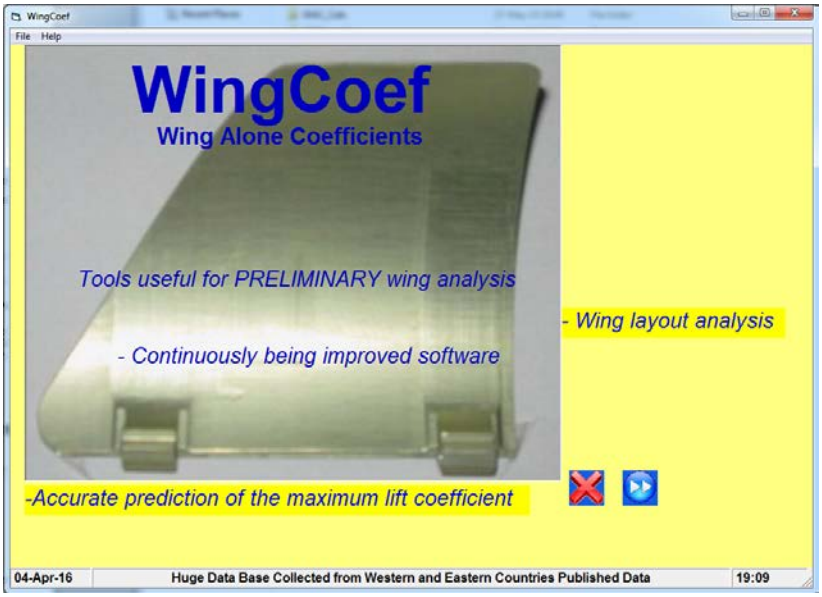
PROGRAM WingCoef - WING ALONE AERODYNAMIC COEFFICIENTS – DESCRIPTION –

1. PURPOSE AND POSSIBILITY

The purpose of the program is preliminary aerodynamic design, quick and easy estimation of aerodynamic coefficients of wing alone. Program calculates non-linear static coefficients and their derivatives and linear dynamic coefficients of the wings alone. The program is based on following sources: Russian literature (Lebedev[1]) and Belocerkovski[2]), and western literature (Martin-Marietta[3]) and Wing[4]). The calculation procedure could be done as a function of Mach number or of angle of attack for various shapes of wings: delta wings, rectangular and clipped delta wings. Aerodynamics characteristics of wing alone obtained by the program can be used as input data for programs which calculates aerodynamic coefficients of whole configuration.



Welcome window

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1) Лебедев, А.А., Чернобровкин, Л.С.: *Динамика полета беспилотных летательных аппаратов*, Машиностроение, Москва 1973.

2) Белоцерковский, С. М., Скрипач, Б. К., Табачников В. Г.: *Крыло в нестационарном потоке газа*, Наука, Москва, 1971.

3) Aielo, G. F., Batewan. M. C., “Aerodynamic Stability Technology for Maneuvrable Missiles”, ADA 070250. 1979.

4) Nielsen, J.N., Hemsch, M.J., Smith, C.A.: “A Preliminary Method for Calculating the Aerodynamic Characteristics of Cruciform Missiles to High Angles of Attack Including Effects of Roll Angle and Control Deflections”, ONR-CR215-226-4F (ADA 054349), Nielsen Engineering & Research, Inc. Mountain View, California 94043, 1977.

