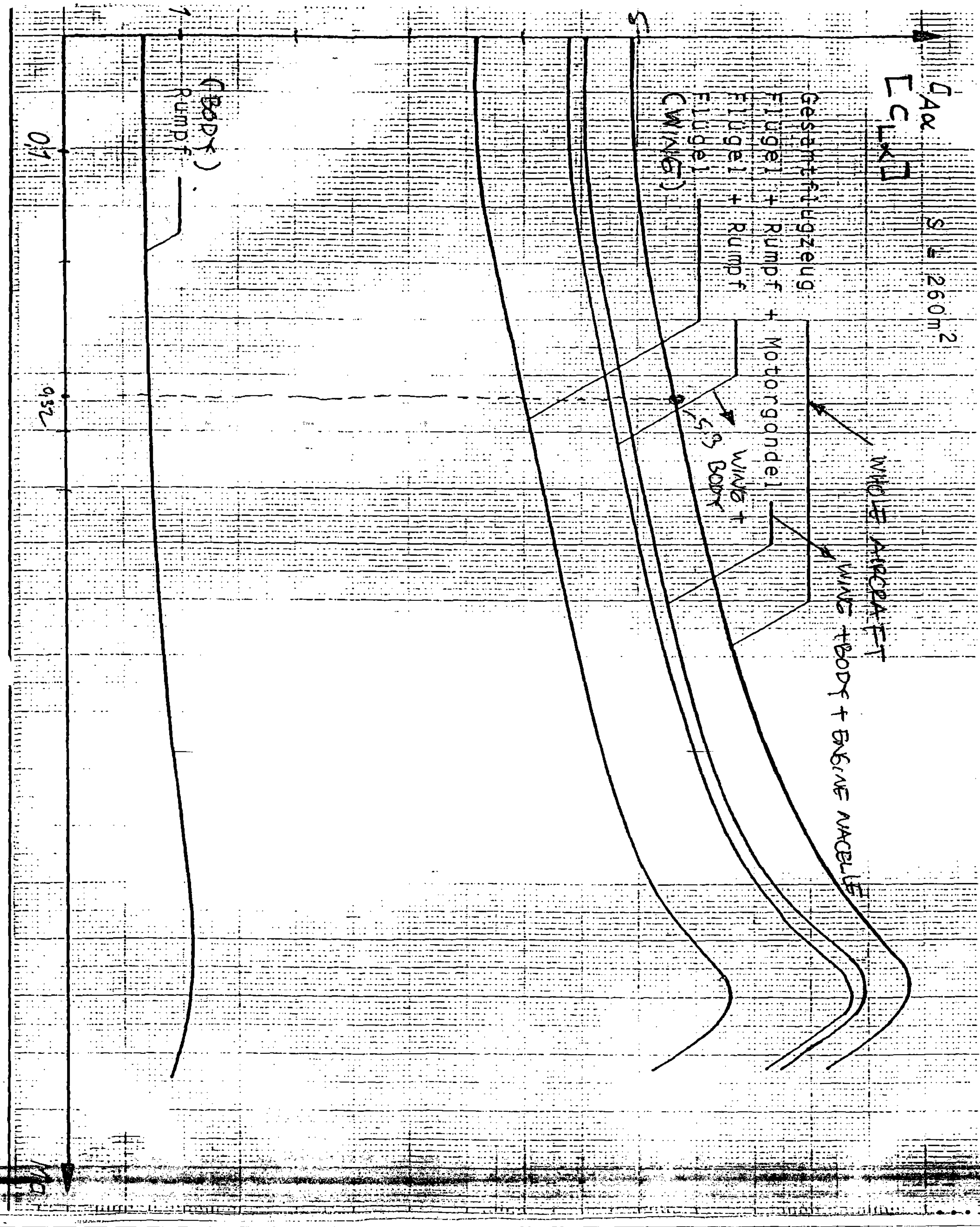
Anstellwinkel bei Auftrieb Null

(ZERO LIFT ANGLE OF ATTACK)



Auftriebsanstieg als Funktion der Machzahl

(LIFT-SLOPE AS FUNCTION OF MACH-NUMBER)

