Diplomarbeitspräsentation

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
Department Fahrzeugtechnik und Flugzeugbau

Dimensionierung und Entwurf von Strahlverkehrsflugzeugen mit Statistiken– Programmentwicklung von PreSTo und Anbindung an PrADO

Sanjay Luthra
1.Prüfer: Professor Dr.-Ing. D. Scholz, MSME
2.Prüfer: Professor Dr.-Ing. H. Zingel

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
Department Fahrzeugtechnik und Flugzeugbau

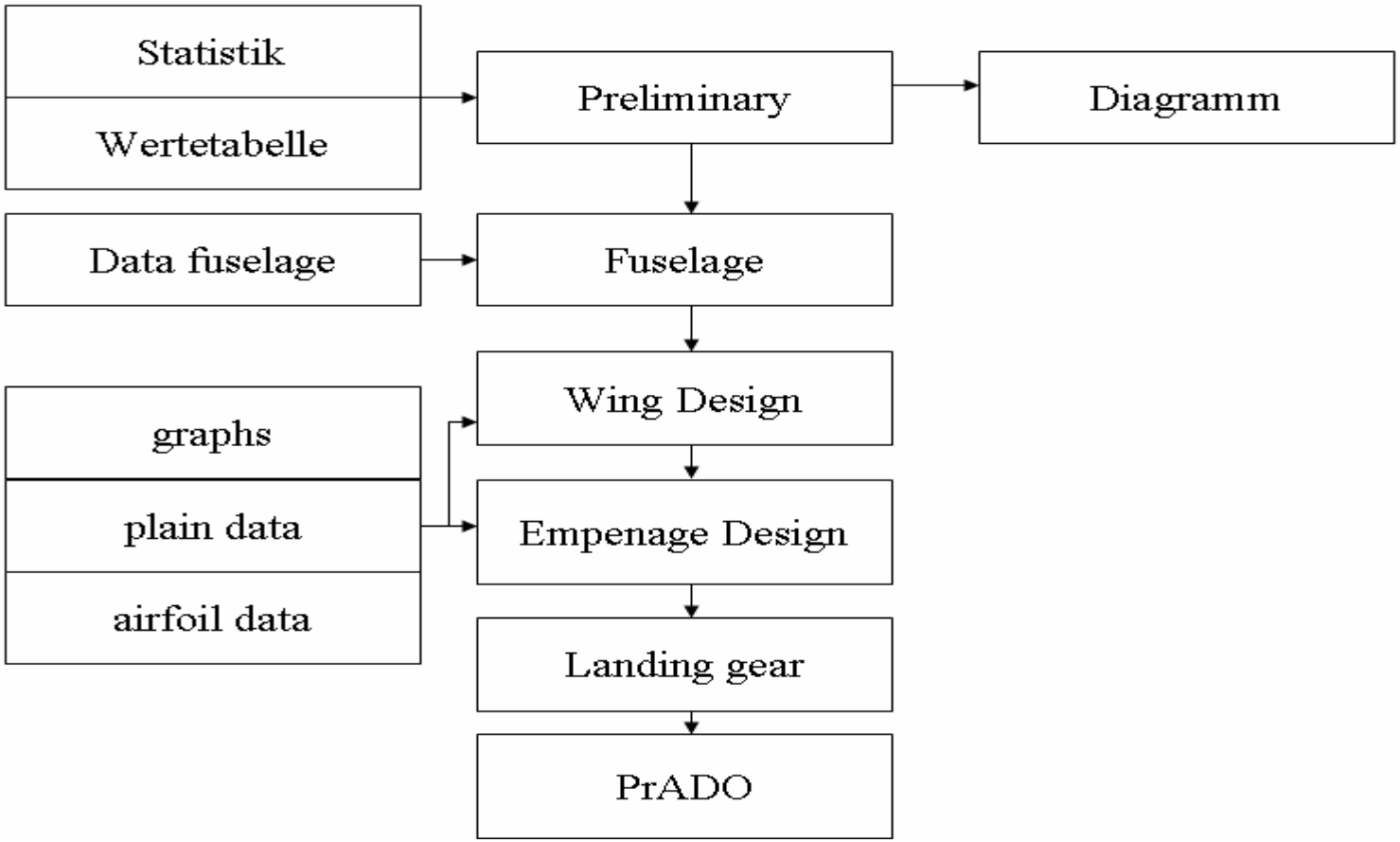
Inhaltsübersicht

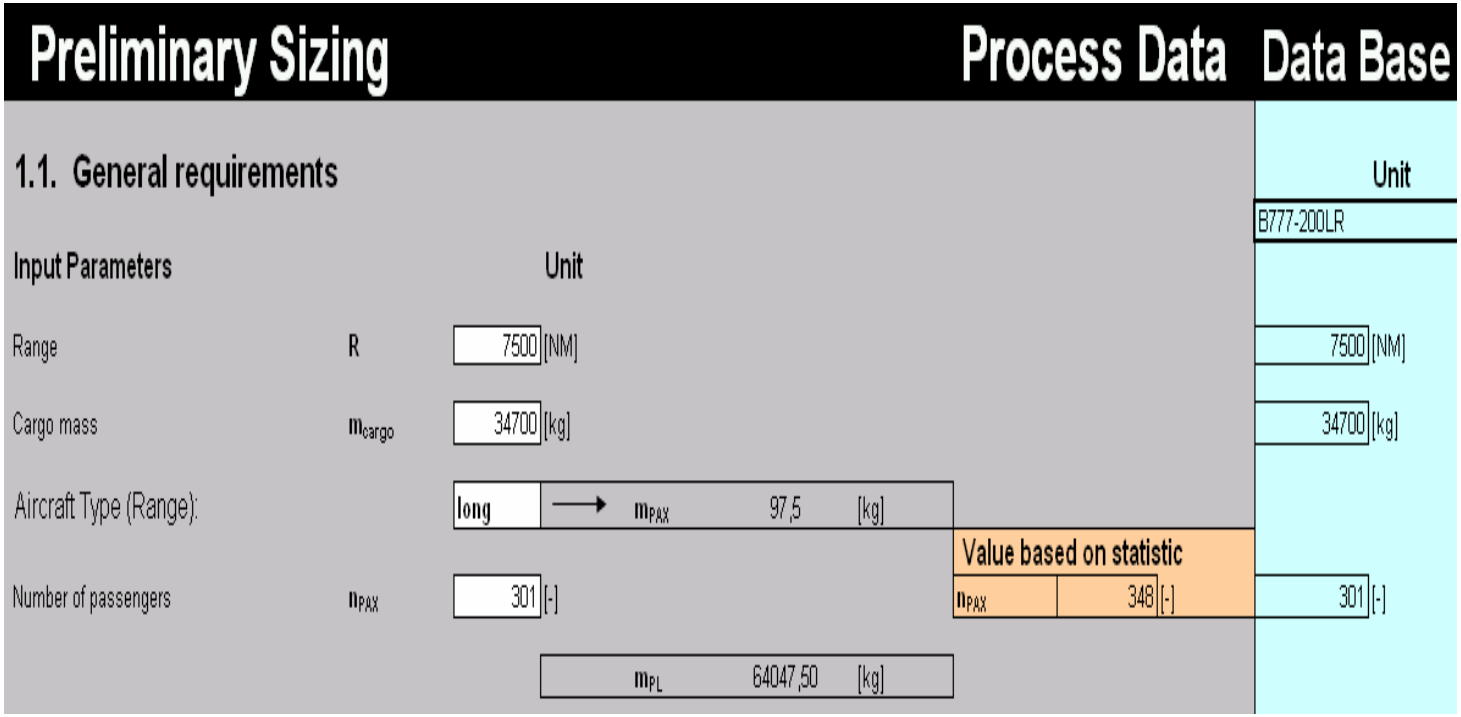
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
Department Fahrzeugtechnik und Flugzeugbau

Aufgabenstellung

- In das bestehende Tool Statistiken einfügen
- Datenbank erstellen
- Die einzelnen Dateien verknüpfen und vereinheitlichen
- Die Vorgabedatei von PrADO in Excel erstellen

Aufbau von PreSTo




Preliminary Sizing
Process Data
Data Base
1.1. General requirements
Unit
B777-200LR
Input Parameters
Unit
Range
R
7500 [NM]
7500 [NM]
Cargo mass
m_{cargo}
34700 [kg]
34700 [kg]
Aircraft Type (Range):
long
m_{PAX} 97,5 [kg]
Value based on statistic
Number of passengers
n_{PAX}
301 [-]
n_{PAX} 348 [-]
301 [-]
m_{PL} 64047,50 [kg]