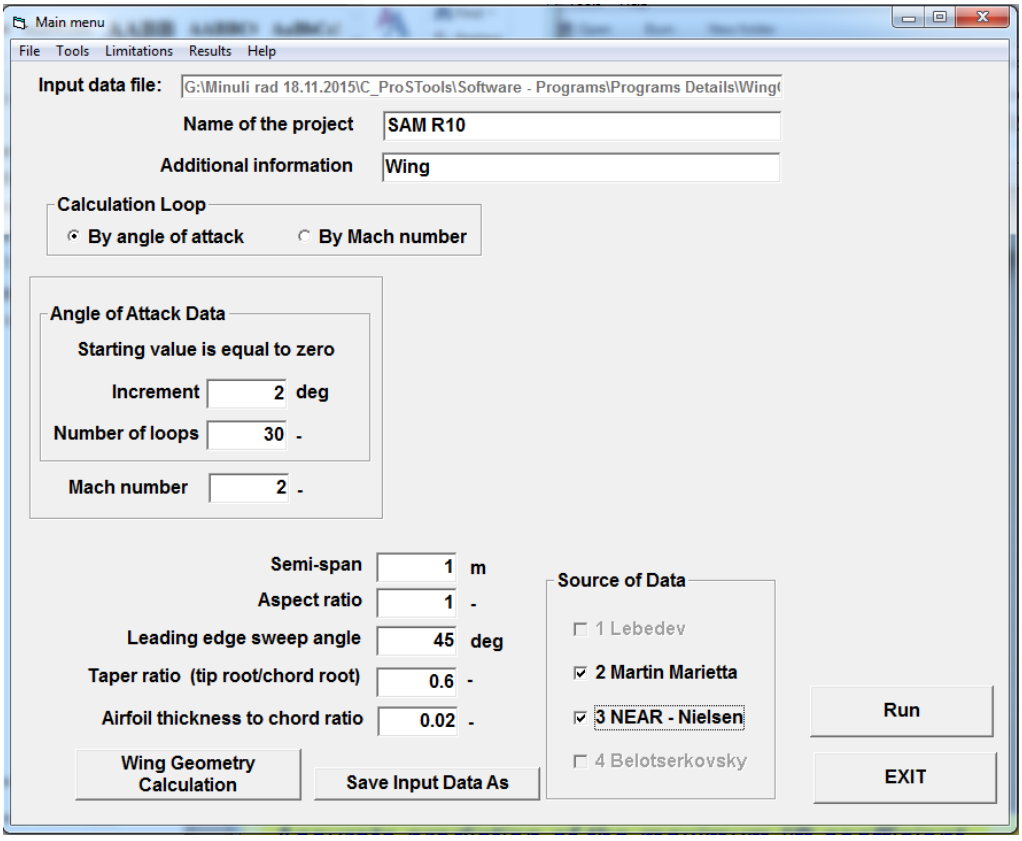
2. LIMITATIONS

Limitations of input parameters depend on method to be used and are listed in the above table

Source	Mach number	Aspect ratio	Angle of attack (degree)
Lebedev	0÷5	0÷∞	0÷20
Belocerkovski	0÷5	0÷∞	0÷6
Martin-Marietta	0.8÷3	0.5÷2.6	0÷180
Wing	0.8÷3	0÷2.6	0÷90

3. INPUT DATA

Geometrical and aerodynamic characteristic of trapezoid shapes wings (aspect ratio, leading edge sweep angle, taper ratio and airfoil thickness to chord ratio. Data can be entered through GUI as shown in next figure.



Main input data window.

Input file content

The content and structure of file with input data is given in the next table. It can be formed by user through Notepad editor and save as ".dat" file. It is also formed automatically under the name "Restart.dat" when program

finish successfully (recommended option).

No.	Symbol	Description	Units
1.	*Name*	Project name (30 characters)	-
2.	*Info*	Additional information about missile (60 characters)	-
3.	i_{calc}	Type of calculation identifier: 1 – in function of angle of attack, 2 – in function of Mach number ,	-
4.	Ma	Mach number for the calculation	-
5.	$(Ma)_{\min}$	Starting Mach number	-
6.	ΔMa	Increment of Mach number	-
7.	n_{Ma}	Number of do-loops for calculation	-
8.	$b/2$	Semi-span of the wing alone	m
9.	A	Wing alone aspect ratio	-
10.	Λ_0	Leading-edge sweep angle	deg
11.	λ	Taper ratio $(\lambda = c_t/c_r)$	-
12.	t/c	Airfoil thickness to chord ratio	-
13.	$\Delta\alpha$	Increment of angle of attack	deg
14.	n_α	Number of do-loops for calculation	-
15.	α	Angle of attack for calculation	deg
16.	i_{method}	Method of calculation identifier 1 – Lebedev 2 – Martin Marietta 3 – NEAR – Nielsen 4 – Belotserkovsky	-
17	i_{end}	$i_{\text{end}} = 5$, End of calculation identifier	-

