

STUDIES IN WEAR LIFE OF NORMAL AND
SPECIALLY FINISHED WOVEN COTTON APPAREL FABRICS

VOLUME - II

BY

GARIGIPATI VISWESWARA SARMA

TEXTILE TECHNOLOGY DEPARTMENT

SUBMITTED

IN FULFILMENT OF THE REQUIREMENTS OF

THE DEGREE OF

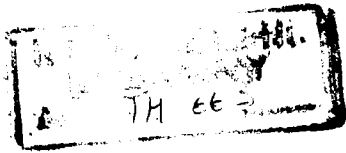
DOCTOR OF PHILOSOPHY

TO THE

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

DECEMBER, 1978

TH
077.00.000
SFB 10.2



CERTIFICATE

This is to certify that the work reported in this Ph.D. Dissertation has been done by G.V. Sarma under our guidance and supervision. To the best of our knowledge, the work is original and has not been submitted to any other University, Educational Institution or any other body for awarding the Degree of Doctor of Philosophy.

(*Amrik Singh*)
Dr. AMRIK SINGH

(*S.R. Ranganathan*)
Dr. S.R. RANGANATHAN

PREFACE TO VOLUME II

Volume II deals mainly with theoretical aspects. These include theoretical models for tear length distributions (Chapter 8) for frayed lengths (Chapter 9) and data from service wear trials to demonstrate the validity of these models.

Chapter 10 deals with a description of representative wear parameters like the number of tears and frays, etc. by counting Stochastic process. Methods of deducing wear life in time durations are also described in the same Chapter.

Chapter 11 deals with variations in the wear resistance of apparel fabrics as measured by retained levels of mechanical properties as well as actually observed tear and wear damage and the many factors to which these variations could be traced.

Methods of estimating the "Critical Stress" and "Critical Strength" are described in Chapter 11 and illustrated.

The manner in which the nature and directions of predominant tensions in an end-use could be assessed is illustrated in Chapter 11 in which some modifications were introduced in the manner of placing the fabric in the apparels made of special weaves.

In Chapter 12, a theoretical model is proposed to describe Flex Abrasion cycles. A large volume of data is presented to demonstrate the applicability of this theoretical model as well as to examine the often confronted bimodality in abrasion test results.

The theoretical aspects are summarised as a part of Chapter 13 and areas of further research are covered in Chapter 14.

Papers published from the work in Volume ^{II} are listed at the end (after references) and reprints are enclosed.

CONTENTS - VOLUME II

CHAPTER NO.8

THEORETICAL MODELS TO DESCRIBE THE TEAR LENGTH DISTRIBUTIONS IN WOVEN APPAREL FABRICS IN SERVICE.

Leading
Page
No.

SECTION : I - FORMULATION AND DEVELOPMENT OF THEORETICAL MODELS.

1. Introduction	395
2. Definition of Tear Length	397
3. <u>Formulation of the Waiting Time Model</u>	397
3.1 Discrete Model	397
3.2 Continuous Model	398
4. <u>General Expressions</u>	399
4.1 Discrete Model for Yarns ruptured	399
4.2 Continuous Model for Length Torn.	400
5. <u>Physical Interpretation of the General Expressions.</u>	402
5.1 Large tearing force applied continuously	402
5.2 Given Amount of Energy	403
5.2.1 Energy Dissipation Model	403
5.2.2 Mathematical Formulation.	403
5.2.3 Nature of the Parameters in the Energy Dissipation Model.	404
5.2.3 (i) Proof that $\mu(x)$ is a steadily increasing function in x	405
5.2.3 (i) (a): Analytical Proof that $\mu(x)$ is a strictly monotonically increasing function in x .	406
5.2.3 (i) (b). Proof by Geometric Considerations.	408

	<u>Leading Page No.</u>
5.2.3 (i) (c) Some examples of a steadily increasing function $\mu(x)$	409
5.2.3(ii) Proof that the instantaneous probability of rupture of the threads decreases steadily.	409
5.2.3(ii) (a) Analytical	409
5.2.3(ii) (b) From Physical considerations	409
5.2.3(iii)(o) Remarks on the assumption of constant work done (or expended) with particular reference to the oscillatory nature of $\mu(t)$.	410
5.2.4 Dependence of the Model and its parameters on Fabric Factors.	413
5.3 Energy supplied intermittently	415
5.4 Force Decay Model	415
5.5 Forces applied intermittently	416
5.6 Large Force over a wide area.	416
5.7 Discussion	417
6.0 <u>Geometric and Exponential Models</u>	417
6.1 Introduction	417
6.2 Assumptions	418
6.3 Derivation	418
6.4 Properties	419
6.4.1 Constant risk function	419
6.4.2 Lack of Memory	419
6.4.3 Multiple Yarn Rupture	419
6.5 Discussion of Assumptions.	420
6.6 Physical Interpretation of Parameters	420

