

HIGHER TECHNICAL INSTITUTE

MECHANICAL ENGINEERING DEPARTMENT

DIPLOMA PROJECT

DESIGN OF A SUPERSONIC NOZZLE FOR
A COLD NANOPARTICLE DEPOSITION

M/1017

MICHALIS ARKADIOU

JUNE 2006

**DESIGN OF A SUPERSONIC NOZZLE
FOR A COLD NANOPARTICLE
DEPOSITION**

by

MICHALIS ARKADIOU

Project report submitted to the
Department of Mechanical Engineering
of the Higher Technical Institute
Nicosia Cyprus

in partial fulfillment of the requirements of the
diploma of

TECHNICIAN ENGINEER

In

MECHANICAL ENGINEERING

June 2006

HIGHER TECHNICAL INSTITUTE	PROJECT NO
	3664

ABSTRACT

This project comprises an investigation of the requisite design and operational characteristics of a supersonic nozzle. Gaseous flows through such nozzles are forced to obtain supersonic speeds that can also be imparted to solid particles that are carried along by the flow. Such speeds can enhance the adherence of these particles on a solid substrate without loss of their characteristic properties.

The aforementioned process can be used when the properties of the substrate need to be improved. If the deposition process is performed properly, it is possible to achieve surface properties similar to those of the powder being used. Even though this method is used nowadays in industry several operational improvements are needed for better results.

For the design of the nozzle two main pieces of information are required: the governing equations that characterize a particular gaseous flow through the nozzle coupled with the design parameters that typify the manufacture of the nozzle. If the information is thoroughly documented and properly understood then the nozzle can be properly designed, manufactured and used for the purpose stated above.

The relevant theory for supersonic nozzles was obtained by studying the characteristic behavior of compressible flow. An in-depth theoretical understanding of the process was a prerequisite prior to the evaluation of any design and operational parameters. The design options were evaluated against the actual apparatus that is used nowadays in industry and is available in the form of various patents.

A thorough manipulation of the design parameters in relation to the flow characteristics was performed and a representative design has been proposed.

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to my supervisor Dr. Nicos Angastiniotis, Lecturer at the Higher Technical Institute, for his great effort, help and advice; without his guidance I would have not been able to materialize my tasks and fulfill my own expectations. His detailed explanation of the project, the correct timing and the sources of information that were provided to me were of such extent and precision that gave me the strength and knowledge to complete my project in time.

My sincere thanks should also be conveyed to:

- 1) Dr I. Angelis, Lecturer at the Higher Technical Institute, for his great help in preparing the manuscript of the project.
- 2) Dr C. Marouchos, Lecturer at the Higher Technical Institute, for his authoritative help in computer programming.
- 3) Mr. N. Papanastasiou, Lecturer at the Higher Technical Institute, for his great help in preparing the design of the nozzle.
- 4) Mr. H. Haridemou, Lab Assistant at the Higher Technical Institute, for his help in the overall design of the project.

CONTENTS

	<u>Page</u>
Abstract	i
Acknowledgements	ii
Contents	iii
List of figures	vi
List of tables	vii

CHAPTER 1

INTRODUCTION

1.1	Aims and Objectives	1
1.2	Procedure Followed	1
1.3	Project Concepts	3

CHAPTER 2

THEORETICAL BACKGROUND

2.1	Basic information	4
2.2	Stagnation and Static Properties	4
2.3	Velocity of Sound and Mach Number	7
2.4	One - Dimensional Isentropic Flow	9
	2.4.1 Variation of Fluid Velocity with flow_Area	11
	2.4.2 Property Relations for Isentropic Flow of Ideal Gases	13
2.5	Isentropic Flow Through Nozzles	14
	2.5.1 Converging Nozzles	14
	2.5.2 Converging - Diverging Nozzles	19
2.6	Normal Shocks in Nozzle	22
2.7	Flow through Actual Nozzles and Diffusers	24
	2.7.1 Nozzle Efficiency (η_v)	24
	2.7.2 Velocity Coefficient (C_v)	26
	2.7.3 Discharge Coefficient (C_d)	26
	2.7.4 Diffuser Efficiency (η_d)	27
	2.7.5 Pressure Recovery Factor (F_p)	29
	2.7.6 Pressure Rise Coefficient (C_{pr})	29
	2.7.7 Momentum Equation	30

CHAPTER 3

PROCEDURE

3.1	Methodology	31
3.2	Objectives	31
3.3	Theoretical principles	32
3.4	Internet Search	32
3.5	The most Appropriate Patents	33
3.6	The most Suitable Patent	34

CHAPTER 4

APPARATUS CONFIGURATION AND NOZZLE DESIGN

4.1	Project Objectives	36
4.2	Design Formulae	36
4.3	Calculations	40

CHAPTER 5

PRESENTATION OF RESULTS AND DISCUSSION

5.1	Outline	48
5.2	Procedure	48
5.3	Spaying Nozzle Applications	49
5.4	Nozzle Operation	50
5.5	Information on Nozzle Design	52
5.6	Improvements	53
5.7	What It Is Preferred	54
5.8	What to be Avoided	55
5.9	Possible Problems	55
5.10	Powders Used	56
5.11	Nozzle Construction	57
5.12	Description of the Design	57
	5.12.1 Nozzle Design	57
	5.12.2 Apparatus Configuration	60
5.13	Chapter Summary	62

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1	Project Objectives	64
6.2	Project Results	65
6.3	Project Implementation	65

REFERENCES

66