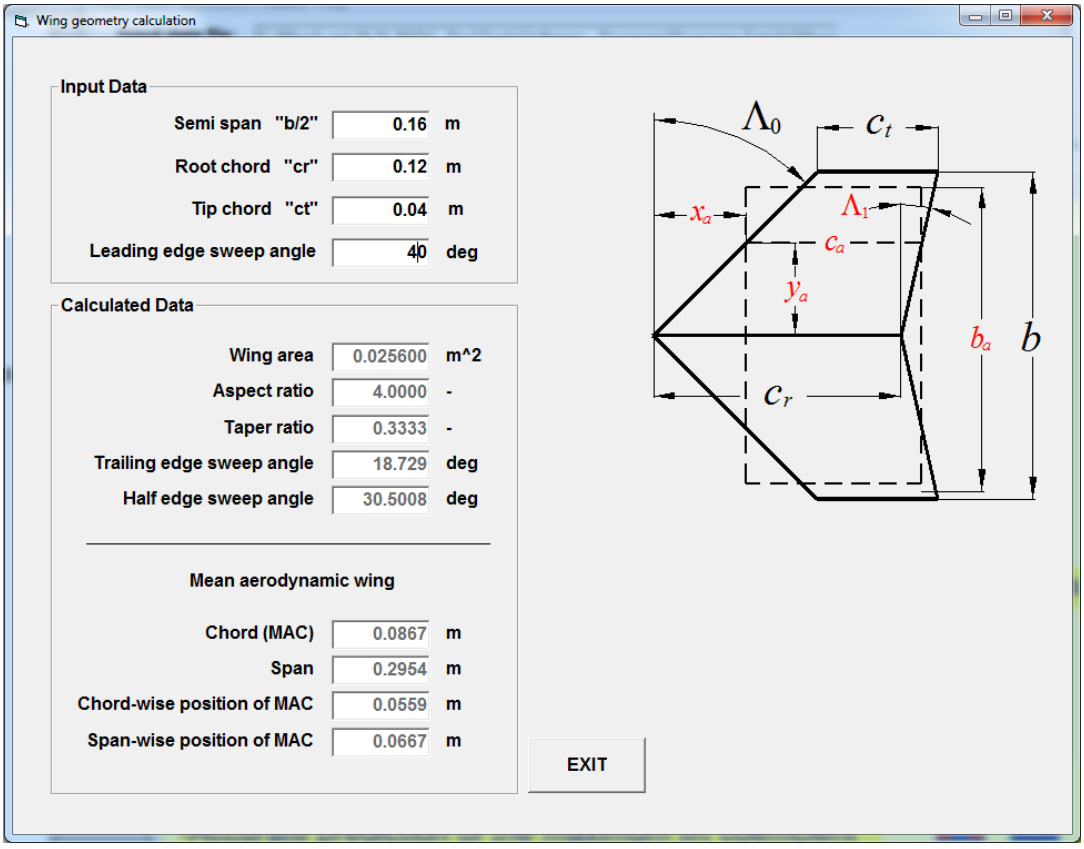
Example 1. – Content of the file SparrowWing-Alpha.txt

```
SPARROW
FIRST WING SECTION
         1 - ANGLE OF ATTACK DO LOOP
     1.500 - MACH NUMBER
     0.398 - SEMI SPAN OF WING ALONE [m]
     2.594 - WING ALONE ASPECT RATIO
    45.000 - WING LEADING EDGE SWEEP ANGLE [deg]
     0.196 - WING TAPER RATIO (Ct/Cr)
     0.060 - AIRFOIL THICKNESS TO CHORD RATIO
     2.000 - INCREMENT OF ANGLE OF ATTACK [deg]
```

```
         5 - NUMBER OF ANGLES OF ATTACK
         1 - LEBEDEV
         2 - MARTIN-MARIETTA
         3 - NEAR
         4 - BELOTSERKOVSKY
         5 - STOP
```

Example 2. – Content of the file SparrowWing-Mach.txt

```
SPARROW
 FIRST WING SECTION
         2 - MACH NUMBER DO LOOP
       0.850 - STARTING MACH NUMBER
      0.100 - INCREMENT OF MACH NUMBER
        20 - NUMBER OF LOOPS FOR CALCULATION
     0.398 - SEMI SPAN OF WING ALONE [m]
     2.594 - WING ALONE ASPECT RATIO
    45.000 - WING LEADING EDGE SWEEP ANGLE [deg]
     0.196 - WING TAPER RATIO (Ct/Cr)
     0.060 - AIRFOIL THICKNESS TO CHORD RATIO
     10.000 - VALUE OF ANGLE OF ATTACK [deg]
         1 - LEBEDEV
         2 - MARTIN-MARIETTA
         3 - NEAR
         4 - BELOTSERKOVSKY
         5 - STOP
```



Wing geometry calculation window.