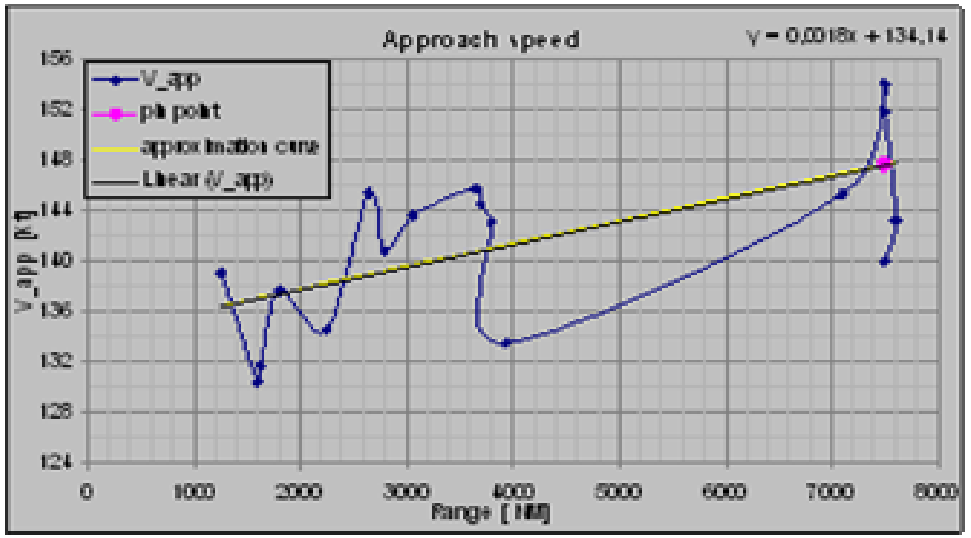
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
Department Fahrzeugtechnik und Flugzeugbau

Statistischer Wert (Anfluggeschwindigkeit)

- **Abhängig von der Reichweite**
- **Durchschnittswert von 17 Flugzeugen**
- **Vapp = 147,64 Kt bei R= 7500 NM**

Approximation curve for approach speed

gradient	exponent	abscissa	V_{app}	
0,0018	1	134,14	147,64	[Kt]



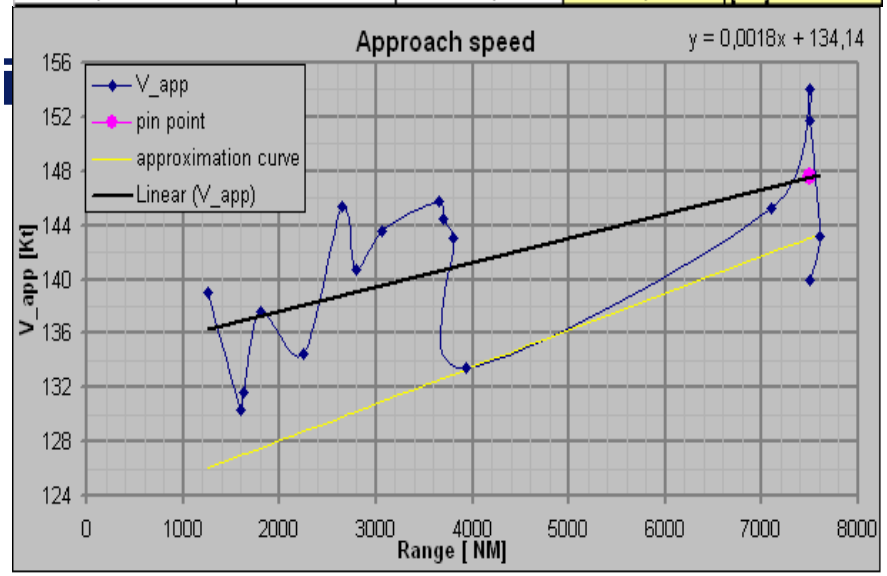
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
Department Fahrzeugtechnik und Flugzeugbau

Statistischer Wert mit Approximation-Kurve

- Y=m*x^n+b
- Durchschnittswert von 2 Flugzeugen
- Vapp= 143,075 Kt bei R = 7500NM

