Encl : 03. List of Monographs prepared by Venugopal, P

Monographs by Prof. Dr. P. Venugopal, IIT Madras, Chennai – 600 036, India. Enclosure includes Standard Lecture Notes/PPT for Guest Lectures
As on November, 2011

The following are the monographs written by Prof. P. Venugopal

1. Two volumes on Metal Forming Equipment – for 60 hrs of lecture) inclusive of Maths and Subjective Aspects

2. Mathematical Treatment of Metal Forming Processes, (for 40 hrs of lecture), [Course Contents are furnished to reflect the depth of this unique course]

3. Metal Forming Technology (for UG Students), (for 45 hrs of lecture),

4. Press Tools for Metal Forming: (for 55 hrs of Lecture) (Two Volumes), [Course Contents are furnished to reflect the depth of this course]

4.1 Bulk Forming: Design &Analysis of tools concerning Hot and Cold Extrusion, Drop Forging, Heading, Ironing, Swaging, Spinning, Thread Rolling, etc,

4.2 Sheet Metal Forming: Design & Analysis of Sheet Metal Cutting, Bending, Deep Drawing, Tractrix Die etc, Fine Blanking & Fine Forming (2010 monograph) [Contents are furnished for the last chapter prepared in 2010-2011]

5. For Invited Guest Lectures:

5.1 *Addressing Errors in Metal Forming Techniques to ensure net-shape, (for 2 hrs of lecture)*

5.2 *Role of Metal Forming Machines on Metal Forming, (for 2 hrs),*

5.3 *Surface Engineering on Metal Forming, (for 2 Hrs),*

5.4 *High Strain Rate Forming Machines & Applications For Metal Forming, (for 2 hrs)*

5.5 *Cold extrusion of Sintered P/M Preforms, (for 2 hrs),*

5.6 *Applications of Siebel's Equation on Processes, Tools and Machines, (for 2 hrs),*

5.7 *Hydrostatic Extrusion of Metals and Materials, (2 hrs)*

5.8 *Hydrostatic and Hydro forming of Sheet Metals, Augmented Rolling, Forging, Cutting, (Fine Blanking) etc, (for 20 hrs),*

5.9 *Application of Fluid Power Engineering in Metal Forming, (10 hrs)*

5.10 *Trends in Metal Forming (10 hrs)*

5.11 Cold Extrusion Techniques and Their Significances (2 hrs)

5.12 Hot Drop Forging Techniques and Tooling Techniques (2 hrs)

5.13 An Overview of Forming Processes and Forming Machines (2 hrs)

5.14 Flow Curves and their applications in Metal Forming (2) hrs

6. Experiments in Metal Forming Technology (about 45 experiments) (for two semesters of 10 months). [Course Contents are furnished to reflect the depth of this Laboratory Manual]

Orientation of Mathematical Treatment of Metal Forming Machine Tools

DETAILED CONTENTS

0. Objectives	01
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Machine has influence on Working Stresses	05
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On the Optimal Working Condition	10
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Wedge Type Crank/Eccentric Press	153
Math of Flywheel, Utility Factor,	154-162
Connecting Rod Design	163-165
Applied Problem related to ω-time analysis	166-168
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Press Tools For Metal Forming

Encl : 05.1.

Course developed by Em. Prof. Dr. P. Venugopal for fifty hours through power point

0.	**OBJECTIVES OF THE COURSE. ON PRESSTOOLS FOR METAL FORMING**	
0.1	Importance of tool zone in metal forming system. [After KURT	LANGE].
0.2	Significance of Tool Stiffness & its pivotal role on tolerance,	efficiency.
0.3	Evolution of tools for constraints and switch over situations,	Amortization.
0.4	Resonance effect. (Arising out of the so called unit loading or break load or maximum force)	through
0.5 of	Deformation Efficiency & System Efficiency - focused towards energy philosophy.	conservation
0.6	Tool Economics.	
0.7	Why Billet Preparation assumes importance? (Surface Engineering in Metal Forming).	

Tooling for Bulk Forming and Sheet Metal Forming since, one of the classification of Metal Forming is based on this aspect also.