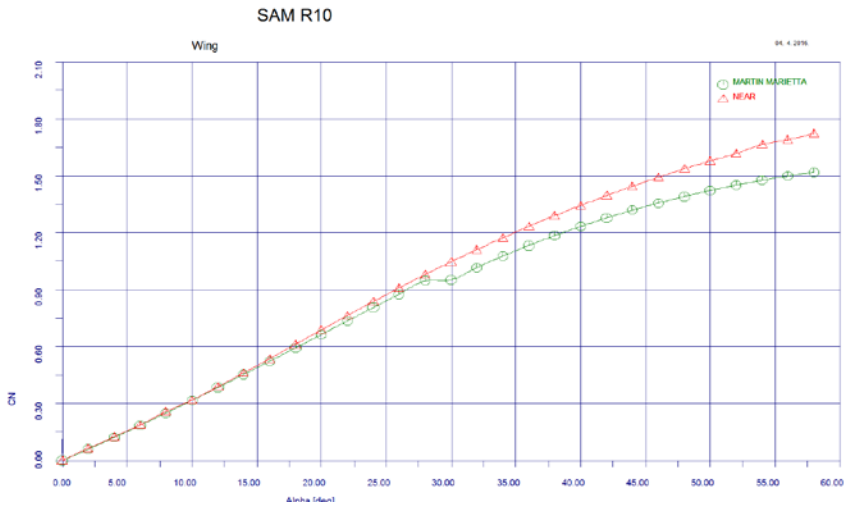
4. OUTPUT DATA

Output results are placed in next files: *TABLE.DAT* and *DRAW.DAT* with wing normal force coefficient and axial and lateral position of wing normal force if table form and in form prepared for obtaining picture of results. All data are also plotted on graphs.

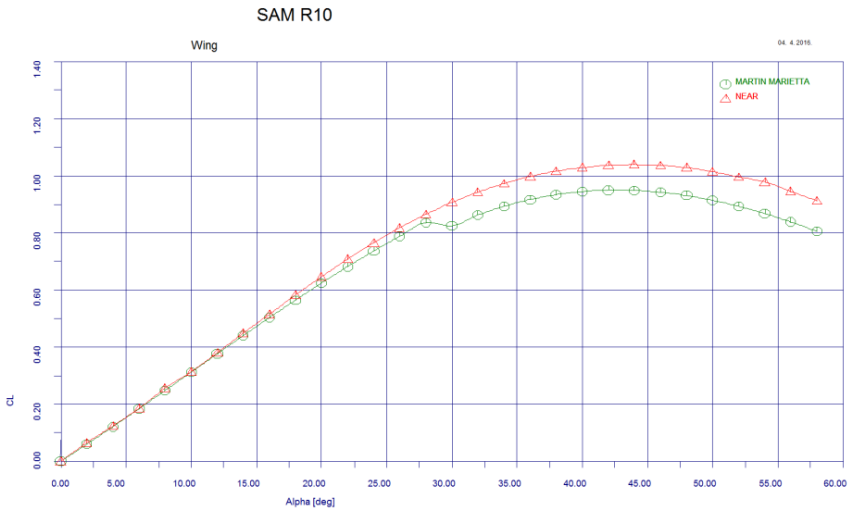
Coefficient vs. Angle of Attack

Files of output data in function of angle of attack

File Name		Short Description
OutputVsAlpha.dat	–	File contains summary of aerodynamic coefficients in function of angle of attack in tabular form and input data used for calculation.
ACvsAlpha.dat	–	File contains static aerodynamic coefficients in function of angle of attack.
ACvsAlphaDamp.dat	–	File contains damping derivatives of aerodynamic coefficients. File is formed only in the case when Belotserkovsky metod is chosen as calculation option.
Restart.dat	–	File contains input data to start (restart) program.
Messages.dat	–	File contains program run time messages.



Nonlinear normal force coefficient – comparison of two methods.