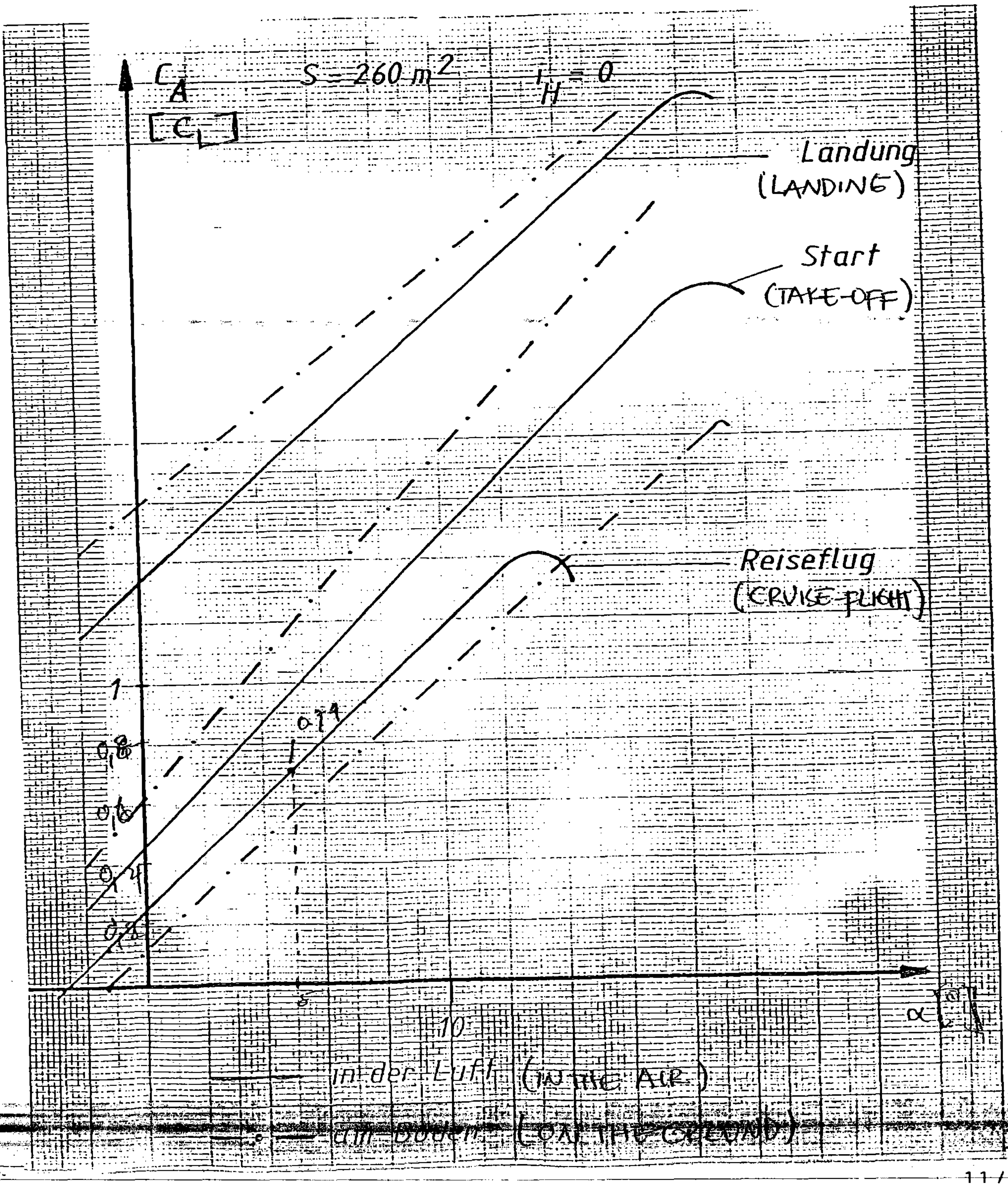


.../10/

(LIFT-COEFFICIENT OF WHOLE AIRCRAFT AT SLOW AIRSPEEDS)