		<u>Leading Page No.</u>
7.	<u>WEIBULL'S MODEL</u>	420
7.1	Introduction	420
7.2	<u>When k is greater than unity</u>	421
7.2.1	Assumptions	421
7.2.2	Derivation	421
7.2.3	Remarks	422
7.2.4	Interpretation of parameters	422
7.3	<u>When k is less than unity</u>	422
7.3.1	Assumptions	422
7.3.2	Derivation	423
7.3.3	Interpretation of the parameters	423
7.4	Case when $k = 1$	423
8.0	<u>SUMMARY</u>	423

FIGURES (Chapter No.8) : Section I

- Fig. 1 Measurement of Tear Length X_N consisting of N Ruptured yarns.
- Fig. 2 Plot of the convex function $Y = I(x)$ and the line through origin $Y = Ix$.
- Fig. 3 Representation of Oscillatory risk function $\mu(x)$ with increasing mean trend.

CHAPTER NO.8

THEORETICAL MODELS TO DESCRIBE THE TEAR LENGTH DISTRIBUTIONS IN WOVEN APPAREL FABRICS IN SERVICE.

SECTION.- II: APPLICATIONS AND VALIDITY OF THE THEORETICAL MODELS

Description

1. Introduction	425
2. Fitting of Distributions	425
2.1. Data Sources	425

	<u>Leading Page No.</u>	
2.2	Measurement and Classification	425
2.3	Estimation of Parameters	426
2.4	Fitting of Distributions	427
2.4.1	Weibull's Parameters	427
2.4.2	Fits of Exponential Models.	428
2.4.3	Fits of Weibull's Models	428
3.	<u>Comparison of the Parameters of the Models</u>	429
3.1	Illustration	429
3.2	Remarks	430
4.	<u>Correlation of the Parameter μ with laboratory tests.</u>	430
4.1	Introduction	430
4.2	Correlation with Elmendorf tear test	431
4.3	Influence of External Factors.	431
4.3.1	Direction of large Tearing Loads or Large Amounts of Tear Energy.	431
4.3.2	Severity of End-use Tearing Conditions.	432
5.	<u>Physical Significance of Theoretical Models and Their Parameters.</u>	434
5.1	Exponential Model	434
5.2	Weibull's Model	434
6.	<u>Conclusions</u>	435
	TABLES I to IV	437 - 442
	ADDENDUM I	443

FIGURES : (Chapter No.8)Section II

Fig. 1 : Correlation between the parameters μ and
Elmendorf Tear Strength.

CHAPTER NO.9

A THEORETICAL MODEL TO DESCRIBE FRAYED LENGTHS IN
WOVEN APPAREL FABRICS.

Description of Contents.

1.	Introduction	444
2.	<u>The Gaussian or Normal Distribution as a Model for the frayed lengths at the inner fold of the collar of a shirt.</u>	445
2.1.1	The Gaussian or Normal distribution for a continuous frayed length Z	445
2.1.2	Derivation of the Gaussian Distribution for a continuous frayed length at collar fold of a shirt.	445
2.1.3	Derivation	447
2.2	<u>Gaussian Distribution as a limiting form of a Binomial Expression when the length is Discontinuous along the fold or an edge.</u>	447
2.2.1	The expression for frayed length in Discontinuous case.	447
2.2.2	Assumptions.	448
2.2.3	Derivation of Gaussian law as the limiting case of Binomial Expression for yarns ruptured.	449
3.	<u>Results and Discussion</u>	450
3.1	Service wear trial of shirts for civilian use No.1	450
3.2	Goodness of fit of Normal distribution to frayed lengths.	453
	TABLES I to .III	454 - 456
Fig. 1	Goodness of fit of Normal Distribution to neck sizes of test subjects in a civilian wear trial (Chapter No.4)	
Fig. 2	Departure from Normal probability law of severe frays at collars of Line-dry shirts i.e. code L.	

CHAPTER NO.10

STOCHASTIC TREATMENT OF WEAR PARAMETERS AND ESTIMATION OF WEAR LIFE IN TIME DURATIONS.