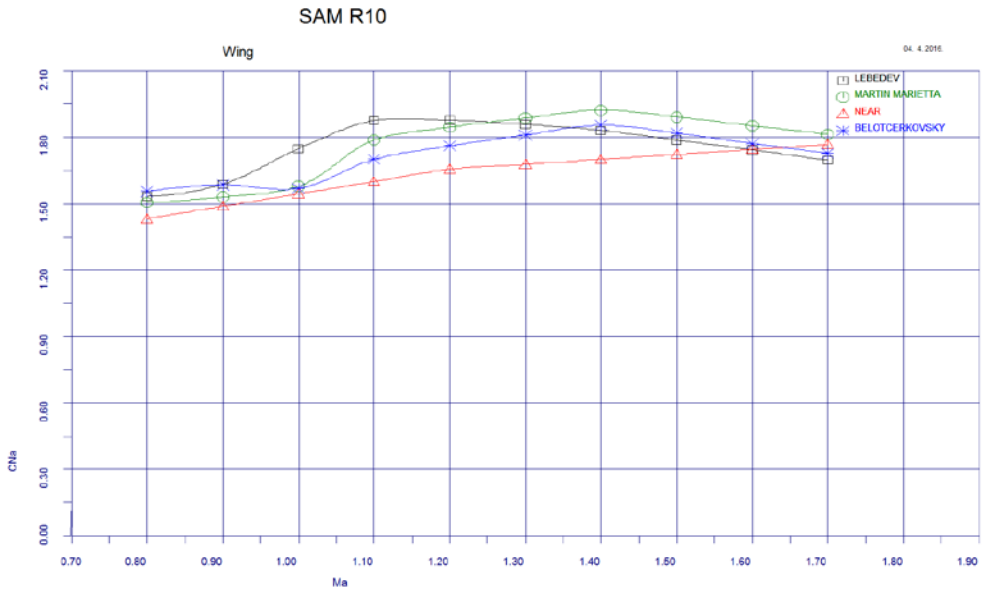


Nonlinear lift force coefficient – comparison of two methods.

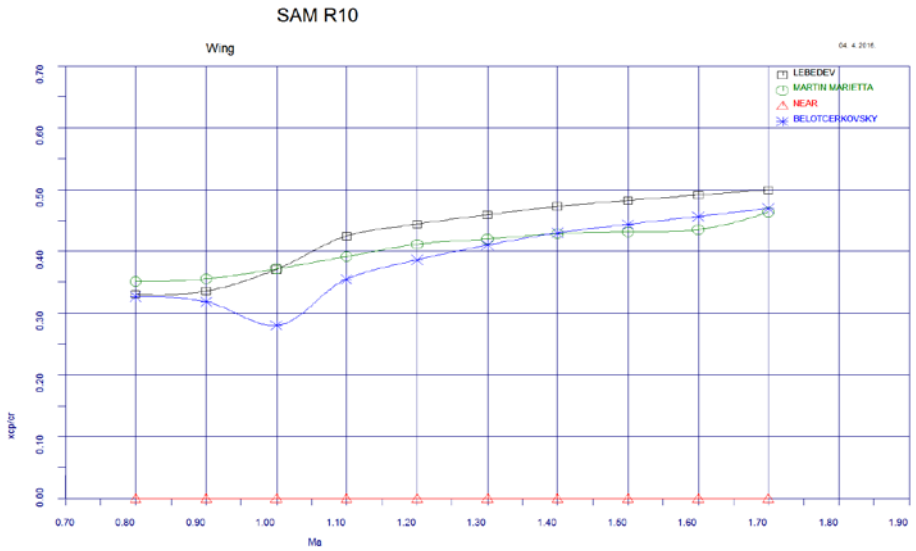
Coefficient vs. Mach Number

Files of output data in function of Mach number

File Name		Short Description
OutputVsMach.dat	–	File contains summary of aerodynamic coefficients in function of Mach number in tabular form and input data used for calculation.
ACvsMach.dat	–	File contains static aerodynamic coefficients in function of Mach number.
ACvsMachDamp.dat	–	File contains damping derivatives of aerodynamic coefficients in function of Mach number.
Restart.dat	–	File contains input data to start (restart) program.
Messages.dat	–	File contains program run time messages.



Normal force coefficient derivative – comparison of four methods.