Auftriebsbeiwert des Gesamtflugzeugs

bei niedrigen Geschwindigkeiten

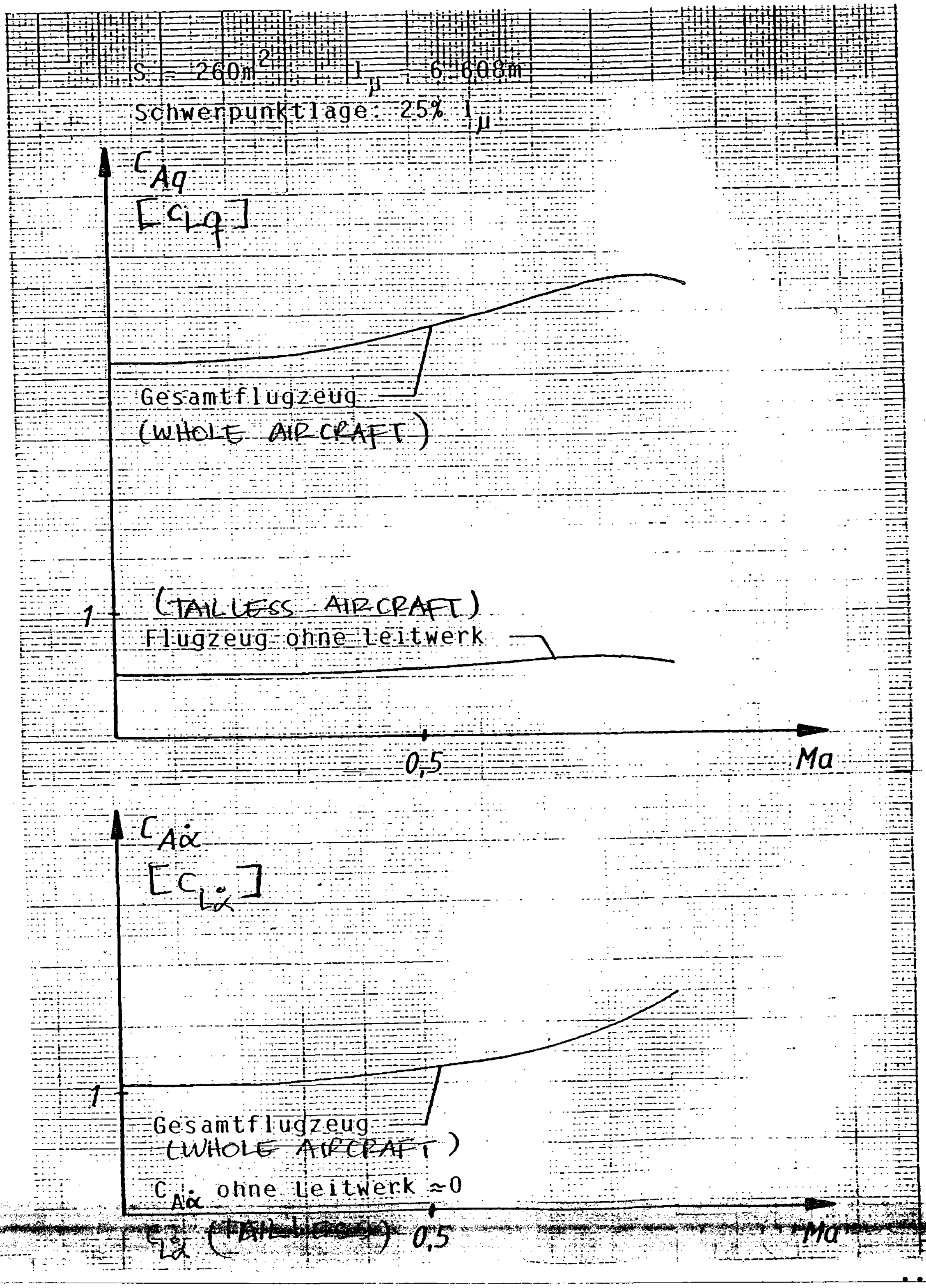


(LIFT-SLOPE DUE TO PITCH-RATE)

