

Report 6: Oblique Shock Wave

Submitted to:
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By:

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Nomenclature

N.S. Navier Stokes, page 1

| w.r.t. with respect to, page 1

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1 Problem Statement

Produce charts that describe the change of supersonic flow properties when it turned away from itself.

2 Mathematical Model

The most general governing equation is N.S. equation. This is any dummy text just to show the capabilities of nomenclatures of L^AT_EX w.r.t. L^AT_EX.

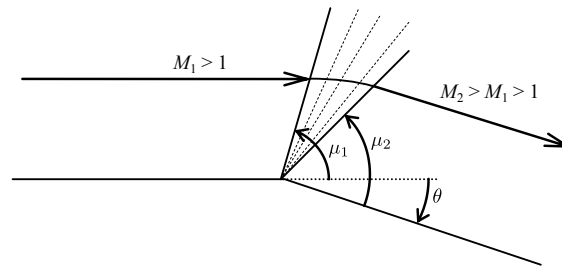
$$\mu = \sin^{-1} \left(\frac{1}{M} \right) \quad (1)$$

$$\left(\frac{a_0}{a} \right)^2 = 1 + \frac{\gamma - 1}{2} M^2 \quad (2)$$

3 Assumptions

- | | |
|--|--|
| <ol style="list-style-type: none">1. Steady Flow2. Quasi-dimensional flow; (area is variable with x only).3. Body forces can be neglected; (weight of fluid).4. Viscous stresses are absent. | <ol style="list-style-type: none">5. Changes in potential energy are neglected.6. Perfect gas.7. Thermally perfect gas.8. Adiabatic flow with no external work. |
|--|--|

4 Analysis

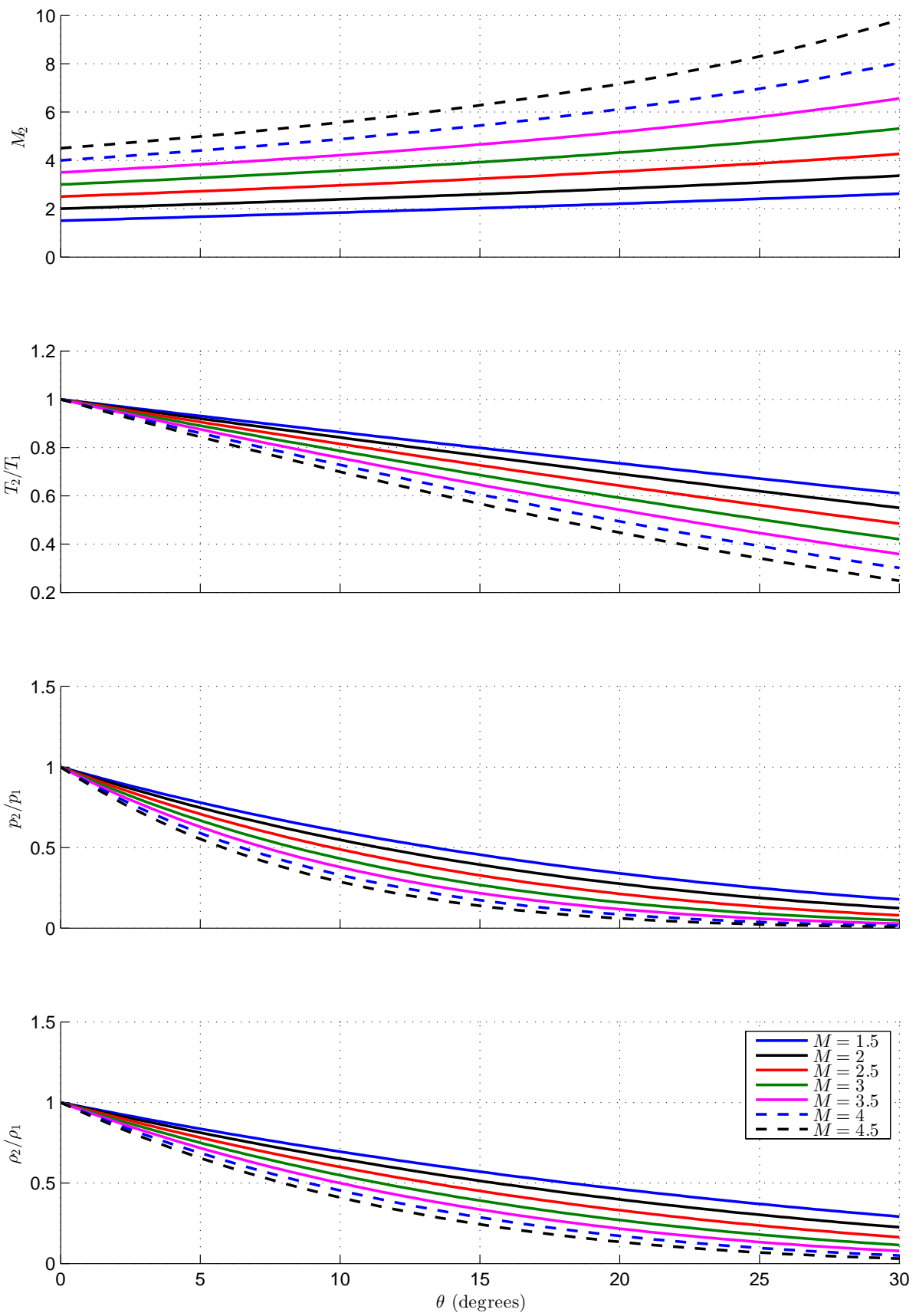


We can derive the formula that governs super flow expansion as:

$$\nu(M_1) = \nu(M_2) + \theta \quad (3)$$

$$\nu(M) = \sqrt{\frac{\gamma + 1}{\gamma - 1}} \tan^{-1} \left(\sqrt{\frac{\gamma - 1}{\gamma + 1}} (M^2 - 1) \right) \tan^{-1} \left(\sqrt{M^2 - 1} \right) \quad (4)$$

4.2 Results



The following table is just for demonstration. It doesn't provide any useful information.