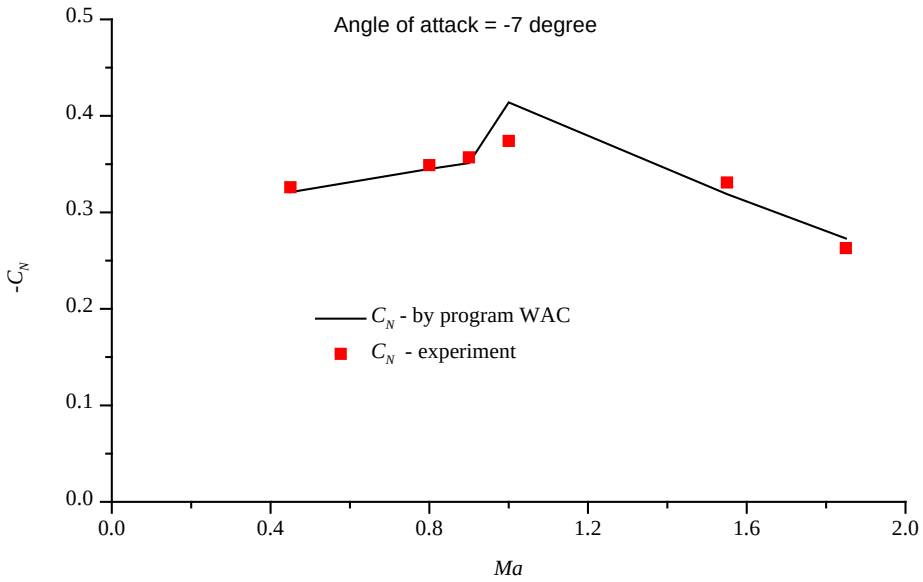
Center of pressure – comparison of three methods.