1.	Introduction	457
2.	Theory	458
2.1	Definition of Stochastic Process	458
2.2	Definition of Poisson Process	458
2.3	Definition of Stationary Poisson Process	459
2.3.1	Tests for Poisson Process	459
2.3.1(a)	Test for Stationary Poisson Process	459
2.3.1(b)	Test for trend-free Poisson Process	460
2.3.1(c)	Test to examine if two observed rates μ' and μ'' differ significantly.	460
2.3.1(d)	Time-dependent Poisson Process (non-homogeneous) and estimation of mean rate $\mu(t)$	460
2.4	COMPOUND POISSON PROCESS. -	461
3.0	<u>Applications of the Stochastic Models</u>	462
3.1	<u>Tear Parameters as a Stationary Poisson Process.</u>	462
3.1.1	Results from Service Wear Trial of shirts given to school children.	462
3.1.2	Results from a Service Wear Trial of shirts in a civilian End-use.	463
3.2	<u>Number of Places frayed as a Stochastic Process.</u>	465
3.2.1	Introduction	465
3.2.2	Results and Discussion	465
3.3.	<u>Progressive Tear Length as a Compound Poisson Process.</u>	467

3.4	<u>Estimation of Wear Life in Time Durations.</u>	468
3.4.1	Progressive Tear Length $X(t)$ as a end-point in a group of shirts.	468
3.4.2	Progressive number of Tears $N(t)$ as an end-point in a group of shirts (ignoring lengths of tears)	469
3.4.3	Mean time durations for the first tear of a shirt as an end-point.	470
3.5	<u>Critical Discussion</u>	471
4.0	<u>Probabilistic Estimates of Life Durations - an Illustration.</u>	473
	TABLES : I to V	478 - 484
	TABLES VI to VIII	469 - 471

FIGURES (Chapter No.10)

Fig. 1 Progressive Number of tears; Actual Vrs. Theoretical

CHAPTER NO.11

ON VARIATIONS IN SOME OBSERVATIONS / TEAR AND WEAR DAMAGE AND RETAINED LEVELS OF MECHANICAL PROPERTIES OF APPARELS IN SERVICE AND THEIR INTER-RELATIONSHIPS.

1.	Introduction	485
2.	Variations in Retained Mechanical Properties	486
2.1	<u>Service Wear Trial of Shirts for Civilian use No.1.</u>	
2.1.2	Materials and Methods	487
2.1.3	Zonewise Mean Values	487
2.1.4	Other Zones	489
2.2.	<u>Service Wear Trial of Shirts for School Boys (No.2)</u>	490
2.2.1	Materials and Methods	490

2.2.2	Results and Discussion	490
2.2.3	Zone-to-Zone variations	491
3.	<u>Variations in Tear and Abrasion Damage Observed on Garments in Service and their relationship with retained levels of mechanical properties.</u>	494
3.1	<u>Service Wear Trial of Shirts for School Boys No.1:</u>	494
3.1.1	Variations in Test Subjects.	494
3.1.2	Critical Stress Definition and Estimation	495
3.1.2(a)	Introduction	495
3.1.2(b)	Definition	496
3.1.2(c)	Estimation of Critical Stress Levels	496
3.1.2(d)	Earlier Results	498
3.2	<u>Results of Service Wear Trial of Shirts and Pants No.1.</u>	499
3.2.1	Introduction	499
3.2.2	Materials and Methods	499
3.2.2(a)	Fabrics	499
3.2.2(b)	Uniforms	499
3.2.2(c)	Test Subjects	500
3.2.2(d)	Sampling and Distribution	500
3.2.2(e)	Wearing and Laundering	501
3.2.2(f)	Mechanical Properties of Fabrics	501
3.2.2(g)	Testing Methods	501
3.2.2(h)	Laboratory tests on Salvaged Uniforms	501
3.2.3	<u>Results and Discussion</u>	502
3.2.3(i)	Directional Tear Performance of Shirts in Service.	502

3.2.3(ii)	Directional Tear Performance of Pants in Service.	502
3.2.3(iii)	Localized Weakening	503
3.2.3(iv)(A)	Failure Performance	503
3.2.3(iv)(B)	Retained Tensile Strength	504
3.2.3(v)	Dependence of Occupationwise Tear Scores on Retained Tensile Strength on Estimation of Critical Stress.	506
3.2.3(vi)	<u>Effect of Modifications on Tear and Wear Performance.</u>	507
3.2.3(vi)(A)	Shirts	507
3.2.3(vi)(B)	Pants	508
3.2.3(vii)	<u>SUMMARY AND CONCLUSIONS</u>	509

TABLES I TO XXIX	511 to 539
------------------	------------

FIGURES IN CHAPTER NO.11

Fig.1 : Critical Strength Index

Fig.2 : Photomacrographs of Typical Edge-abraded Samples
(Filling Yarns along the edge).

