Technical Report Writing

In addition to performing the engineering activities, an engineer has to prepare operating and assembly manuals, requests for proposals (RFP), responses to proposals, research and development reports, and articles for publications. Writing for these specific purposes is called technical writing. Technical writing is totally different from creative writing. The difference between the two styles of writing is similar to the difference between a text on Physics and a novel. A technical report or a paper generally consists of reporting and/or interpretation of data/physical phenomena. The report should be written in a purely objective and impersonal manner and reflect the writer’s effort in addressing a technical problem. The results are to be judged on the basis of engineering experience and common sense. Most technical reports are written in third person, past tense. Generous use of the technical terminology is employed. For the description of the laboratory equipment, scientific laws and the presentation of results, present tense should be employed. The use of personal pronouns should be avoided. A technical report generally contains a clear outline of the problem, mathematical equations, drawings, charts, tables and graphs, etc. For completeness purposes, they always require explanations at appropriate locations within the text of the report. Technical reports must be accurate and to the point. Superfluous and unsupported assertions should never be made. Conclusions and recommendations must be based on the results presented in the report. It must be technically correct and without any ambiguities. In this respect technical report writing is hard work.

A report or a technical paper usually consists of the following parts.

1. Title Page
2. Nomenclature
3. Abstract (or Summary)
4. Introduction (or Background)
5. Technical Approach (or Methodology)
6. Description of Experimental Setup and Tools Used
7. Results
8. Conclusions

Explanation

1. Title Page:
   The title page should contain the title of the project, the authorship and their affiliation and date of submission.

2. Nomenclature:
   This part of the report is optional. Here all the symbols used should be defined. Alternately, the symbols can be defined in the text where they appear for the first time. For big and complex reports (like a big proposal or final report on a contract), it is suggested that a list of the symbols with appropriate definitions should be provided up front. For reports with limited objectives (e.g. research papers or class reports), it is recommended that the symbols should be defined within the text after they appear for the first time.

3. Abstract:
   It is a brief summary of the essential content of the technical report. Its length should be about 200 words or less. The abstract usually contains a brief statement of the objectives, the methods used to fulfill those objectives, most significant results, and conclusion. No graph, sketch, table, or equations should be used or referred to in the abstract. It is recommended that the abstract be written after the report has been finished. It is imperative that a great deal of attention is paid to the writing of the abstract. A majority of the readership (like upper administration) of the report will confine their focus to this part of the report. Only those dealing directly with the subject matter of the report will look into the details.

4. Introduction:
   The purpose of the introduction is to provide the appropriate background on the subject matter. The introduction should describe the objectives of the work and the method and scope of the investigation, and the reasons for carrying out the work. Appropriate references to any earlier
work must be acknowledged. Usually, figures, sketches, or tables are not presented in the introduction. Unlike the abstract, there is no upper limit on the length of the introduction; however, an effort to keep it concise is always recommended.

5. Methodology or Technical Approach:
This part of the report should identify the theoretical principles and equations used in accomplishing the work. The equations should be numbered and follow the order of the principles they represent. Any supporting sketch of diagram related to the problem should be provided. Definitely, these are not the diagrams representing the results that you have obtained. These diagrams must be labeled and should appear after a reference has been made in the text.

A discussion of the sources and the extent of experimental and/or computational uncertainties should be included. One must be cognizant of the fact that the precision of the measuring device is compatible with the objectives of the investigation. Similarly, the computational technique that is being used also is stable and does not pollute the results. For example, a scale usually employed in grocery stores cannot accurately measure a microgram of an expensive chemical. A careless inversion of an ill-conditioned matrix can affect the final outcome of a computational experiment.

6. Description of the Experimental Setup or Tools Used:
A sketch of the setup with appropriate identification of the components should be included. All the measuring devices and the samples tested should be briefly described. In case it is purely a computational effort, a description of the numerical methodology or the use of specialized software and the language in which the computer code is written should be provided.