Approximation curve for approach speed

gradient	exponent	abscissa	V_{app}	
0,00273	1	122,6	143,075	[Kt]



Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
Department Fahrzeugtechnik und Flugzeugbau

Preliminary: Fünf Flugphasen

- **Landung**
- **Start**
- **Steigrate im 2. Segment**
- **Steigrate beim Durchstarten**
- **Reiseflug**

Landung

1.2. Wing loading at max. take-off mass based on requirement of Landing			Unit					
Input Parameters		Unit						
				Values based on statistic				
Statistic Values	No			s_{LFL}	1875,35	[m]		
				k_{app}	1,747	[(m/s^2)^0,5]		
				$C_{L,max,L}$	2,578	[-]		
				m_{ML}/m_{TO}	0,741	[-]		
				v_{app}	147,64	[Kt]		
Approach speed	v_{app}	140,00	[Kt]					
				Values for the next steps				
Factor	k_{app}	Manual input		s_{LFL}	1676	[m]	1676	[m]
		1,758	[(m/s^2)^0,5]	k_{app}	1,758	[(m/s^2)^0,5]	1,758	[m/s^2)^0,5]
Max. lift coefficient, landing	$C_{L,max,L}$	2,6	[-]	$C_{L,max,L}$	2,6	[-]	2,6	[-]
Mass ratio, landing - take-off	m_{ML}/m_{TO}	0,623	[-]	m_{ML}/m_{TO}	0,623226	[-]	0,623226	[-]
				v_{app}	140	[Kt]	140	[Kt]
Temperature above ISA (288,15K)	ΔTA	0	[K]				0	[K]
				Results				
				v_{app}	139,91	[Kt]	140	[Kt]
				s_{LFL}	1678,13	[m]	1676	[m]
				k_L	0,11417	[kg/m^3]	0,11417	[kg/m^3]
				σ	1,000	[-]	1	[-]
				m_{ML}/S_W	497,487	[kg/m^2]	483,000	[kg/m^2]
				m_{MTO}/S_W	798,245	[kg/m^2]	775,000	[kg/m^2]

Start

1.3. Thrust-to-weight ratio based on requirement of take off

Input parameters			Unit					
Statistic Values		No		Values based on statistic				
				s_{TOFL}	2851,25	[m]		
				k_{TO}	2,025	[m^3/kg]		
				$C_{L,max,TO}$	2,038	[-]		
Factor	k_{TO}	Lecture		Values for the next steps				
		2,340	[m^3/kg]	k_{TO}	2,34	[m^3/kg]	2,34	[m^3/kg]
Take-off field length	s_{TOFL}	3350	[m]	s_{TOFL}	3350	[m]	3350	[m]
Max. lift coefficient, take-off	$C_{L,max,TO}$	Manual input	[-]	$C_{L,max,TO}$	1,88	[-]	1,88	[-]
Max. lift coefficient, take-off (manual input)	$C_{L,max,TO}$	1,88	[-]					
Temperatur above ISA (288,15K)	ΔT_{TO}	15	[K]				15	[K]
				Results				
				σ	0,950519545	[-]	0,95	[-]
		Update here!		a	0,00039089	[m^2/kg]	0,00037000	[m^2/kg]
Wing loading at max. take-off mass	m_{MTO}/S_W	798,25	[kg/m^3]	$T_{TO}/m_{MTO}*g$	0,3120244	[-]	0,28700000	[-]

Steigrate im 2. Segment

1.4. Thrust-to-weight ratio based on requirement of 2nd Segment

Input parameters

Statistic Values		No					
				Values based on statistic			
				A	8,973	[-]	
				$C_{D,0}$	0,01835	[-]	
				$\Delta C_{D,slat}$	0,00325	[-]	
				e	0,740	[-]	
				Values for the next steps			
Aspect ratio	A	9,34	[-]	A	9,34	[-]	9,34 [-]
Lift-independent drag coefficient, clean	$C_{D,0}$	Lecture					
		0,0200	[-]	$C_{D,0}$	0,02	[-]	0,02 [-]
Lift-independent drag coefficient, slats	$\Delta C_{D,slat}$	Manual input					
		0,0000	[-]	$\Delta C_{D,slat}$	0	[-]	0 [-]
Oswald efficiency factor; landing configuration	e	Lecture					
		0,7000	[-]	e	0,700	[-]	0,7 [-]
Number of engines	n_E	2	[-]				2 [-]
				Results			
				$C_{L,TO}$	1,3055556	[-]	1,3055556 [-]
				$\Delta C_{D,flap}$	0,0102778	[-]	0,0102778 [-]
				$C_{D,P}$	0,0302778	[-]	0,0302778 [-]
				E_{TO}	11,527	[-]	11,527 [-]
				$\sin(\gamma)$	0,024	[-]	0,024 [-]
				$T_{TO} / m_{MTO}{}^{*}g$	0,2215079	[-]	0,2215079 [-]