Auftriebsanstieg infolge Nickgeschwindigkeit

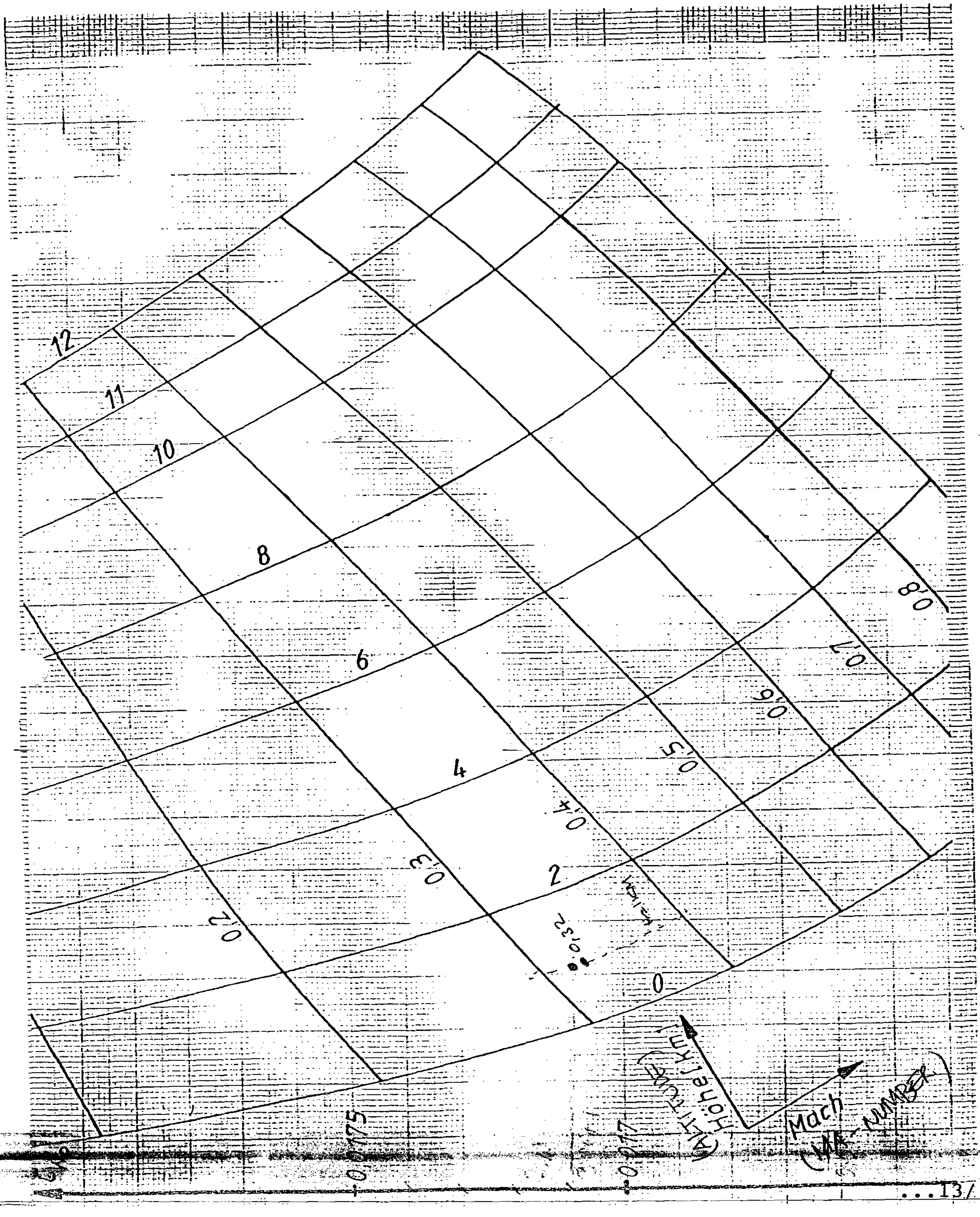
(LIFT-SLOPE DUE TO AOA-CHANGE)

