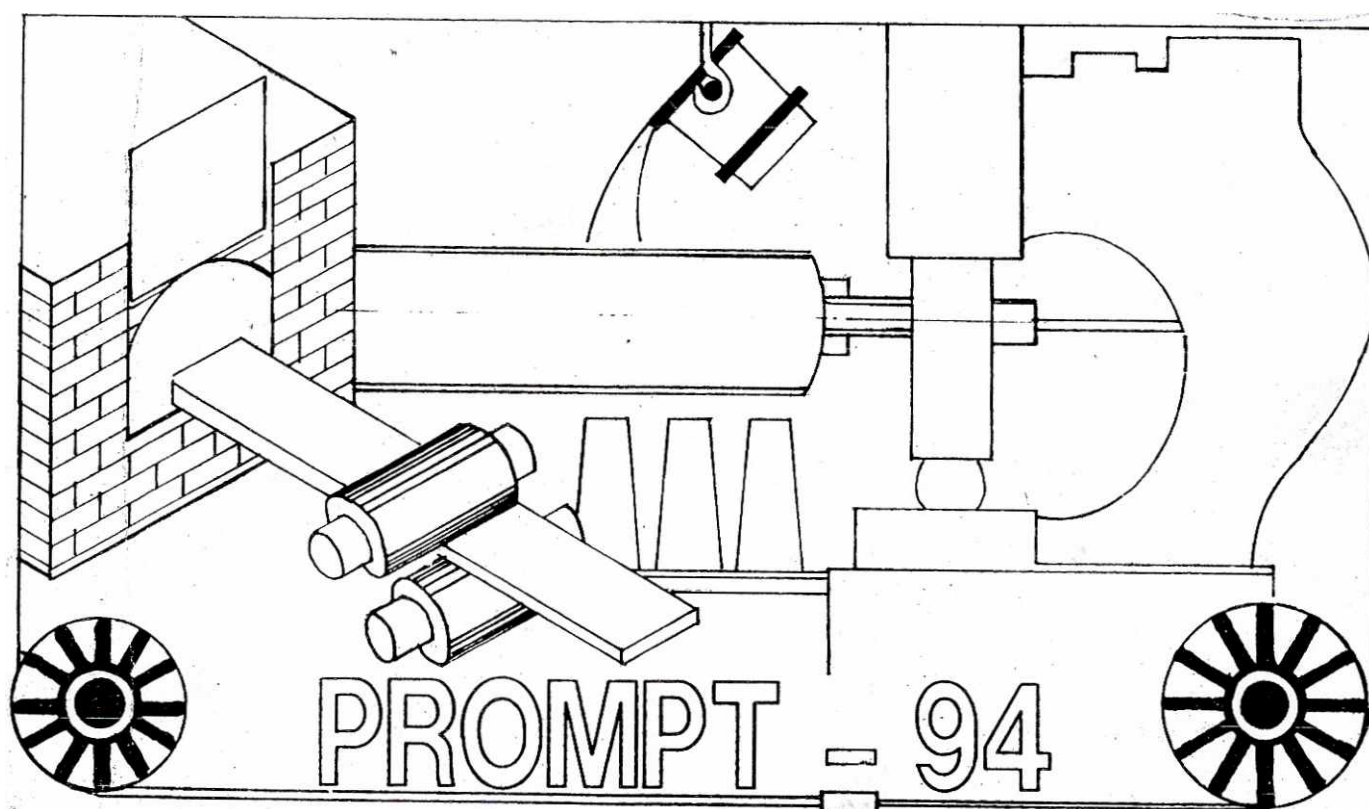


**TAILORING OF PROPERTIES  
THROUGH MECHANICAL PROCESSING**

**A PRACTICAL APPROACH**



N:AL. ARCHIVL  
No

Organised by

**NATIONAL METALLURGICAL LABORATORY**  
**JAMSHEDPUR-831007.**

Workshop  
on  
TAILORING OF **PROPERTIES** THROUGH MECHANICAL  
PROCESSING -- **A PRACTICAL APPROACH** (PROMPT-94)

23-24 September 1994, N.M.L Jamshedpur

## PREFACE

**As** a part of promoting interaction between the National Metallurgical Laboratory, which is a premier R & D institution under the banner of Council of Scientific & Industrial Research, and the Industries this Workshop has been organised. This is with a view to supplement the basic knowledge on various mechanical processing techniques to practising engineers, who may not have sufficient time and approach to literature.