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
Department Fahrzeugtechnik und Flugzeugbau

Steigrate beim Durchstarten

1.5. Thrust-to-weight ratio based on requirement of missed approach

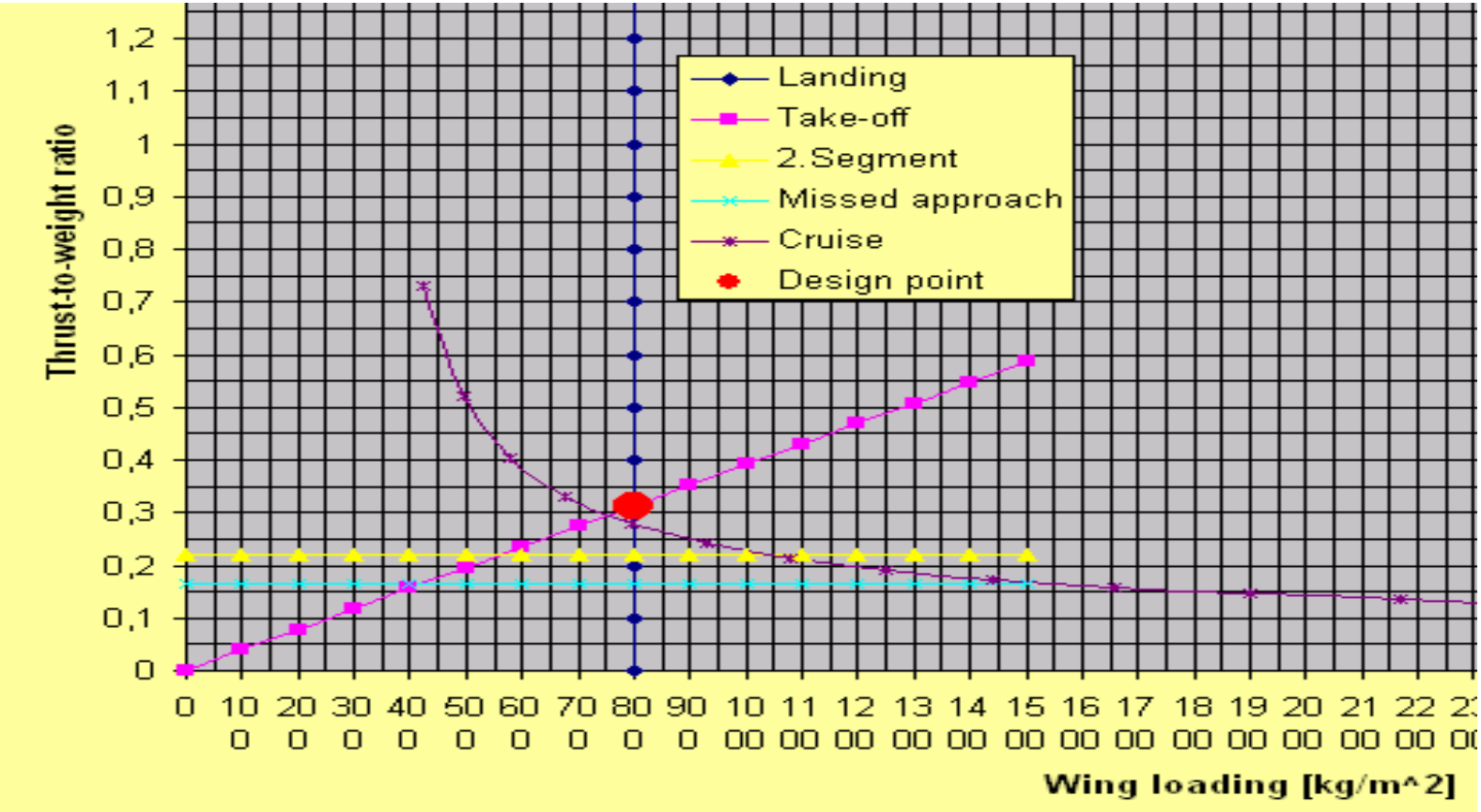
Input parameters

Statistic Values	No			Values based on statistic			
				$C_{D,0}$	0,0184	[-]	
				$\Delta C_{D,slat}$	0,0074	[-]	
				Values for the next steps			
Lift-independent drag coefficient, clean	$C_{D,0}$	Manual input					
		0,02	[-]	$C_{D,0}$	0,0200	[-]	0,02 [-]
Lift-independent drag coefficient, slats	$\Delta C_{D,slat}$	Manual input					
		0	[-]	$\Delta C_{D,slat}$	0,0000	[-]	0 [-]
Certification basis:	FAR part 25						
				Results			
				$C_{L,L}$	1,5385	[-]	1,5384615 [-]
				$\Delta C_{D,flap}$	0,0219231	[-]	0,0219231 [-]
				$\Delta C_{D,gear}$	0,015	[-]	0,015 [-]
				$C_{D,P}$	0,0569231	[-]	0,0569231 [-]
				E_L	8,936	[-]	8,936 [-]
				$\sin(\gamma)$	0,021	[-]	0,021 [-]
				$T_{TO} / m_{MTO}{}^{*}g$	0,16566	[-]	0,1656556 [-]

Reiseflug

Max. glide ratio	E_{max}	No						
Max. glide ratio	E_{max}	20,25	[-]					
				Values for the next steps				
