WORK 1: **ANALYTICAL CALCULATION OF THE SUPERSONIC DIFFUSER AND NOZZLE**

(DEADLINE: 50% of the course)

PART 1

Goal: Find the optimal geometry of the **planar supersonic diffuser** (Fig. 1), which has a 3-shockwave configuration (2 oblique and one normal shockwave) with the minimal losses of full pressure and maximum mass-flow rate, varying independent variables.

Independent variables are θ_1, θ_2 - angles of the diffuser wall and M_∞.

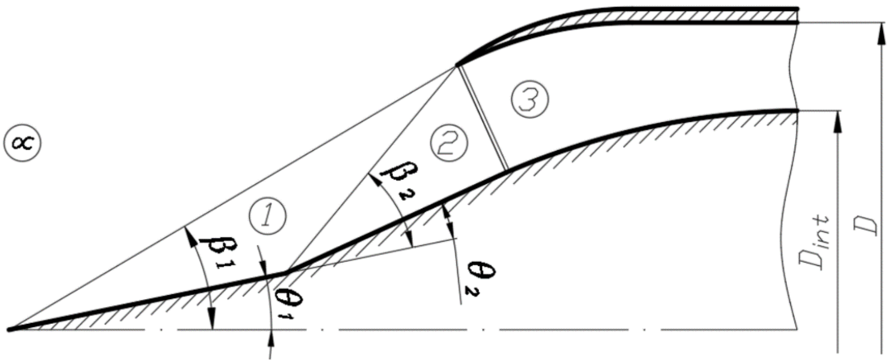

Fig. 1 Planar supersonic diffuser

General rules for the Report:

1. Make a report using ABNT format;
2. Keep the same text size all over the work, including figures;
3. Do rounding of the numbers to 4-digits or less. Works with more than four significant digit numbers will not be accepted;
4. Put report filename: "WORK *Number* – *Name*.PDF," where *Number* =1 for Work1, 2 for Work2, etc., Name – Student's full name;
5. Use just good or excellent-quality images with a white background;
6. The size of text on images should be similar to the size of the main text and readable;
7. The graphs should have square or close to Golden Ratio proportions;
8. Put MATLAB code in the appendix. Archives (*.zip, *.rar, etc.) are not accepted;
9. **Will not be accepted:**
   - pictures and tables with a colorful or black background;
   - pictures of tables, text, or formulas;
   - reports with very little text, which does not allow evaluation of the Report.

Report structure (part 1):

1. Build the equation system describing the flow inside the planar 3-shockwave diffuser [1]. *Try to avoid information that will not be used directly in current work*;
2. Describe the method of the optimal diffuser search [2], the gradient search method is recommended;
3. Calculate the diffuser using the models (it.1 and 2);

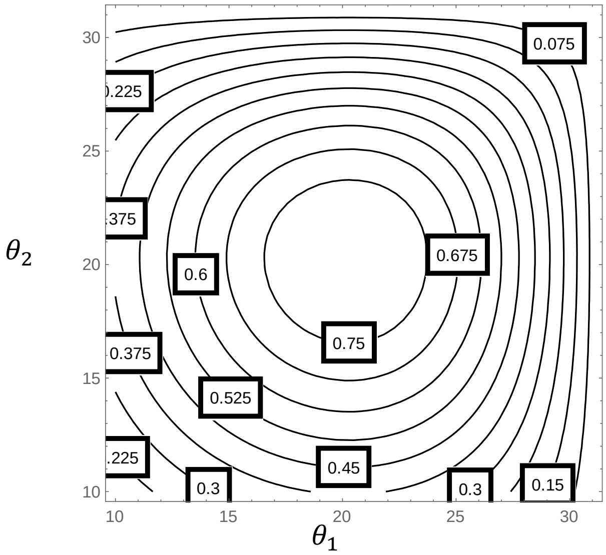

Fig. 2 Efficiency of the diffuser

4. Tabulate and plot the flow properties M, P, T, V, ρ, pressure losses at stations 1 - 3, drag force, similar to the following:

Parâmetro \ Ponto	∞	1	2	3
Mach				
Pressão (10^x Pa)				
Temperatura (K)				
Velocidade (m/s)				
Densidade (kg/m^3)				

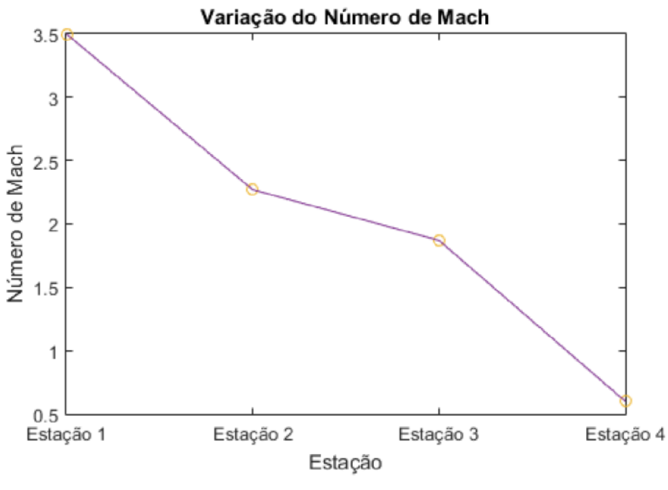

Fig. 3 Variation of the Mach number

PART 2

Goal: Analyze analytically flow in the conical and bell-shaped nozzles using the results from PART *1*.

Initial Data: From PART *1*.

Report structure (part 2):

1. Build the equation system describing the flow with the heat addition [3];
2. Build the equation system describing the flow inside the convergent-divergent nozzle [1 – 2].

Try to avoid useless information in current work.