**The** present Workshop has been designed in such a way that Academicians like University Professors, Practising Engineers and R & D Scientists can focus the salient basic features and also crucial problems occurring in mechanical working area. Areas like rolling of metals, forging, extrusion, wire drawing, cladding, thermomechanical treatment are covered. Another interesting work on the emerging technology which is a combination of application of pressure in the liquid state, commonly known as 'Squeeze Casting' has also been dealt with.

The lectures delivered during the course of the Workshop have been collated in the form of the present book.

24th September, 1994: SATURDAY

LECTURE SESSION - III

Hours

An Overview of Manufacturing Methods of  
Tin Mill Black Plate (IMBP) and Its  
Quality Requirements (P.K.Banerjee)

..

0930 to 1015

. k

TEA

1015 to 1045

Technology of Steel Tube Making  
(V.N.Todi and C.B.Lunawat)

1045 to 1130

Role of Indian Standards in Tailoring the  
Properties of Wrought Steels (N.Mitra)

1130 to 1215

Processing of Non-Ferrous Alloys Through  
Extrusion (K.Lal and S.C.Dev)

.0

1215 to 1300

LUNCH

1300 to 1400

LECTURE SESSION - IV

Thermo-mechanical Processing for Tailoring  
Properties in Steels (B.N.Ghosh and N.K.Das)

1400 to 1445

Superplastic Forming of Metals  
(M.P.Singh)

1445 to 1530

11

Evaluation of Hot Workability Through  
Processing Mhps (V.V.Kutumbarao)

1530 to 1615

COPENDING SESSION

1615 to 1630

TEA

. o

1630

Workshop on  
TAILORING OF PROPERTIES THROUGH MECHANICAL  
PROCESSING -- A PRACTICAL APPROACH

**PROGRAMME**

23rd September, 1994: FRIDAY

REGISTRATION: 0900 to 0930 hrs

INAUGURAL TALK -- **Nature: The Best Tailor  
of Materials** by Professor P.Ramachandra Rao  
Director, National Metallurgical Laboratory: 0930 to 1030 hrs

VOTE OF THANKS:

TEA: 1030 to 1100 hrs

LECTURE SESSION - I		Hours
<b>Quality Aspects of Special Forgings of Low Alloy Steels</b> (S.Pandit)	..	1100 to 1145
<b>Tailoring of Properties Through Squeeze Casting Technique</b> (P.K.Biswas)	..	1145 to 1230
<b>Forging Technology -- AS Applied to Automobile Industry</b> (S.R.Sharma)	..	1230 to 1315
LUNCH	..	1315 to 1415
 LECTURE SESSION - II		
<b>Wire Drawing-Influence of Manufacturing Practice on Wire Quality and Properties</b> (M:Viswanathan)		<b>1415 to 1500</b>
<b>Roil Qualities and Economic Utiliza- tion of Rolls</b> (Umesh Singhal)		1500 to 1545
TEA	..	1545 to 1600
<b>Roll Cladding and Property Develop- ments</b> (S.C.Dev and B.N.Ghosh)	..	<b>1600 to 1645</b>
Mechanical Processing in Magnetic Materials (V.Rao)	..	1645 to 1730

## NML AT A GLANCE

The foundation stone of the National Metallurgical Laboratory, Jamshedpur, was laid down by (Late) Pandit Jawarlal Nehru, our first Prime Minister, on September 26, 1950. It aimed at fostering applied and fundamental metallurgical research and development work on indigenous ores, minerals, refractories, ferrous and non-ferrous metals and alloy etc. in relation to their potential applications in Indian mineral and metal industries.

Over the years. NML grew from strength to strength and developed expertise in different areas of metallurgy and material science. Today, the laboratory can boast of an excellent infrastructure in terms of men, materials and equipments. NML has grown into a huge complex employing 220 scientists with a supporting staff of 800. accounting for more than 60% of the total wage bill.

NML could establish a linkage with its user organisations. In the vastly changed context of to-day, quantifying the economic and social benefits of NML's R&D activities and cost-benefit studies in terms of utilisation of the know-hows developed by NML will indeed be a difficult task. As per an estimate made in 1991, NML technologies had yielded savings of Rs 23 crores a year by way of import substitution and another Rs 95 crores by avoidance of losses - besides Rs 671 crores a year through utilization of technologies for value addition.