Oswald efficiency factor	e_{cruise}	Manual input						
		0,850	[-]	e_{cruise}	0,850	[-]	0,85	[-]
By-pass ratio	BPR	8,900	[-]	BPR	8,900	[-]	8,9	[-]
Relative wetted area	S_{WET}/S_W	6,000	[-]	S_{WET}/S_W	6,00	[-]	6	[-]
Mach number, cruise	M_{CR}	0,84	[-]	M_{CR}	0,840	[-]	0,84	[-]
Speed ratio	v/v_m	Manual input		v/v_m	0,952	[-]	0,952	[-]
Speed ratio (Manual input)	v/v_m	0,952	[-]	k_E	15,8	[-]	15,8	[-]
Factor k_E	k_E	Manual input						
Factor k_E (manual input)		15,8	[-]					
Equivalent surface friction coefficient	$C_{f,eqv}$	0,003	[-]	Results				
				E_{max}	19,71309886	[-]	19,713	[-]
				$C_{D,0}$	0,0160452	[-]	0,0160452	[-]
Read design point from matching chart!				$C_{L,m}$	0,63	[-]	0,6326023	[-]
(Given data is correct when take-off and landing is sizing the aircraft at the same time.)				$C_L/C_{L,m}$	1,1033825	[-]	1,1033825	[-]
				C_L	0,6980023	[-]	0,6980023	[-]
		Update here!		E	19,618	[-]	19,618	[-]
Wing loading	m_{MTO}/S_W	798,25	[kg/m^2]	m_{MTO}/S_W	798,25	[kg/m^2]	775	[kg/m^2]
Thrust-to-weight ratio	$T_{TO}/(m_{MTO}*g)$	0,31202442	[-]	$T_{TO}/(m_{MTO}*g)$	0,3120244	[-]	0,287	[-]