Auftriebsanstieg infolge Anstellwinkeländerung



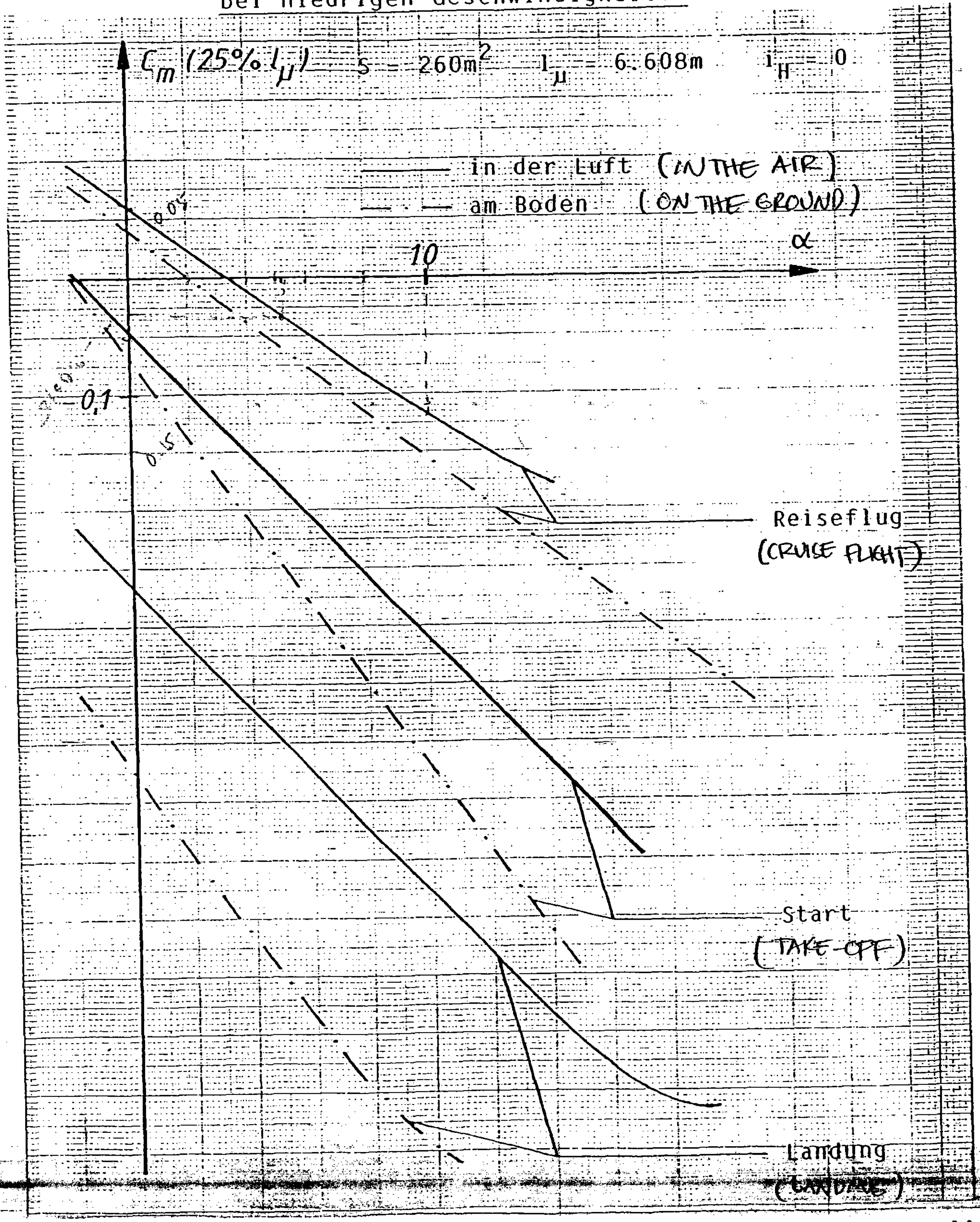
Nullwiderstandsbeiwert als Funktion von Höhe und Machzahl

(ZERO DRAG COEFFICIENT ALS FUNCTION OF ALTITUDE & MA-NUMBER)