### **A Few Achievements :**

NML has been involved in exhaustive batch and pilot investigations on various ores and minerals from all over the country. Based on the know-how developed, several mineral processing plants have been commissioned in the country. Detailed characterisation, processing and/or agglomeration studies on Iron Ores and other raw materials of the Ferrous industry for all the Steel Plants of the country have been done by NML. The recent ones being those for Paradip Steel Plant. Orissa: Rastriya Ispat Nigam, Visakhapatnam and Durgapur Steel Plant. Durgapur. In Coal. four froth flotation plants have been set up based on NML's know-how for the recovery of fine coal values at the washeries of TISCO. Jamadoba (West Bokaro); CCL. Gidi and BCCL. Dugda. In the area of Copper Ores, plants based on flow-sheets developed at NML include those at Rakha and Malanjkhand. GMDC, Kadipani (Gujarat) and MPMMC. Chandidongri (Madhya Pradesh) are utilising NML's flow-sheet to produce acid grade fluorspar from low grade ore. India's first commercial plant for producing Magnesium has been put up by Southern Magnesium and Chemicals Ltd., Rajamundry (AP). based on the NML's Technology.

The national creep testing facility at NML has generated a comprehensive database on the high temperature (creep) behaviour of all indigenous steel useful to power plants and methodologies for estimating remaining life for power plant components. NML has developed new grades of manganese-containing steel for high temperature use. NML's technology for the production of low-carbon ferro alloys is being utilized by a number of units producing Fe-Mo, Fe-W, Fe-V, Fe-Mn and Fe-Cr alloys. NML's technology has been used for production of battery grade manganese dioxide from Indian ores by MOIL, Nagpur. Also a 50 kg/day pilot plant has been set up in Rangoon, Myanmar, based on the technology.

NML is a pioneer in the country in producing and supplying standard reference materials for chemical analysis. Recently sample orders were executed for Germany. This is saving foreign exchange and also contributing to the domestic requirements.

NML has done considerable amount of work on metallic corrosion inhibitors. The important inhibitors developed at NML are (1) Metasave - Sulphuric acid pickling inhibitor, (2) NML-Vapour Phase Inhibitor, (3) NML Hydrochloric acid inhibitor, (4) NML-Galvasave. Some of the users are Tata Steel, TCIL Jamshedpur, and so on. M/s Metoil Corporation. Jamshedpur has been producing Metasave and recently taken the Galvasave know-how for commercialisation. A good number of coatings have been developed at NML for steel and aluminium based on co-polymer vinyls. In the area of zinc rich primers, two types of primers developed and evaluated in chemical and fertilizer industries. One is alkali silicate and the other is ethyl silicate. The alkali silicate being water based is very cheap in comparison to organic solvent based. These coatings have been evaluated by different paint manufacturers and steel furniture manufacturers. Recently M/s Tube Products of India. Madras has taken the calorising of steel technology for its commercialisation.

NML's efforts lead to the increase in productivity of brass and bell metal castings. Coke consumption was appreciably reduced and melting losses decreased from 10% to 4% in furnace designed using waste material. Rejection rate was brought down to 6-7% from 30-35% in the commercial aluminium utensil unit. NML's designed Mini Cupola and Equiblast Cupola are extensively used by small foundries.

#### **Current R&D Programme :**

To meet the new situation arising from changes in the Centre's policies, NML has put more emphasis on sponsored research projects. The concept of "joint venture" has already yielded some encouraging results. Private companies like Usha Martin and Panyam Cements have engaged NML for trouble shooting and consultancy works. Recently NML has completed the consultancy projects for a number of clients viz. M/s Dankuni Coal Complex of Coal India Ltd.; M/s SIIL Paloncha Kothaguda; M/s Saha Minerals Ltd., Sahibganj; M/s 'frimax Agencies Pvt.Ltd. Madras; M/s Tamil Nadu Newsprint Ltd, Madras; M/s Dhanbad Chemicals Pvt.Ltd; Malanjkhand Copper Project of Hindustan Copper Ltd.; M/s Hindustan Zinc Ltd, Udaipur; M/s Kudremukh Iron Ore Co.Ltd., M/s Gujarat Mineral Development Corporation; and so on.