Entwurfsdiagramm



Kraftstoffmassenanteil einzelner Flugphasen

				Values for the next steps				
Spec.fuel consumption, cruise	SFC_{CR}	0,00001526	[kg/(N*s)]	SFC_{CR}	0,00001526	[kg/(N*s)]	0,00001526	[kg/(N*s)]
Spec.fuel consumption, loiter	SFC_{loiter}	0,00001526	[kg/(N*s)]	SFC_{loiter}	0,00001526	[kg/(N*s)]	0,00001526	[kg/(N*s)]
Distance to alternate	$S_{To,alternate}$	200	[NM]	$S_{To,alternate}$	200	[NM]	200	[NM]
Extra fuel for long range	extra fuel	0,05	[-]	extra fuel	0,05	[-]	0,05	[-]
Relative operating empty mass	m_{OE}/m_{MTO}	Manual input		m_{OE}/m_{MTO}	0,4170	[-]	0,417	[-]
Relative operating empty mass (manual input)	m_{OE}/m_{MTO}	0,417	[-]	n_{PAX}	301	[-]	301	[-]
FAR Part121-Reserves	International			s_{res}	1064900	[m]	1064900	[m]
				t_{loiter}	1800	[s]	1800	[s]
				B_s	32486733,27	[m]	32486733,27	[m]
				B_t	131049	[s]	131048,7953	[s]
Aircraft Type	Business jet			Results of fuel fractions				
M_{ff} per flight phases	Roskam			$M_{ff,CR}$	0,6521	[-]	0,6521	[-]
				$M_{ff,RES}$	0,9678	[-]	0,9678	[-]
				$M_{ff,loiter}$	0,9864	[-]	0,9864	[-]
Fuel-Fraction, engine start	$M_{ff,engine}$	0,98	[-]	$M_{ff,engine}$	0,99	[-]	0,99	[-]
Fuel-Fraction, taxi	$M_{ff,taxi}$	0,992	[-]	$M_{ff,taxi}$	0,995	[-]	0,995	[-]
Fuel-Fraction, take-off	$M_{ff,TO}$	0,99	[-]	$M_{ff,TO}$	0,995	[-]	0,995	[-]
Fuel-Fraction, climb	$M_{ff,CLB}$	0,993	[-]	$M_{ff,CLB}$	0,98	[-]	0,98	[-]
Fuel-Fraction, descent	$M_{ff,DES}$	0,994	[-]	$M_{ff,DES}$	0,99	[-]	0,99	[-]
Fuel-Fraction, landing	$M_{ff,L}$	0,995	[-]	$M_{ff,L}$	0,992	[-]	0,992	[-]
				$M_{ff,std}$	0,6245	[-]	0,6245	[-]
				$M_{ff,res}$	0,9261	[-]	0,9261	[-]
				M_{ff}	0,5783	[-]	0,5783	[-]

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
Department Fahrzeugtechnik und Flugzeugbau

Grundlegende Parameter

Results				
m_F/m_{MTO}	0,4217	[-]	0,4158	[-]
m_{OE}/m_{MTO}	0,4170	[-]	0,417	[-]
m_{PAX}	97,5	[kg]	97,50	[kg]
m_{PL}	64047,50	[kg]	64000,00	[kg]
m_{MTO}	397017,03	[kg]	347800,00	[kg]
m_{ML}	247431,33	[kg]	223200,00	[kg]
m_{OE}	165556,10	[kg]	149200,00	[kg]
m_F	167413,43	[kg]	144600,00	[kg]
S_w	497,36	[m^2]	462,00	[m^2]
T_{TO}	1215253,06	[N]	979220,47	[N]
T_{TO}/n_E	607626,53	[N]	489610,23	[N]
$m_{F,erf}$	170846,00	[kg]	149666,73	[kg]
$V_{F,erf}$	213,56	[m^3]	187,08	[m^3]
m_{MPL}	64047,50	[kg]	64000,00	[kg]
m_{MZF}	229603,60	[kg]	213200,00	[kg]
m_{ZF}	229603,60	[kg]	213200,00	[kg]
$m_{F,res}$	29337,67	[kg]	25700,76	[kg]

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
Department Fahrzeugtechnik und Flugzeugbau

Auslegung der Flugzeugkomponenten

- **Rumpf**

  Kreisquerschnitt, Anzahl der Reihen und Sitze pro Reihe, Rumpflänge und -durchmesser