EXTRUSION OF METALS AND MATERIALS

0.	Special Features of Extrusion with respect to Other Metal Forming Processes. to show percentile reduction achievable. A preamble to Press Tools For Forming	Math Metal

1. DEFINITION, DEVELOPMENT & THE PROCESSES
2. Classification (Hot, Cold and Warm)
3. Application of Extrusion (System Analysis extendable to other similar family of processes)
4. Mathematical Treatment of Extrusion Processes (Solid, Tube and Cupping)
5. Variables influencing Extrusion Processes (FLD in Hot Extrusion)

5.1 ISOTHERMAL & ADIABATIC EXTRUSION

6. METHODS TO AVOID ADIABATIC EXTRUSION (HEAT MANAGEMENT)

6.1 TAPERED HEATING OF BILLET (compensation for heat rise)

6.2 COOLING OF CONTAINER/DIE/EXTRUDATE (do)

DETAILED TREATMENT OF EXTRUSION RELATED TOOLING

6.3 LUBRICATEDEXTRUSION/ BACK EXTRUSION (compensation for heat rise)

6.4 VELOCITY IS INTENTIONALLY IMPEDED (strain rate control)

6.5 AREA OF DIE APERTURE IS INCREASED (do)

6.6 DIE CONTAINER SELECTION TO ENSURE INCREASE IN AREA OF DIE/No. OF DIES$\Uparrow \Rightarrow$ IMPEDING VELOCITY,

7 LOAD MANAGEMENT

7.1 $F_{TOT} = F_{IDEAL} + F_{FR.CONTAINER} + F_{SHEAR} + F_{FR.\ MANDREL})$

AIM IS TO ENSURE $F_{TOTAL} \Rightarrow F_{IDEAL}$

8. Cold extrusion – Principles, Basic Survey, Applications

9. Lubrication in Cold extrusion – (Surface Engineering Aspects).

10. A Note on the Cold extrusion of sintered powdered metallurgical preforms.

11. Defects and Remedial measures in extrusion.

DETAILED TREATMENT OF EXTRUSION RELATED TOOLING

1. Tool Design. Quote from LANGE "SUCCESS OF COLD EXTRUSION IS DEPENDENT ON TOOLING".

1.1 How to Predict the Load for the basic processes of cold extrusion?

a. Basic Processes - a brief survey.

b. Method 1. [Metal Progress, May, 1971] - Analogue Method.

c. Method 2. [Sheet No: 69002,ICFG, ISME, Source Book on Cold Extrusion, ASM, Ohio, 1974] - Determination of Extrusion Pressure.

d. Method 3. [ICFG Data Sheet no: 1/70, Ibid.] - Calculation of Pressures for Cold Forward Extrusion of Steel Rods.

e. Method 4. [ICFG Data Sheet no: 2/70, Ibid.] - Calculation of Pressures for Cold Extrusion of Steel Cans.

f. Method 5. Mathematical Analysis of Forward Solid Extrusion.

g. Method 6. Mathematical Analysis For hollow forward extrusion.

h. Method 7. Mathematical Analysis For Backward Can Extrusion. [DIPPER Model].

i. Method 8. Using Deformation Efficiency & Limitations. [Refer data sheet enumerating this point].

j. Method 9. Using Correction Factors.

k. Method 10. Using rationalized parameter in terms of mean flow stress.

1.2 General Aspects of Tooling in Cold Extrusion [ICFG Data Sheets, CIRP Vol.3 and Consultancy and lab made tools - discussion].

1.3 Punch design for backward can extrusion.

1.3.1 Effects of punch face shapes on the extrusion pressure.

1.3.2 Effects of punch cross sectional shapes on extrusion pressure. After KAST]

1.3.3 Dimensioning of nose, bearing, stem, punch body and punch shank.

1.3.4 Punch Design for Research Work.

1.4 Die Design for backward can extrusion.

1.4.1 Lamae' Theory, Lamae Line - Derivations.

1.4.2 Types of dies.

1.5 Punch Design for forward extrusion variations.

1.6 Ibid. For hollow extrusion, Variations.

1.6.1 Integral Mandrel.

1.6.2 Fixed mandrel.

1.6.3 Moveable mandrel.

1.7 Design of Die Inserts for forward extrusion.

1.7.1 Unsplit.

1.7.2 Horizontally split.

1.7.3 Longitudinally split.

1.8 Concepts of Design on Multistage tooling.

1.9 Calculation of Die Assembly.

1.9.1 Stress distribution concepts with working stress; shrink ring, shrink ring and working stress.

1.9.2 Design of Shrink -Calculations.

1.10 Pressure pad design.

1.11 Knock out design.

1.12 Punch shoe and die housing.

2. What is required out punch & Die (properties a to g).

2.1 Selection of tool steel materials to meet a to g. (metallurgical properties).

3. Causes of Failure and Remedial Measures.

3.1 Punch.

3.2 Die.

3.3 Pressure Pad.

3.4 Die Shrink Ring.

3.5 Knock out.

4. Methodologies to truncate the extrusion pressures. [Ph.D. M.Tech, M.S.Projects & B.Tech Carried out the Laboratory under the guidance of Prof. P. Venugopal].
5. Guidance Values for possible work piece dimensions, % reduction, wall and base thickness vide mathematical treatments.
6. Tolerance on Cold Extrudes [VDI Data Sheets after Prof. H. W. WAGENER , Neumeyer Kabelmetal, Germany].
7. Design problems for wheel hub, anchor bolt, valve retainer seat, shock absorber tubing and varieties of similar family of products. [Consultancy materials of Prof. P. Venugopal].