Angle(θ)	Temperature	Pressure	Density
0	123	111	444
20	500	222	444
40	640	222	444
90	200	222	444

5 Conclusion

We see that we can still obtain solutions for M_2 for $\theta > 90^\circ$. But, however I think the solutions for $\theta > 90^\circ$ aren't practical.

Pressure, temperature & density increases as the kinetic energy increase as in [1].

Appendices

A Matlab Codes

Code 1: Report6_main.m

```
1 clc
2 close all
3 clearvars
4
5 set(groot, 'DefaultAxesColorOrder', [0,0,1;0,0,0;1,0,0;0,0.5,0;1,0,1])
6 set(groot, 'DefaultAxesLineStyleOrder', '-|--|-.')
7 set(groot, 'DefaultLineLineWidth', 1.5);
8
9 gamma=1.4;
10 theta_d_vec=linspace(0,30);
11
12 M_1_vec=1.5:.5:4.5;
13
14 yAxesTitles_tex={'M_{2}', 'T_{2}/T_{1}', 'p_{2}/p_{1}', '\rho_{2}/\rho_{1}'}
15     };
16 for ii=1:length(yAxesTitles_tex)
17     subplot(length(yAxesTitles_tex),1,ii);
18     hold on;
19     grid;
20     if ii~=length(yAxesTitles_tex), set(gca, 'XTickLabel', []);end
21     ylabel(['$', yAxesTitles_tex{ii}, '$'], 'interpreter', 'latex');
22 end
23 xlabel('$\theta_{\text{d}}$ (degrees)', 'interpreter', 'latex'); %This applies to the
24     bottom subplot
25 M_1_legend_tex=cell(length(M_1_vec),1);
26 ii=1;
27 for M_1=M_1_vec
28     M_2=M_2o(M_1, theta_d_vec, gamma);
29     subplot(4,1,1); plot(theta_d_vec, M_2);
30
31     T_2_T_1=(1+(gamma-1)/2*M_1*M_1)./(1+(gamma-1)/2*M_2.^2);
32     subplot(4,1,2); plot(theta_d_vec, T_2_T_1);
33
34     p_2_p_1=T_2_T_1.^(gamma/(gamma-1));
35     subplot(4,1,3); plot(theta_d_vec, p_2_p_1);
36
37     rho_2_rho_1=T_2_T_1.^(1/(gamma-1));
```

```

38 subplot(4,1,4);plot(theta_d_vec,rho_2_rho_1);
39
40 M_1_legend_tex{ii}=['$M= ',num2str(M_1),'$'];
41
42 ii=ii+1;
43 end
44
45 legend(M_1_legend_tex,'interpreter','latex');
46
47 set(groot,'DefaultAxesColorOrder','remove')
48 set(groot,'DefaultAxesLineStyleOrder','remove')
49 set(groot,'DefaultLineLineWidth','remove');
50
51 export_figure(gcf,'||',{ 'figures'},[],{'pdf','emf'})

```

Code 2: function M_2o.m

```

1 function M_2_vec=M_2o(M_1,theta_d_vec, ...
2     gamma) %optional arguments
3 if nargin<3
4     gamma=1.4;
5 end
6
7 theta_vec=deg2rad(theta_d_vec);
8 n1=sqrt((gamma+1)/(gamma-1))*atan(sqrt((gamma-1)/(gamma+1)*(M_1^2-1)))-
9     atan(sqrt(M_1^2-1));
10 %Newton Raphson iteration
11 M_2_vec=1.1*ones(size(theta_d_vec));
12 for ii=1:length(theta_d_vec)
13     f=sqrt((gamma+1)/(gamma-1))*atan(sqrt((gamma-1)/(gamma+1)*(M_2_vec(ii)
14         ^2-1)))-atan(sqrt(M_2_vec(ii)^2-1))-theta_vec(ii)-n1;
15     fdash=1/(M_2_vec(ii)^2-1)^(1/2)*M_2_vec(ii)/(1+(gamma-1)/(gamma+1)*
16         (M_2_vec(ii)^2-1))-1/(M_2_vec(ii)^2-1)^(1/2)/M_2_vec(ii);
17     M_2_n=M_2_vec(ii)-f/fdash;
18     while abs(M_2_vec(ii)-M_2_n)>=100*eps %This is dangerous. Infinte loop
19         can occur!!
20         M_2_vec(ii)=M_2_n;
21         f=sqrt((gamma+1)/(gamma-1))*atan(sqrt((gamma-1)/(gamma+1)*(M_2_vec
22             (ii)^2-1)))-atan(sqrt(M_2_vec(ii)^2-1))-theta_vec(ii)-n1;
23         fdash=1/(M_2_vec(ii)^2-1)^(1/2)*M_2_vec(ii)/(1+(gamma-1)/(gamma+1)
24             *(M_2_vec(ii)^2-1))-1/(M_2_vec(ii)^2-1)^(1/2)/M_2_vec(ii);
25         M_2_n=M_2_vec(ii)-f./fdash;
26     end
27     M_2_vec(ii)=M_2_n;

```

24 | [end](#)

References

- [1] J. D. Anderson, Modern Compressible Flow, McGraw-Hill, New York, 1990.
- [2] Report (1).
- [3] Report (3).