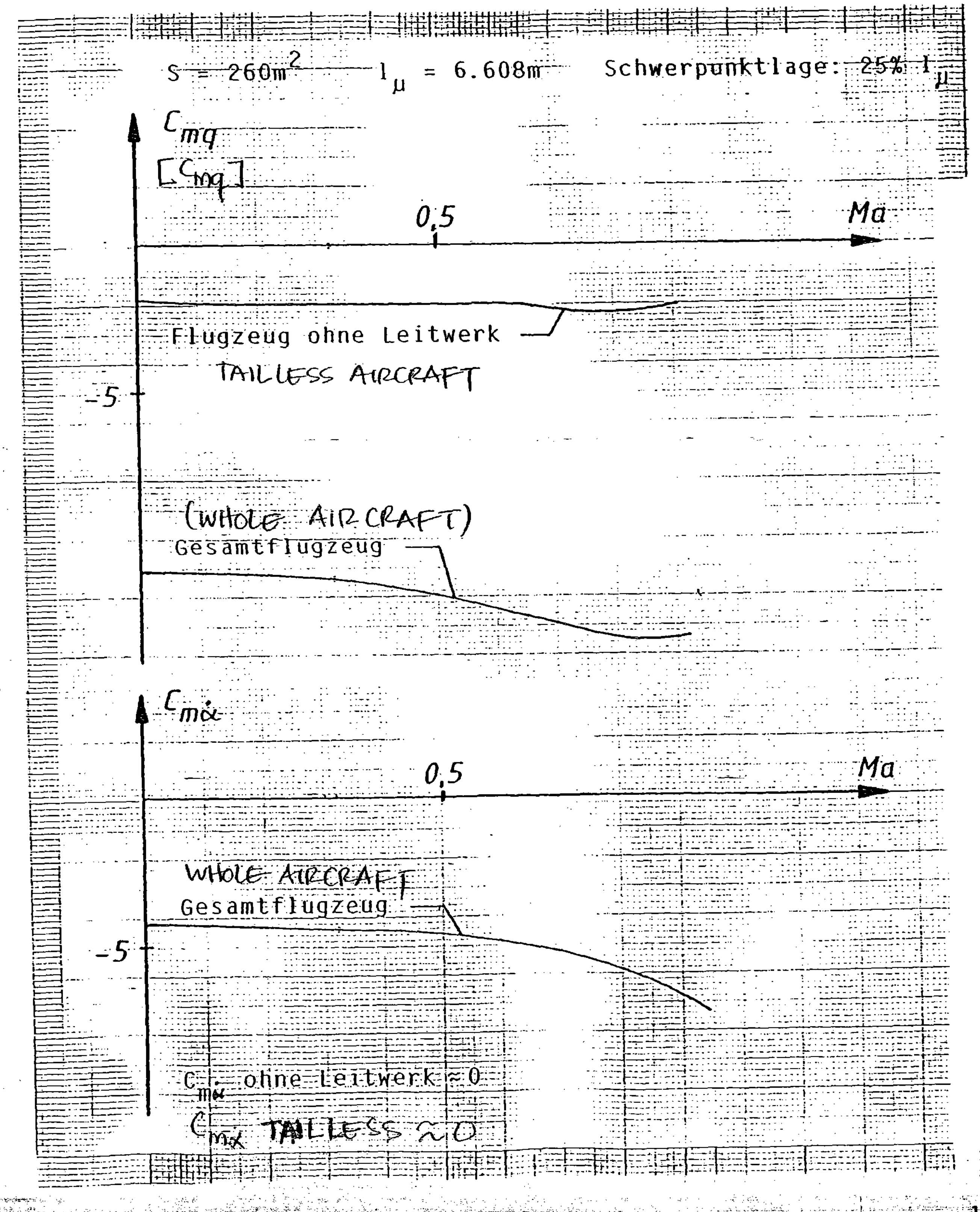


PITCH MOMENT COEFFICIENT OF WHOLE AIRCRAFT AT LOW AIRSPEEDS

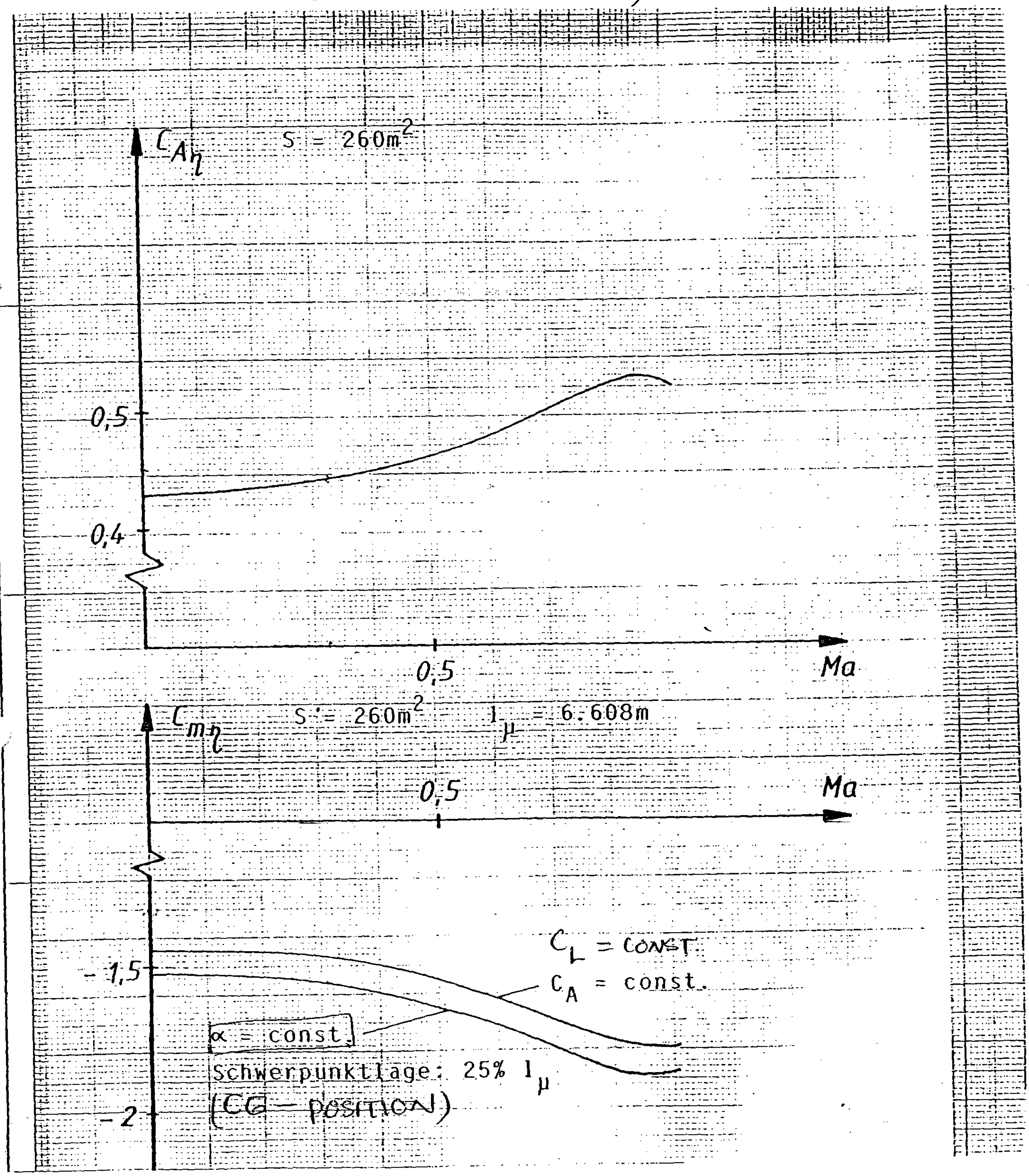
Nickmomentenbeiwert des Gesamtflugzeugs bei niedrigen Geschwindigkeiten



Nickdämpfung und Abwindverzögerung
PITCH DAMPING & UPWIND LAG)