8. Production Sequence Decision. [Vide Consultancy assignments by Prof. P. Venugopal].
9. Design Aspects of tools for Sintered P/M Preform Cold Extrusion [vide papers published by P. Venugopal etal in J. of Matls. Process. Technol & AIMTDR Proceedings - about 38 papers on this chapter alone from 1988 till date, July, 2007].

CONTENTS OF COLD HEADING - BOLT AND NUT PRODUCTION

0. Introduction
1 Definition of upsetting, upset strain, upset ratio, specific change in length
2. Application
3. Processes and Tooling
3.1 Difference between Bolt master and Nut Former
3.2 Open Die Configuration
3.3 Closed Die Configuration
3.4 Significance of Coning and Guidance Value
3.5 Special retracting Die header
3.6 Process Planning for Uniform Properties of High tensile Fasteners
REFER DATA SHEETS PROVIDED

CONTENTS ON TOOLING FOR DROP FORGING

0. Introduction

1. Definition, Merits, Applications

2. Fundamentals

2.1 Static Flow Stress, Dynamic Flow Stress, Forming Efficiency or Multiplication Factor, Shape difficulty and Shape difficulty factor, Configuration Number

3. Classification

3.1. Open Die Forging

3.2. Closed Die Forging

3.3.Smith Forging, Machine Forging

4. Analysis of Closed Die Forging

5. Groups of Interstage Processes

5.1. Change of Cross Section

5.1.1. Material Displacement

5.1.1.1. Drawing out

5.1.1.2. Spreading out

5.1.1.3. Radial Forging

5.1.1.4. Fullering

5.1.1.5. Extrusion

5.1.1.6. Roll Forging

5.1.2. Material Concentration

5.1.2.1. Full Upsetting

5.1.2.2. Edge Upsetting

5.1.2.3. Central Upsetting

5.1.2.4. Closed Die Upsetting

5.1.2.5. Heading in Horizontal Forging Machine

5.1.2.6. Edging with Saddle

5.1.3. Combined Material Displacement and Concentration

5.1.3.1. Roll Forging

5.1.3.2. Heading and Extrusion

5.1.3.3 Inverted Swaging

5.2. Change of Direction
5.2.1. Forming by Bending
5.2.2. Bending by shear
5.3. Processes for Hole Making
5.3.1. Solid Piercing
5.3.2. Hollow Piercing
5.3.3. Erhardt Flow piercing

5.4. Process for Parting
5.4. Shear Cutting
5.4.2. Wedge Cutting
5.4.2.1. Necking
5.4.2.2. Central
5.4.2.3. Closed Slit
5.4.2.4 Open Slit

6. Nomograms to estimate force and work for drop forging

7. Tools for Drop Forging

7.1 Design in accordance with fiber concentration
7.2 Design in accordance with parting line and rules
7.3 Design in accordance with natural draft
7.4 Design in accordance with Preforms for consistency
7.5 Types of Dies
7.5.1 Standard Die with Land and Gutter
7.5.2 Dies with Inserts
7.5.3 Locked Dies
7.5.4 Multipart and Multiple impression Dies
7.5.5 Influence of Machine on Die Wear
7.5.6 Fillets and Radii Design
7.5.7 Design of Land and Gutter
7.5.8 Scale Loss Estimation
7.5.9 Optimal Production Sequence of Preforms for Drop Forging
7.6. Forge Drawing and Tolerancing the Drop Forging
.7.7 Defects in Drop Forging and remedial Measures. (Discussed during the various sections themselves)