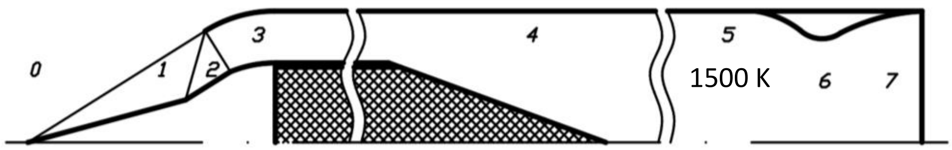

Fig. 4 Flow in the Ramjet motor

3. Take results from *PART 1* at the exit of the diffuser (Fig. 4, point 3). Calculate the change of the flow properties between points 4 and 5 due to the flow area change. Assume the heat addition, which raises the temperature of the flow in zone 5 by T=1500K (point 5) [3]. Using the nozzle inlet diameter (point 5) equal to the diffuser exit diameter $D_{inlet} = D_{diff}$, calculate the flow properties in the nozzle inlet with the assumption of the isentropic processes.

4. Calculate the nozzle geometry, starting from initial parameters (point 5), use the nozzle exit diameter equal to combustion chamber diameter $D_{exit} = D_{diff}$, (Fig. 5);

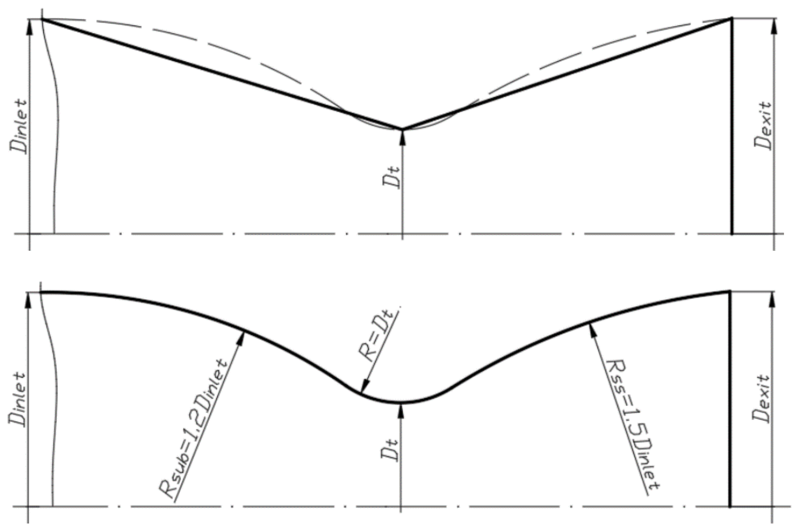

Fig. 5 The Nozzles: conical and bell-shaped (recommended sizes)

5. Calculate the flow properties (M, P, T, V, ρ) analytically inside the

   a) conical nozzle;
   b) bell-shaped nozzle;
   Build the graphics similar to Ref. 1, Fig 10.12;

6. Compare results of calculation (5.a) and (5.b);

7. Make a drawing of the **diffuser** and **nozzle** in CAD software, indicating the dimensions (sizes and angles) and shockwave angles.

Initial Data

Diffuser size D=0.1m

No.	Student's Name	Mach	Altitude, km
1	Alex da Motta Chaves	2.0	0
2	Alexandre Ponte Carvalho	2.5	0
3	Allecsander Lelis Silva	3.0	0
4	Ana Paula Lopes Gonçalves	3.5	0
5	Arthur Borges Bringel Machado	2.0	3
6	Beatriz Carvalho Wang	2.5	3
7	Bruna Leticia Souza Fontes	3.0	3
8	Bruna Lorrane Jardim Ribeiro	3.5	3
9	Bruno Giuliani Gomes	2.0	6
10	Felipe Moreno Lago dos Anjos	2.5	6
11	Fernando Barroso Vasconcelos Mendes	3.0	6
12	Gabriel Metre Resende	3.5	6
13	Giulliano Cezar Ferreira Fonseca Santos	2.0	10
14	Isaac Moura de Alencar	2.5	10
15	Isabella Feitosa Policema	3.0	10
16	Jean de Andrade Silva	3.5	10
17	Jonas Santos de Oliveira	2.0	15
18	Júlia Ribeiro Felipe	2.5	15
19	Leonardo Julio Chagas Souza	3.0	15
20	Lidiane Lais Silva Santos	3.5	15
21	Lucas Alves Ferreira de Sousa	2.0	18
22	Luiz Alexandre de Goes Nogueira Georg	2.5	18
23	Mateus Silva Sant'Ana	3.0	18
24	Matheus Borges Sampaio	3.5	18
25	Matheus Filippe Santos Alves	2.0	22
26	Mayra Carolina Pinto de Souza	2.5	22
27	Natalia Martimon Ferreira	3.0	22
28	Nicolle Augusta Moreira Lucena	3.5	22
29	Pedro Lacerda Montes	2.0	25
30	Rafael Paiva Lobo	2.5	25
31	Roberto Diniz Ramalho da Rocha	3.0	25
32	Victor Augusto Pereira da Silva	3.5	25
33	Victor Tadeu Ribeiro Baptista	3.0	30
34	Vitor Mendes Pacheco de Freitas	3.5	30
35	Wivian Alves dos Reis Correa	2.5	30
36		2.0	30

References:

1. Anderson, J. Fundamentals of Aerodynamics, McGraw-Hill, 5th edition, 2010.
2. BERTSEKAS, Dimitri P; NEDIC, Angelia; OZDAGLAR, Asuman E. Convex analysis and optimization. Belmont: Athena Scientific, 2003. xv, 534 p. ISBN 1886529450
3. ANDERSON, John David. Modern compressible flow: with historical perspective. 3rd ed. New York: McGraw-Hill, 2003. xvi, 760 p. ISBN 9780072424430).