7. Results and Discussion:
This is the most important part of the report, where the findings have to be reported. Most of the engineering results are presented in the form of tables, charts, and graphs. Each of these entities should be numbered and provided with a one-line caption. These entities should then be fully described in the text as to what each table and chart stands for and why it is important that it has been included in the report. Appropriate discussion of the results for trends, self-consistency, accuracy, and meeting
the original objectives must be provided. It is the duty of the writer to sort out the results in a logical and systematic fashion and convince the reader about their validity. Quantitative discussion of any errors from the expected results should be clearly pointed out. Avoid any discussion of irrelevant and insignificant aspect of the results. (Note: proposals do not have results sections.)

8. Conclusions:

The most significant conclusions reached in the results and discussion section should be summarized herein. These should be listed in the order of their significance and preferably in an itemized form. References to figures or tables should not be included, and no new information should be introduced in this section. However, suggestion for further investigations can be made.

Samples of Technical Reports

Three samples are given here; the first is suitable for engineering students writing a homework report, the second is a technical paper, and the third is a technical presentation.

1 – to be sent (homework)


a. Nomenclature

\[ A(x) \] area variation
\[ f \] function
\[ k_{\text{inlet}} \] constant
\[ k_{\text{exit}} \] constant
\[ M \] Mach number
\[ \square \] ratio of specific heats of the gas flowing through the nozzle
\[ x \] distance along the nozzle
\[ \text{tol} \] tolerance for numerical solutions

Subscripts:
\[ \text{inlet} \] refers to the nozzle inlet
\[ \text{exit} \] refers to the nozzle exit
b. Objective
The main objective of this project is to solve for the Mach numbers (subsonic and supersonic) corresponding to each value of \( x \) in a converging-diverging nozzle and to plot Mach number vs. \( x \).

The area \( A(x) \) variation for the nozzle with respect to the length \( x \) is given by the following expressions:
\[
A(x) = 1 + (k_{\text{inlet}} - 1)(1-x/5)^2 \quad 0 \leq x \leq 5
\]
\[
A(x) = 1 + (k_{\text{exit}} - 1)(x/5)^2 \quad 5 \leq x \leq 10 \tag{1}
\]
where \( k_{\text{inlet}} = k_{\text{exit}} = 3 \), and \( x_{\text{exit}} = 10 \).

The Mach number distribution of gas in the nozzle is governed by the following equation:
\[
f(M, A) = \frac{1}{M^2} \left[ \frac{2}{M^2 + 1} \right] + \frac{1}{2} M^2 \left[ \frac{\sqrt{\gamma + 1}}{\sqrt{\gamma}} \right] \frac{A}{A^*} = 0 \tag{2}
\]
where \( A^* = \text{Throat Area} = 1 \).

c. Methodology
The relationship between area and Mach number comes from gas dynamics and is given as:
\[
f(M, A) = \frac{1}{M^2} \left[ \frac{2}{M^2 + 1} \right] + \frac{1}{2} M^2 \left[ \frac{\sqrt{\gamma + 1}}{\sqrt{\gamma}} \right] \frac{A}{A^*} = 0 \tag{2}
\]
where \( A \) is the area at any section of the nozzle. \( A^* \) is the throat (minimum area = 1) area and \( \gamma \) is the ratio of specific heats of the gas flowing through the nozzle. For air, \( \gamma = 1.4 \), and for realistic situations arising in propulsion applications, \( \gamma \) can be closer to unity.

The governing flow equation cannot be solved analytically, so in order to analyze the given problem it is solved numerically using Newton’s method. We initiate one loop on \( x \), which increases \( x \) from 0 to 10. It can be observed that for a particular value of \( x \) we can obtain a corresponding value of \( A \) from equation (1) that leads to one equation for \( M \). The problem is reduced to solving this equation using Newton’s method. Newton’s method requires an initial guess for \( M \). For a guess that is closer to the solution, Newton’s method will converge quadratically. For a poor or bad
guess, the Newton’s method can diverge. The iterative solution process that updates the solution is given as follows:

\[
M_{k+1} = M_k - \frac{f(M_k, A)}{\left(\frac{\partial f}{\partial M}\right)_{M=M_k}} \quad k = 0, 1, 2\ldots,
\]

As it is known that at any station \( x \) there is a possibility of two solutions, supersonic and subsonic, the choice of the initial guess further becomes critical.