CONTENTS ON
CUTTING

0. INTRODUCTION TO TERMINOLOGIES & MECHANISM

0.1 Grouping

0.1.1 Plain Blanking

0.1.2 Piercing

0.1.3 Lancing

0.1.4 Cutting off or Parting off

0.1.5 Fine Edge Blanking/Smooth Blanking (Hydrostatic Cutting)

1. Cutting Forces : (perimeter) (thickness) (shear stress)

1.1 Methods to reduce the Cutting Forces

1.2 The Need to Know the Center of Pressure

2 Methods of Cutting Operations

2.1 Standard Single Stage Cutting

2.2 Progressive Die Cutting

2.3 Compound Die Cutting

2.4 Combination Die Cutting

3. Fine Blanking

3.1 Impingement Ring types

3.2. Calculation of Impingement Force

3.3 Calculation of Counter Force

3.4 Total Force for Fine Blanking

4. Defects and Remedial Measures.

REFER COMPLETE DATA SHEETS PROVIDED

CONTENTS OF BENDING

1. INTRODUCTION
2. Grouping of bending based on Tool Motion
3. Nomenclature in Bending
4. Difference between “V” and “U” bending

5. Moment and Force Analysis from basic principles5.1

5.1 Moment – derivation

5.2 Force – derivation

5.3 Unit Moment Curves Rationalized over Mean Flow Stress for Engineering Materials

5.4 Edge Strain

5.5 Spring Back

5.6 Blank Length

5.7 Optimal Die Span

5.8 Free Bending Force and Die bending Force for Spring Back Correction [Ref: AICTE Project on Characterization of Ironing and Bending, Prof. P. Venugopal, January, 2001]

5.9 Design Configurations of various Tools.

6. Defects in Bending and Remedial Measures.

STRETCH BENDING STUDIES OF SHEET METAL – A NEW ATTEMPT USING RUBBER

A B. Tech Project by Sri Harsha Nandam [Roll. No: MM 05 B 021] in **MAY, 2009.** Under the Guidance of Prof. Dr. P. Venugopal,

Materials Forming Laboratory (MFL), Dept.of Metallurgical & Materials Engg (MME),

Indian Institute of Technology Madras

Preamble, Stretch Bending, Objectives of the attempted work, tooling, experimental, results and discussions with graphs.

CONTENTS OF DEEP DRAWING

1. Definition of Deep Drawing based on CIRP Production Engineering Dictionary
2. Analysis of Deep Drawing for Force Estimation [*Ref: Kurt Lange, Hand Book of Metal forming, McGraw Hill Publ. N.Y., 1985, H.W. Wagener, Compendium II on Metal Forming Processes, IIT Madras, 1970*]

2.1 Stresses in Deep Drawing of Rotation and Axis Symmetric Component
2.2 Ideal Force
2.3 Blank Holder Force
2.4 Friction Force

2.5 Bending Force
2.6 Total Force
2.7 Influence of "n" on occurrence of maximum force (for selection of suitable mechanical press)
2.8 Force Formulae based on Literature – [*Siebel & Beisswänger, Romanowski & Oëler and Käiser*]
2.9 Optimal Blank Folder Pressure for Engineering materials

3 Tooling for Simple Deep Drawing
4. Redrawing and Types of Redrawing
4.1 Straight Draw (30^0 and 45^0 & 90^0 Blank Holder Plate,)
4.2 Reverse Redraw

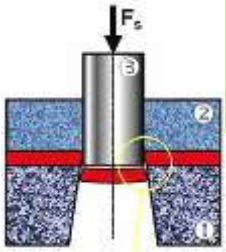
5. Blank Diameter Estimation

5.1 Analytical (Surface area of blank is equal to that of drawn part)
5.2 Graphical Methods using *Pappus* theorem
5.3 Graphical Method For Rectangular Cup
5.4 Use of Draw Beads

6. Defects in Deep Drawing & Remedial Measures (First Order Wrinkles, Second Order Wrinkles [pucker effect], earing, orange peel defect, thinning, wall tearing, spring back etc).
7. Use of Tractrix Die for thick Sheets. (Competing with warm deep drawing). Consultancy *Work*]

IRONING AS A FINISHING PROCESS – A FIRCTION AIDED PROCESS

1. Definition of the Process/Technique, **CIRP No:2351**,
2. Mechanism of Ironing,
3. Force Analysis (vide hollow extrusion model) to bring about the contribution of friction between punch and inner face of the part,
4. Tooling Aspects,
5. Influence of Die Included Angle for low Tearing Force and Total Ironing Force (addressed to conservation of energy philosophy),
6. Ironing Technique – a candidature for friction prone material – sintered p/m preforms and associated economics.