Photo: - I: Accelerotor Edge-Abraded Sample of Twill 'FACE'

Photo: -II: Accelerotor Edge-abraded Sample of Twill 'BACK'

Fig.3 : Photomacrographs of typical Edge-abraded Sample
(Filling yarns along the Edge)

Photo: -I: Bottomfolds of Salvaged Pants: 'FACE'

Photo: -II: Bottomfolds of Salvaged Pants: 'BACK'

CHAPTER NO.12

A THEORETICAL MODEL TO DESCRIBE FLEX ABRASION CYCLES AND INVESTIGATION OF BI-MODALITY IN ABRASION CYCLES AND CHARACTERIZATION OF ABRASION CYCLES BY EXTREME VRS CENTRE MEASURES.

	<u>Leading Page No.</u>
1. INTRODUCTION	540
1.1 Earlier Work on Interpretation of Bimodality	540
2. <u>Development of Theoretical Model For The End-Point Cycles In A Flex Abrasion Test.</u>	545
2.1 Brief Description of the test	545
2.2 <u>Nature of yarn Rupture and the Related Theoretical Distributions.</u>	547
2.2.1 Simultaneous and Independent Rupture of perfectly Uniform yarns exposed to identical rubbing, flexing and bending actions.	548
2.2.2 Case of Independent rupture non-uniform yarns.	549
2.2.3 Formulation of the Waiting-Time Model	550
2.2.3.1 Assumptions	551
2.2.3.2 Formulation of the Waiting Time Model for the number of yarns.	552
2.2.3.3 Formulation of the Waiting Model for the continuous Distribution.	553
2.3 <u>Derivation of the Weibull's Model with Shape Parameter greater than unity.</u>	554
2.4 Some Important Properties of the Weibull's Distribution.	555
2.4.1 To show that if k_1 is greater than k_2 then the risk function $\mu_1(x_1)$ is greater than $\mu_2(x_2)$ for $x_1 < x_2$.	557
2.5 Discussion of the Theoretical Model	559

3.0	<u>DATA ON NORMAL AND SPECIALLY FINISHED TWILL FABRICS</u>	561
3.1	Materials and Methods	561
3.1.1	Test Samples	561
3.1.2	Abrasion Tests	562
3.1.3	Statistical Treatment	562
3.2	<u>Results of Flex Abrasion Tests.</u>	563
3.2.1	Flex Abrasion Test	563
3.2.2	Effect of Weave	564
3.2.3	Effect of Tensions	564
3.2.4	Wet Vrs. Dry Tests	567
3.2.5	Actual Fits by Sample Moments.	567
3.2.6	Goodness of Fit and Shape Parameters	568
3.2.7	Other Parameters of the Distribution and Central Measures of Flex Abrasion Cycles.	568
3.2.8	Dispersion	570
3.3	<u>Results of Flat Abrasion Tests</u>	571
3.3.1	Graphical Analysis	571
3.3.2	Shape Parameters Estimated Graphically	572
3.3.3	Goodness of Fit and Evaluation of Flat Abrasion by different Statistical Parameters	573
3.3.4	Evaluation by Different Statistical Parameters	573
4.0	<u>RESULTS OF DURABLE PRESS SHIRTS .</u>	574
4.1	Introduction	574
4.2	Materials and Methods	575
4.2.1	Laboratory Evaluation	575
4.2.2	Abrasion Tests	575

4.2.3	Fitting of Theoretical Distribution to Abrasion Data	576
4.3	Results of Weibull's Distribution	576
4.3.1	Flex Abrasion Test Results	576
4.3.2	Flat Abrasion Results	580
4.4	Results of Weibull's parameters for Characteristic Small Values and Central Measures.	580
4.4.1	Flex Abrasion	580
4.4.2	Flat Abrasion	582
5.0	<u>Summary</u>	583
6.0	<u>A CRITICAL REVIEW OF RESULTS OBTAINED</u>	585 - 595
	TABLES I to X	596 - 605