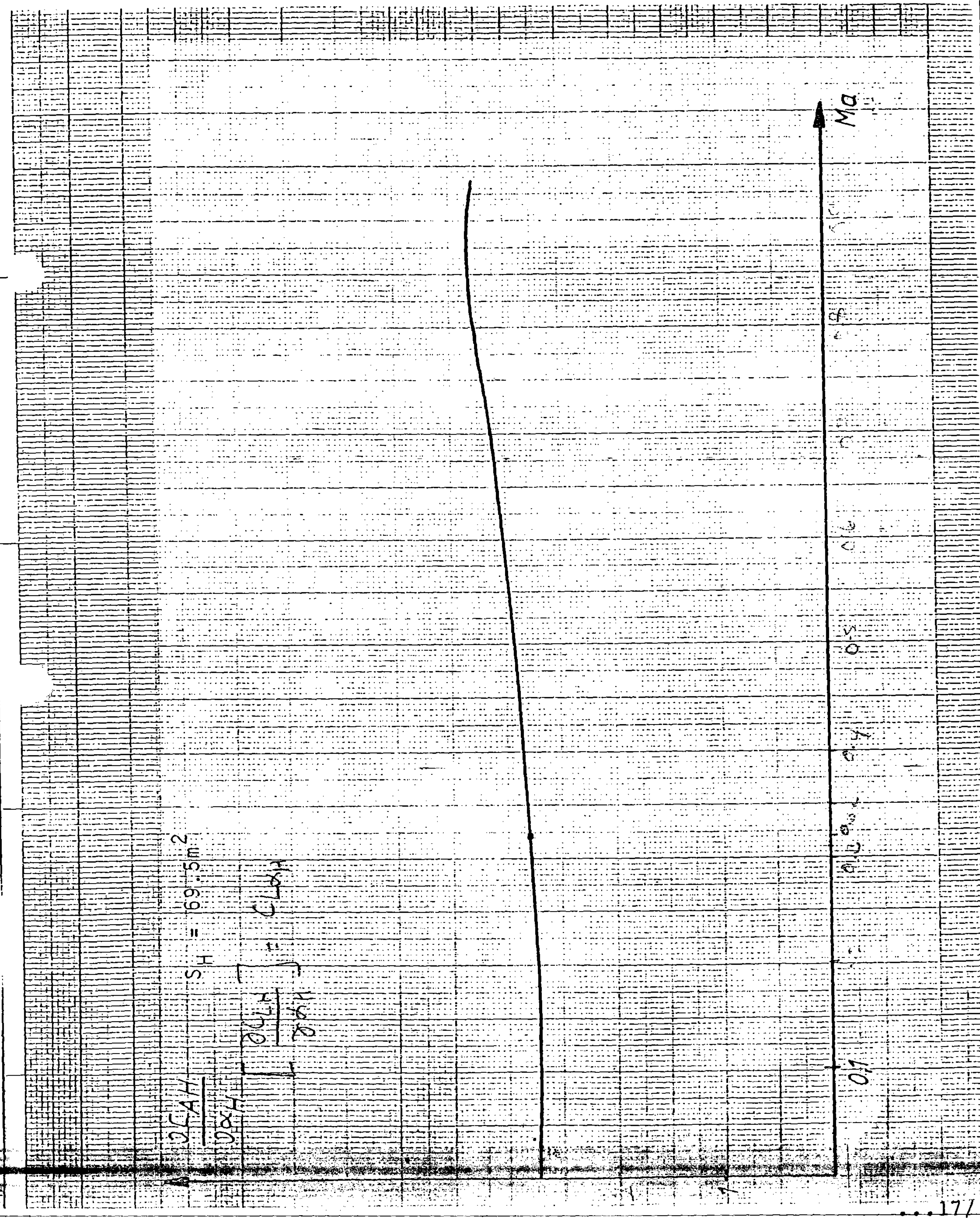


Höhenruderwirksamkeit
(ELEVATOR-EFFECTIVENESS)

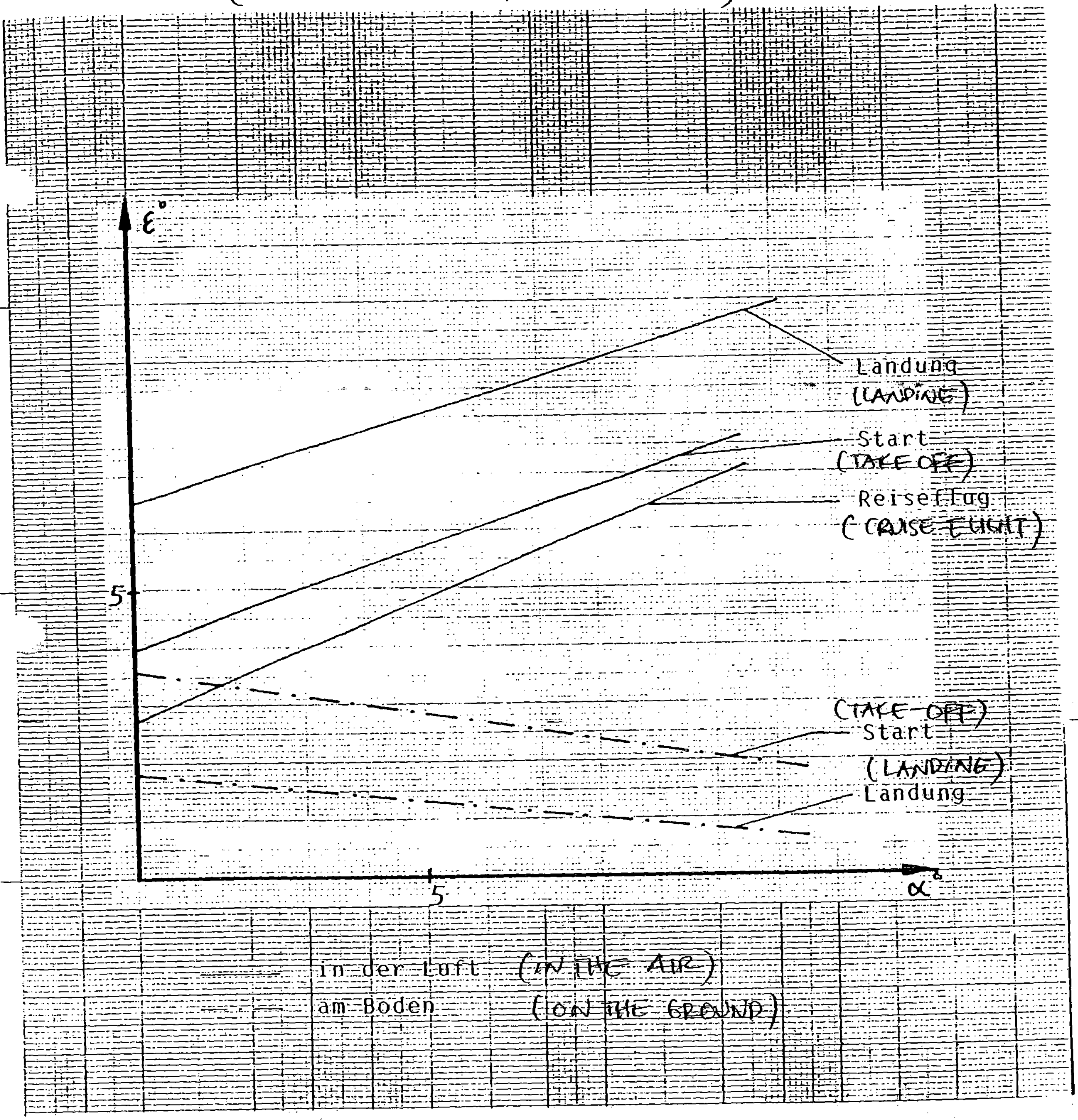


Auftriebsgradient des Höhenruders

(LIFT COEFFICIENT OF ELEVATOR)