Press Tools For Metal Forming,, VOL-II of II
PART II
FINE BLANKING

Fine Blanking and Forming

Contents

The Art of Fine Blanking and Forming [*Source: Courtesy: Feintool Technologie, AG Lyss, Switzerland*]., *Origin* of Fine Blanking [*Source: Net Search*], Basics and Design Aspects [*Source: Courtesy: Parktechnology, Minnesota, USA*] Sequences of Fine Blanking [*Source: Courtesy: Parktechnology, Minnesota, USA*] Examples of Applications [*Source: Courtesy: Feintool Technologie, AG Lyss, Switzerland*] Forces for blanking & piercing [*Sources: Courtesy: Feintool Technologie, AG Lyss, Switzerland, ASM Metals Hand Book, Forming, Ohio, 1975, Grip Flow Com, USA*], V Rings & Associated features [*Sources: Courtesy: Feintool Technologie, AG Lyss Switzerland ASM Metals Hand Book, Forming, Ohio, 1975, Hand Book of Metal Forming, Schuler, Springer Verlag, Berlin, 1998* , Concepts in Strip Layout *[Source: Courtesy: Parktechnology, Minnesota, USA*] Fine Blanking Accuracy [*Sources: Courtesy: Feintool Technologie, AG Lyss, Switzerland, Parktechnology, Minnesota, USA*], Fine Blanked Edge Quality [*Sources: Courtesy: Feintool Technologie, AG Lyss, Switzerland, Parktechnology, Minnesota, USA*], Limits of Geometrical Shapes [*Sources: Courtesy: Feintool Technologie, AG Lyss, Switzerland, Parktechnology, Minnesota, USA*], Steel Structures for Fine Blanking [*Sources: Courtesy: Feintool Technologie, AG Lyss, Switzerland, Parktechnology, Minnesota, USA*], Fine Blanking Tools [*Sources: Courtesy: Feintool Technologie, AG Lyss, Switzerland, Parktechnology, Minnesota, USA*], Clearances per side for Fine Blanking [*Source: Courtesy: Feintool Technologie, AG Lyss, Switzerland*], Special Fine Blanking Presses [*Sources: Courtesy: Feintool Technologie, AG Lyss, Switzerland, Parktechnology, Minnesota, USA*], Varieties of Tools [*Source: Courtesy: Feintool Technologie, AG Lyss, Switzerland*] , Derivation of flow stress with Engineering Stress, Ultimate tensile Strength, Strain hardening exponent -Analysis made by the author, Force Analysis for bending and Fine Blanking [*Source: Courtesy: Feintool Technologie, AG Lyss, Switzerland, analysis by the author*], Force Analysis of for Hobbing & Fine Blanking [*Source: Courtesy: Feintool Technologie, AG Lyss, Switzerland, analysis by the author*] Force Analysis for Semi-Piercing [*Source: Courtesy: Feintool Technologie, AG Lyss, Switzerland, analysis by the author*] Force Analysis for Upsetting *[Source: Courtesy: Feintool Technologie, AG Lyss, Switzerland, analysis by the author*], Force Analysis for Collar Drawing, Deep Drawing & Fine Blanking [*Source: Courtesy: Feintool Technologie, AG Lyss, Switzerland, analysis by the author*]

Special Acknowledgement by the author goes to M/S Feintool AG Lyss, Switzerland, the Peers in this art of Fine blanking and providing wealth of information in their books, CDs, Pamphlets etc. Their lifetime work is contained in the above.

This monograph by the author would not have been possible for teaching but for the timely, noble gesture of Frau Doris. Fink and Herr. Heinz. Kaderli of M/S Feintool Technologie, AG Lyss, Switzerland.

Fine Blanking and Forming

Contents & Page Numbers

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Sequences of Fine Blanking [*Source: Courtesy: Parktechnology, Minnesota, USA*] PV02

Examples of Applications [*Source: Courtesy: Feintool Technologie, AG Lyss, Switzerland*] PV03

Forces for blanking & piercing [*Sources: Courtesy: Feintool Technologie, AG Lyss, Switzerland, ASM Metals Hand Book, Forming, Ohio, 1975, Grip Flow Com, USA*] PV04, PV 05a to PV0h

V Rings & Associated features [*Sources: Courtesy: Feintool Technologie, AG Lyss Switzerland ASM Metals Hand Book, Forming, Ohio, 1975, Hand Book of Metal Forming, Schuler, Springer Verlag, Berlin, 1998* PV07

Concepts in Strip Layout *[Source: Courtesy: Parktechnology, Minnesota, USA*] PV10

Fine Blanking Accuracy [*Sources: Courtesy: Feintool Technologie, AG Lyss, Switzerland, Parktechnology, Minnesota, USA*] PV11

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Limits of Geometrical Shapes [*Sources: Courtesy: Feintool Technologie, AG Lyss, Switzerland, Parktechnology, Minnesota, USA*] PV18

Steel Structures for Fine Blanking [*Sources: Courtesy: Feintool Technologie, AG Lyss, Switzerland, Parktechnology, Minnesota, USA*] PV22

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