The stopping criteria for iterations is \( |M_{k+1} - M_k| \leq tol \), where

\( k \) is an iteration index and value of \( tol \) (tolerance) is decided by the user and represents the level of accuracy of the final solution. Once the convergence is attained, the final Mach numbers and the corresponding values of all \( x \) are stored in an array and plotted.

d. Results

A computer code for the problem has been written in MatLab and is attached as Appendix 1. The results of this computation are shown in Figures 1 and 2. The variation of area of the nozzle versus \( x \) is displayed in Figure 1. Clearly the throat area of the nozzle is one and is located at \( x = 0 \). The Mach number distribution along the nozzle is shown in Figure 2.

It may be noticed that in the converging portion of the nozzle, a subsonic Mach number at the inlet increases to 1 at the nozzle throat, whereas a supersonic Mach number at the inlet decreases to 1 at the throat. Since the deceleration of supersonic flows takes place across a normal shock wave, this branch of the solution though computed is non-physical. However, in the diverging section of the nozzle both subsonic and supersonic solutions are possible. The realization of either one is determined by other conditions. The convergence of the Newton’s method requires that appropriate initial guess is used to initiate the iterative process. It was also observed that different initial guesses are required to make the subsonic solution converge in the converging (for \( x<5 \)) and diverging (for \( x>5 \)) of the nozzle. For \( x<5 \) the solution converged if we started with an initial guess of \( M = 0.1 \) while for
x > 5 the subsonic solution converged if we started with $M = 0.05$. No such thing was observed while running the code for supersonic case, the supersonic solution converged if initial guess given is greater than 3.

e. Conclusions
Mach number distribution in a converging-diverging nozzle has been calculated using Newton’s method for subsonic and supersonic branches. Newton’s method converges quite rapidly and the convergence depends upon the initial guess.
Figure 1. Plot of area vs. running x co-ordinate
Figure 2. Mach numbers (Subsonic & Supersonic) as a function of $x$
Appendix 1
MatLab Computer Code (% solution of flow in a converging-diverging nozzle using Newton’s method)

function [M,y]=Newton_3(fun,fun_pr,M1,tol,max)
% Find zero near x1 using Newton’s method
% Input:
% fun string containing name of function
% fun_pr name of derivative of function
% fun_2pr name of 2nd derivative of function
% x1 starting estimate
% tol allowable tolerance in computed zero
% max maximum number of iterations
% Output:
% x vector of approximations to zero
% y vector of function values, fun(x)

newton_1_data
counter = 0;
for x = 0:.1:5;
    counter = counter + 1;
    i = 0;
    iter = 0;
    M(1) = M1;
    y(1) = feval(fun,M(1),x);
    y_pr(1) = feval(fun_pr,M(1));

    for i = 2:max
        M(i) = M(i-1) – y(i-1)/y_pr(i-1);
        y(i) = feval(fun,M(i),x);
        y_pr(i) = feval(fun_pr,M(i));
        if abs(M(i) – M(i-1)) < tol
            %disp(‘Newton method has converged’); break;
            end
        end
    iter = 1;
end
if (iter >= max)
    disp(‘zero not found to desired tolerance’);
end
n = length(M);
k = 1:1:n;
out = [k' M' y'];
Mach_num(counter) = M(n);
end
out = [Mach_num'];
x = [0:.1:5];
plot(x,Mach_num);

disp(out)
hold on;

function y = my_func(M,x)
ki = 3;
y = (M.^-2)*((5/6) + (1/6)*M.^2).^6 -(1 + (ki - 1)*(1-x/5)).^2).^2;

function y = my_func_pr(M)
y = (-2/ (M^3)) * (5/6 + (M^2)/6)^6 + (6/(M^2)) * (M/3) * (5/6 + (M^2)/6)^5;
%y = (2.4*M.^-1)*((5/6)+(1/6)*M.^2).^5 -(2*M.^-3)*((5/6)+(1/5)*M.^2).^6;

3 – Technical Presentation

Power Point presentation:
1. Title page with the authors’ names and affiliation
2. Outline of the presentation
   • Problem statement and background
   • Formulation of the problem
   • Method of solution
   • Results and discussions
   • Conclusions

All slides should be brief and simple.