- **Flügel**

  Pfeilung, Zuspitzung, Profildicke, Querruder, Hochauftriebssysteme

- **Leitwerke**

  Höhenleitwerk und Seitenleitwerk

- **Fahrwerk**

  Raddurchmesser und Radabstand, Anzahl der Räder

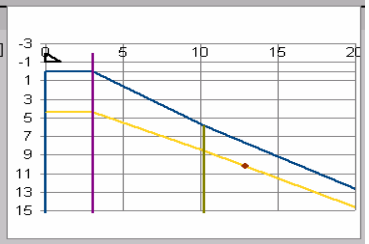
Flügel

Wing design

1 Preliminary sizing data

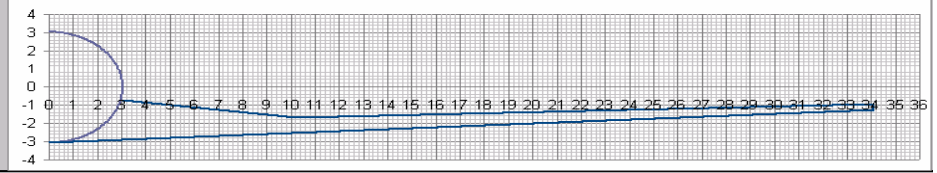
Process Data

max take off weight	m_{MTO}	397017,03 [kg]	Wing loading	W/S	798,25 [kg/m²]	
wing area	S ref	497,36 [m²]				
Fuselage diameter	d_f	6,10 [m]				
cruise mach number	Mc	0,840 [-]				
cruise lift coefficient	C_{Lc}	0,6980023 [-]				
(•) Aspect ratio	A	9,34 [-]	→ Wing Span	b	68,16 [m]	
( ) Wing Span	b	64,80 [m]	→ Aspect ratio	A	8,45 [-]	



2 Overall wing - fuselage arrangement

select wing - fuselage arrangement: low wing



3 Sweep anlge

outer Sweep angle		$\Lambda_{25,o}$	32,00 [°]	sweep LE	$\Lambda_{LE,o}$	34,79 [°]
↑	howe		27,92 [°]	sweep 50%c	$\Lambda_{50,o}$	29,03 [°]
↑	raymer		26,80 [°]	sweep TE	$\Lambda_{TE,o}$	22,55 [°]
				Sweep x%c	x= 10	33,69 [°]
inner Sweep angle		$\Lambda_{25,i}$	30,00 [°]	sweep LE	$\Lambda_{LE,i}$	39,42 [°]
↑	single leading edge		24,24 [°]	sweep 50%c	$\Lambda_{50,i}$	18,41 [°]
				sweep TE	$\Lambda_{TE,i}$	-8,88 [°]
				sweep x%c	x= 10	35,91 [°]

Vorgabedatei von PrADO

DB3 Discription of Winggeometry

				0	2	1	1	**ANFANG-DB3
								C
								C
								C
								C ----------
								C 1. INFORMATION SPECIFYING: Wing Configuration
								C ----------
								C
								C ---------
								C DATA SETS
								C ---------
								C
								<-NF - No. of wings
				0	2	1	1	0 2 1 1
Number of wings	2	→	2					2
								<-IPF1 - Control parameter/type at trailing edge flap/wing
Trailing edge flap/wing								0 2 1 1
Double slotted	5	→	5					5
								<-IPF2 - Control parameter/type of leading edge flap/wing
Leading edge flap/wing								0 2 1 1
Slat	3	→	3					3
								<-FLPOS1 - Position vector/first wing (No. 1)
Position vector/first wing (No. 1)				0	3	1	6	0 3 1 6
Retaining component: Fuselage	1	→	1					1 1 0.36 -0.45 50 0
Number of retaining component	1	→	1					<-FF m**2 Reference area/wing
Relative X-Coordinate	0,36	→	0.36	0	3	1	1	0 3 1 1
Relative Z-Coordinate	-0,45	→	-0.45					497.362115582196
Position of wing Pivot [%]	50	→	50					<-LAMDAF - Aspect ratio/wing
pitch angle/ geometric assembly angle [degree	0	→	0					0 3 1 1
Wing reference area [m^2]	497,36	→	497.362115582196					9.34
Given: Aspect ratio								<-SRF mm Surface roughness/wing
Wing aspect ratio	9,34	→	9.34					0 3 1 1
Surface roughness/wing [mm]	0,01	→	0.01					0.01
								<-FNKBESF - Span occupation degree with leading edge flaps/wing
								0 3 1 1
Span occupation degree with leading edge flaps/v	0,85	→	0.85					0.85

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences
Department Fahrzeugtechnik und Flugzeugbau

Fazit

- Statistiken eingefügt
- Datenbank und die Vorgabedatei erstellt
- Alle Dateien miteinander verknüpft und vereinheitlicht
- Ein Beispielflugzeug dimensioniert
- PreSTo auf die Richtigkeit geprüft
- Erweiterung von PreSTo: Die Statistiken auch über die Nutzlast auftragen