FIGURES IN CHAPTER NO.12

- Fig.1 : Illustration of SIPPEL Effect i.e. Vertex Shifting from Top-left to lower-bottom as the severity of Test conditions diminishes and fatigue Life increases.
- Fig.1-A: Plot of Complementary Cumulative Probability function $q(x)$ for Two Weibull's Populations.
- Fig.2 : Plots of Flex Abrasion Cycles on Weibull's Probability Paper Hd. Load: 4 lbs.; Tension Load: 2 lbs.; Warp ; Dry.Codes: P, D & C.
- Fig.3 : Plots of Flex Abrasion Cycles on Weibull's Probability paper Head Load: 4 lbs.; Tension Load: 2 lbs: Filling; dry; Codes: P, D & C.
- Fig.4 : Plots of Flex Abrasion Cycles x on Weibull's Probability Paper. Head Load : 2 lbs; Tension Load: 4 lbs; Warp; Dry. Codes: P, D & C.
- Fig.5 : Plots of Flex Abrasion Cycles on Weibull's probability paper; Head Load: 2. lbs; Tension Load : 4 lbs; Filling; Dry.Codes, P D & C.

- Fig. 6 : Plots of Flex Abrasion Cycles on Weibull's Probability Paper; Head Load: 4 lbs; Tension Load: 2 lbs; Warp, Wet. Codes: P, D & C.
- Fig. 7 : Plots of Flex Abrasion Cycles on Weibull's Probability Paper; Head Load: 4 lbs; Tension Load: 2 lbs; Filling; Wet. Codes: P, D & C.
- Fig. 8 : Plots of Flat Abrasion Cycles on Weibull's Probability Paper. Head Load : 1 lb; Pressure : 2 psi; Dry. Codes: P, D & C.
- Fig. 9 : Plots of Flat Abrasion Cycles on Weibull's Probability Paper. Head Load: 1 lb.; Pressure; 4 psi. Dry. Codes: P, D & C.
- Fig.10 : Plots of Flat Abrasion Cycles on Weibull's Probability paper; Head Load: 1 lb; Pressure: 1 psi. Wet. Codes: P, D & C.
- Fig.11 : Plot of Warp Flex Abrasion Cycles on Weibull's Probability Paper; Head Load: 4 lbs; Tension Load: 1 lb. Dry, Codes : Plain vrs. Stripes.
- Fig.12 : Plot of Warp Flex Abrasion Cycles on Weibull's Probability Paper; Head Load: 4 lbs; Tension Load: 2 lbs. Dry. Codes: Plain vrs. Stripes.
- Fig.13 : Plot of Warp Flex Abrasion cycles on Weibull's Probability Paper; Head Load : 4 lbs.; Tension Load : 4 lbs. Dry ; Codes: Plain vrs. Stripes.
- Fig.14 : Plot of Flat Abrasion Cycles on Weibull's Probability Paper Head Load : 1/2 lb.; Pressure : 2 psi. Dry; Codes: Plain vrs. Stripes.
- Fig.15 : Plot of Flat Abrasion Cycles on Weibull's Probability paper. Head Load: 1/2 lb.; Pressure: 4 psi.; Dry. Codes: Plain Vrs. Stripes.
- Fig.16 : Plot of Weft Flex Abrasion Cycles on Weibull's paper; Head Load: 4 lbs; Tension Load: 2 lbs; Dry: Codes; Plain Vrs. Stripes.
- Fig.17 : Plots of Weft Flex Abrasion Cycles on Weibull's Probability paper; Head Load: 4 lbs.; Tension Load: 4 lbs. Dry; Codes: Plain vrs. Stripes.

CHAPTER NO.13

SUMMARY OF THE TOTAL WORK, GENERAL CONCLUSIONS AND RECOMMENDATIONS.

	<u>Leading Page No.</u>
1. The main Problem and Objectives	606
2. <u>Prediction of Wear Life of Normal and Specially Finished Apparel Fabrics (VOLUME-I)</u>	607
2.1 <u>Problem of Predicting the Wear Life of Specially finished Apparel Fabrics.</u>	607
2.1.1 Special Finishes	607
2.1.2 The Problem of interaction of Fabric Structure with special Finishes.	607
2.1.3 Modifications in the manner of fabrication of Garments as a means of altering the wear resistance of apparel fabrics and also as a means of assessing the nature directions, and levels of tensions and surface abrasion actions on apparel fabrics.	608
2.2 <u>The Principal Approach made to predict wear life</u>	609
2.3 <u>SUMMARY OF SPECIFIC WORK DONE AND RESULTS OBTAINED.</u>	
2.3.1 Service Wear trials involving Durable Press Garments made from three varieties of Fabrics of U.S. origin.	613
2.3.2 Service Wear Trials involving Normal and Specially finished apparels fabrics of Indian origin.	622
2.3.2.1 Materials.	622
2.3.2.2 Summary of Results.	624
2.3.3. Effect on Wear Life due to modifications in the manner of placing the fabrics in the apparels.	640
2.3.3.1 Shirts.	640
2.3.3.2 Plants (trousers)	642