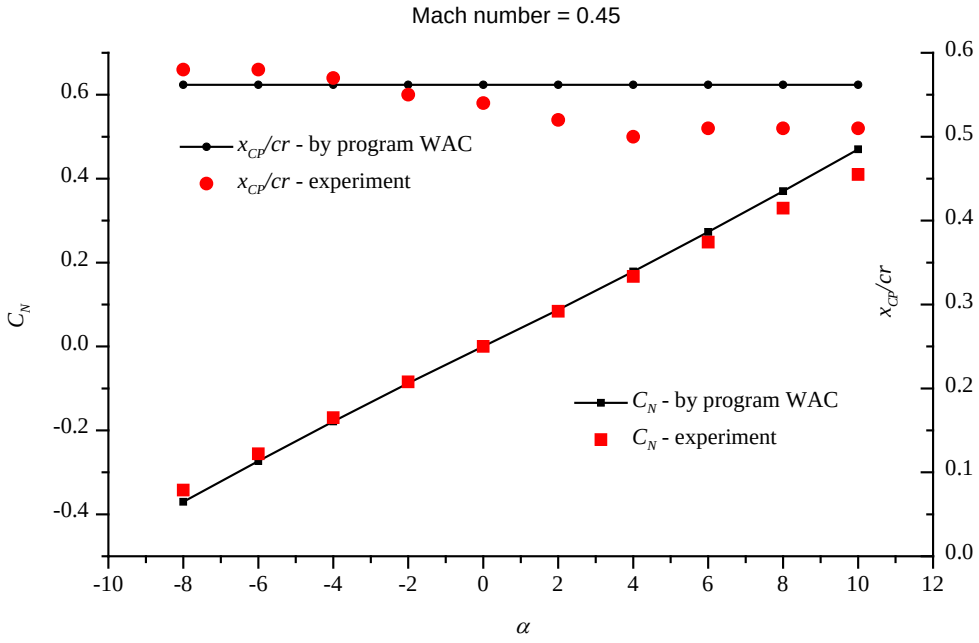
Example - OutputVsMach.dat

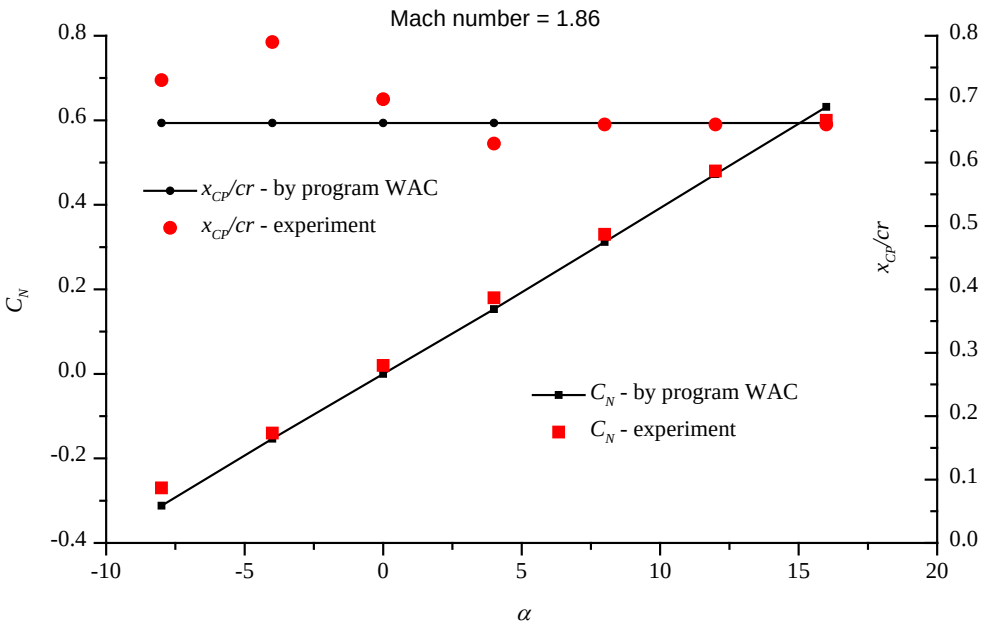
```
 AERODYNAMIC CHARACTERISTIC OF WING ALONE
       SAM R10
       Wing
       DATA SOURCE: LEBEDEV
Alpha = 0.00 deg
ASPECT RATIO = 1.000  WING LEADING EDGE SWEEP ANGLE =45.00 deg
TAPER RATIO =0.600 AIRFOIL THICKNESS TO CHORD RATIO =0.020

       Ma         CNa          CN          CL        Xcp/Cr     Ycp/(b/2)

     0.500      1.4546      0.0842      0.0841       0.3322       0.4277
     0.600      1.4719      0.0851      0.0850       0.3308       0.4277
     0.700      1.4965      0.0863      0.0862       0.3300       0.4278
     0.800      1.5329      0.0882      0.0880       0.3309       0.4279
     0.900      1.5881      0.0909      0.0908       0.3356       0.4281
     1.000      1.7480      0.0989      0.0987       0.3706       0.4288
     1.100      1.8758      0.1052      0.1050       0.4247       0.4293
     1.200      1.8771      0.1047      0.1046       0.4439       0.4297
     1.300      1.8586      0.1033      0.1031       0.4590       0.4299
     1.400      1.8316      0.1014      0.1013       0.4724       0.4302
     1.500      1.7878      0.0987      0.0986       0.4822       0.4304
     1.600      1.7433      0.0960      0.0958       0.4910       0.4307
     1.700      1.6956      0.0930      0.0929       0.4995       0.4309
     1.800      1.6492      0.0902      0.0900       0.5077       0.4311
     1.900      1.6009      0.0872      0.0871       0.5133       0.4317
     2.000      1.5534      0.0843      0.0841       0.5187       0.4322
```

5. COMPARISON WITH EXPERIMENTS

For wing with following characteristics: aspect ratio – 2.26, taper ratio – 0.018, airfoil thickness to chord ratio – 0.025, leading edge sweep angle – 60 degree. Results of calculation are compared with experiment and shown on following diagrams:


Angle of attack = -7 degree
0.5
0.4
0.3
0.2
0.1
0.0
-C_N
0.0
0.4
0.8
1.2
1.6
2.0
Ma
C_N - by program WAC
C_N - experiment


Mach number = 0.45
0.6
0.4
0.2
0.0
-0.2
-0.4
C_N
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
α
0.6
0.5
0.4
0.3
0.2
0.1
0.0
x_{CP}/cr
x_{CP}/cr - by program WAC
x_{CP}/cr - experiment
C_N - by program WAC
C_N - experiment


Mach number = 1.86
x_{CP}/cr - by program WAC
x_{CP}/cr - experiment
C_N - by program WAC
C_N - experiment
C_N
x_{CP}/cr
α
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
0.7
0.5
0.3
0.1
-10
-5
0
5
10
15
20