Abwindwinkel des Leitwerks
(DOWN WASH ANGLE OF HORIZONTAL TAIL)



$$X_u = -\rho/2\, V_o^2 \frac{S}{m} \left[\left(\frac{2}{V_o} C_{Wo} + \frac{1}{a} C_{WM} \right) - \alpha_o \left(\frac{2}{V_o} C_{Ao} + \frac{1}{a} C_{AM} \right) \right] + \frac{1}{am} \frac{\partial F}{\partial Ma}$$

$$X_\alpha = -\rho/2\, V_o^2 \frac{S}{m} \left[C_{W\alpha} - C_{Ao} - \alpha_o C_{A\alpha} \right]$$

$$X_{\dot\alpha} = -\rho/2\, V_o^2 \frac{S}{m} \frac{l_\mu}{V_o} \left[C_{W\dot\alpha} - \alpha_o C_{A\dot\alpha} \right]$$

$$X_q = -\rho/2\, V_o^2 \frac{S}{m} \frac{l_\mu}{V_o} \left[C_{Wq} - \alpha_o C_{Aq} \right]$$

$$X_\Theta = -g \cos\Theta_o$$

$$X_{\alpha K} = X_\alpha - g\cos\Theta_o = X_\alpha + X_\Theta$$

$$X_f = \frac{1}{m} \frac{\partial F}{\partial f}$$

$$X_\eta = -\rho/2\, V_o^2 \frac{S}{m} \left[C_{W\eta} - \alpha_o C_{A\eta} \right]$$

$$Z'_u = -\rho/2\, V_o^2 \frac{S}{m} \left[\frac{2}{V_o} C_{Ao} + \frac{1}{a} C_{AM} + \alpha_o \left(\frac{2}{V_o} C_{Wo} + \frac{1}{a} C_{WM} \right) \right] - \frac{\alpha_o}{am} \frac{\partial F}{\partial Ma}$$

$$Z'_\alpha = -\rho/2\, V_o^2 \frac{S}{m} \left[C_{A\alpha} + C_{Wo} + \alpha_o C_{W\alpha} \right]$$

$$Z'_{\dot\alpha} = -\rho/2\, V_o^2 \frac{S}{m} \frac{l_\mu}{V_o} \left[C_{A\dot\alpha} + \alpha_o C_{W\dot\alpha} \right]$$

$$Z'_q = -\rho/2\, V_o^2 \frac{S}{m} \frac{l_\mu}{V_o} \left[C_{Aq} + \alpha_o C_{Wq} \right]$$

$$Z'_\Theta = -g \sin\Theta_o$$

$$Z'_{\alpha K} = Z'_\alpha - g\sin\Theta_o = Z'_\alpha + Z'_\Theta$$

$$Z'_f = -\frac{\alpha_o}{m} \frac{\partial F}{\partial f}$$

$$Z'_\eta = -\rho/2\, V_o^2 \frac{S}{m} \left[C_{A\eta} + \alpha_o C_{W\eta} \right]$$

$$Z_u = (Z'_u - \alpha_o X_u) \frac{1}{V_o}$$

$$Z_\alpha = (Z'_\alpha - \alpha_o X_\alpha) \frac{1}{V_o}$$

$$Z_{\dot\alpha} = (Z'_{\dot\alpha} - \alpha_o X_{\dot\alpha}) \frac{1}{V_o}$$

$$Z_q = (Z'_q - \alpha_o X_q) \frac{1}{V_o}$$

$$Z_\Theta = (Z'_\Theta - \alpha_o X_\Theta) \frac{1}{V_o}$$

$$Z_{\alpha K} = Z_\alpha + Z_\Theta$$

$$Z_f = (Z'_f - \alpha_o X_f) \frac{1}{V_o}$$

$$Z_\eta = (Z'_\eta - \alpha_o X_\eta) \frac{1}{V_o}$$

$$M_u = \rho/2\, V_o^2 \frac{S}{I_y} l_\mu \left[\frac{2}{V_o} C_{mo} + \frac{1}{a} C_{mMa} \right] + \frac{z_F}{a} \frac{\partial F}{\partial Ma} \frac{1}{I_y}$$

$$M_\alpha = \rho/2\, V_o^2 \frac{S}{I_y} l_\mu C_{m\alpha}$$

$$M_{\dot\alpha} = \rho/2\, V_o \frac{S}{I_y} l_\mu^2 C_{m\dot\alpha}$$

$$M'_q = \rho/2\, V_o \frac{S}{I_y} l_\mu^2 C_{mq}$$

$$M_f = \frac{z_F}{I_y} \frac{\partial F}{\partial f}$$

$$M_\eta = \rho/2\, V_o^2 \frac{S}{I_y} l_\mu C_{m\eta}$$

$$M_q = M'_q + M_{\dot\alpha}$$

$$M_{Wx} = M'_q - M_\alpha$$

aerody. Derivative: C_{WM}, C_{AM}, $\frac{\partial f}{\partial Ma}$, $C_{W\alpha}$, $C_{A\alpha}$, $C_{W\dot\alpha}$, $C_{A\dot\alpha}$, C_{Wq}, C_{Aq}, $\frac{\partial f}{\partial f}$, $C_{W\eta}$, $C_{A\eta}$, C_{mMa}, $C_{m\alpha}$, $C_{m\dot\alpha}$, ~~C_{mq}~~, $C_{m\eta}$

Konfiguration CONFIGURATION	Reiseflug CRUISE-FLIGHT	Landung LANDING	Start TAKE-OFF
k^*	1.250	1.0720	1.1560
C_{WK}	0	0.1200	0.0162
C_{WFW}	0	0.0134	0.0184