3.	<u>THEORETICAL ASPECTS</u> (VOLUME II)	645
3.1	The Need for Theoretical Studies.	645
3.2	<u>SUMMARY OF WORK ON THEORETICAL ASPECTS</u>	650
3.2.1	Theoretical Models to describe tear length distributions in apparels in service- Development of Models.	650
3.2.2	Theoretical Models to Describe tear-length in apparels in service use-Applicability of theoretical models to observed tear lengths in the service use of apparels.	652
3.2.3	Theoretical Models to describe Frayed Lengths	653
3.2.4	Description of Wear parameters by Stochastic Processes and Estimation of Wear Life in Time Durations.	655
3.2.5	Some Observations Variations in retained mechanical properties and observed tear and abrasion damage and their relationships in Wear Life Studies.	657
3.2.6	The Critical Stress and Critical Strength Concepts and their Estimation.	662
3.2.7	A Service Wear Trial of Shirts and Trousers involving Modifications in the manner of placing of Fabrics in Apparels as a Means to find the Directions of predominant tensions and abrasion actions.	664
3.2.8	The Weibull's Distribution to describe Flex Abrasion Cycles.	666
3.2.9	The Applicability of Weibull's Distribution and Interpretation of Bi-modality.	667
3.2.10	The Characterization of Abrasion Life Times by minimal Values Vrs. Central Measures.	670
4.0	<u>GENERAL CONCLUSIONS AND RECOMMENDATIONS TO PREDICT WEAR LIFE.</u>	670
4.1	Damage in Dry vrs. Wet State	671
4.2	Edge Wear in Service and Prediction of the same.	675
4.3	Plane Abrasion	679

4.4	Tearing	681
4.5	Correlation of Service Performance with Laboratory tests.	682
4.6	How to predict Wear Life.	684
5.	RECOMMENDATIONS TO PREDICT WEAR LIFE	687
6.	SUMMARY AND CONCLUSIONS OF THEORETICAL ASPECTS	690

CHAPTER NO.14

AREAS FOR FURTHER RESEARCH AND A CRITICAL APPRAISAL OF WORK DONE

1.	The Need.	694
2.	Standardization of the methods to determine Wear Life.	694
3.	Methods of Evaluation and Interpretation of Physical and Mechanical Properties and Damage in service and laboratory tests to predict Wear Life.	695
3.1	Laboratory tests and their interpretation	695
3.2	The Weibull's Model for abrasion data and bi-modality.	701
4.	Correlation Analysis	704
5.	Prediction of Wear Life and Separation of Mechanical Damage under various Service Conditions.	705
6.	Separation of Chemical Damage	708
7.	Fabric Structure	709
8.	Crosslinked Fabrics.	711
9.	Zonewise analysis.	712
10.	Factors Causing Variations in Wear Damage and Wear Life.	712
11.	Tear Damage and Critical Stress and Critical Strength.	714
12.	Frays	716
13.	Summing up.	718

<u>REFERENCES</u> :	719to 733
<u>APPENDICES</u> :	
Appendix: I - Test Procedures for mechanical Properties and Chemical Analysis	734 - 742
Appendix: II - Criteria for classification of Damage in Service and methods of measuring and scoring of the damage.	743- 747
Appendix: III- Old Scoring System. (A)	748
Appendix: III_ New Scoring System. (B)	749 - 750
Appendix: IV- Modified Scoring System.	751- 752

BIO-DATA OF THE CANDIDATE

LIST OF PUBLISHED PAPERS OR PAPERS PRESENTED FROM THE WORK INCLUDED IN THIS THESIS ALONG WITH COPIES OF REPRINTS

- LIST
- REPRINTS

LIST OF PAPERS UNDER SUBMISSION FROM THE WORK INCLUDED IN THIS THESIS

LIST OF PAPERS PUBLISHED BY THE CANDIDATE WHICH ARE EITHER REVIEWED OR QUOTED FROM EARLIER WORK NOT INCLUDED IN THESIS BUT RELATED TO THE TOPICS COVERED IN THE THESIS ALONG WITH REPRINTS. (For Ready Reference)

- LIST
- COPIES OF REPRINTS.