The component Integrity Evaluation Programme (CIEP) involving an outlay of Rs 6 crores designed under thrust area projects, has evoked good response in core sectors such as energy, oil and steel. The sponsors like Indian Oil, SAIL, Bharat Petroleum, Tata Iron and Steel Co. and the Union Department of Atomic Energy have lent their support to CIEP. The world Bank has given a soft loan of Rs 3.5 crores. This study is envisaged as a thrust area project to involve reliable methodologies for life prediction for critical engineering components with regard to their performance/failure behaviour in industries. With the completion of the project, it is expected to produce benefits in terms of (i) conservation of material through life extension by retirement of a component, (ii) conservation of energy through efficient design and assured performance of materials and components, (iii) reduction in down-time through phased replacement of worn out components during routine shut down for maintenance, and (iv) increase in reliability and safety through prevention of catastrophic failure.

Another thrust area project entitled "Processing of polymetallic sea nodules for the recovery of metallic values" has been progressing well. This involves development of a suitable process for the recovery of metallic values - particularly, copper, nickel and cobalt economically from polymetallic sea nodules through reduction roast, ammonia leaching, solvent extraction and electrowinning. The technology being developed could also be used to recover Ni and Co from the Indian land based nickel resources.

The central Pollution Board has sponsored a project to study the already alarming pollution levels in Howrah from Foundry and other engineering units in the region and to recommend measures to mitigate the problem. The laboratory has signed an MoU with M/s Usha Martin Industries Ltd., which like other agreements with RDCIS, SAIL, TATA Steel, TOIL, is expected to result in mutual benefit. NML has entered into an agreement with M/s STI Biplus Tubing (India) Ltd. to reduce rejection rate owing to poor brazing, copper flow, black spots and tarnishing in the production of copper-coated tubes, at their plant at Dewas (M.P.). Similarly continuing interaction with TATA Steel has resulted in securing yet another interesting project, viz. Bench scale production of nonasized alumina.

NML's Field Stations at Batala, Howrah, Ahmedabad, Digha as well as regional complex at Madras and the regional liaison centre at Calcutta have been considerably contributing towards the solution of the local industrial problems. The NML Madras Unit has been actively engaged in column flotation studies to improve the grades of mineral concentrates. It has developed a fully automatic microprocessor - controlled pilot column.

M/s Tatanagar Bricks Ltd., Jamshedpur, which has recently floated a public issue, is based on NML's know-how for fly-ash based wear resistant ceramics. It has undergone successful trial run, and also in the process of commercial production. NML needs more of such technology transfers to establish its credentials as an economically viable research laboratory to meet the needs of the small and medium industries which are facing resource constraints to undertake their own in-house R&D programmes. Programmes like CIEP can help NML to live up to Nehru's faith in indigenous research and development capabilities.

# Material Shaping

## *Facilities & Expertise*

The Material Shaping Unit of the Materials Processing (Mt?) Division of the National Metallurgical Laboratory is mainly engaged in R & D activities leading to process & product developments as well as providing infrastructural facilities for rolling, forging, wire drawing, extrusion & heat treatment of ferrous & non-ferrous metals and alloys. The facilities existing here also include large equipment for semi-commercial/pilot scale activities. They have facilitated transfer of several technologies for industrial production.

### Major facilities

- 0' Drop Forging Hammers (0.5, 1 T)
- ☐ 2/4 High Rolling Mill (101
- ☐ Extrusion press (500 T)
- ☐ Hydraulic press (500 T)
- ☐ Wire drawing Bench & Drum
- ☐ Varieties of heat treatment furnaces
- Rapid solidification for ribbons and subsequent densification
- ☐ Powder production, Compaction & Sintering
- ☐ Testing of all mechanical properties (Tensile, Impact, Fracture-Toughness & so on)

### Expertise

- ☐ Extrusion of Al & Mg base alloy
- Production of 18/8 austenitic stainless steel sheet, wire and casting
- Varieties of clad materials
- Production of Non-ferrous alloy sheets, bar & wire
- ☐ Production of varieties of contact materials & brazing alloys
- ☐ Production of Ni-free Fe-Mn-N stainless steel sheets & bars
- ☐ Process for production of agricultural tools

## & D Programme

The Material Shaping Unit pursues relevance-oriented (Thrust Area/Sponsored/Interactive/Collaborative) projects and excellence-oriented (Sponsored/Exploratory) research projects. Its expertise in the form of Consultancy and Technical services is made available against fees.



## Know-how transferred

- CI Nickel-free electrical resistance alloy
  - o Ws Cable Work, Faridabad;
  - o M/s Heat-Well, Calcutta
  - o M/s J. S. Engineering, Varanasi
- O Dental amalaam alloy
  - o M/s Derail! India, Jamshedpur;
  - o M/s Shakti Industries, Varanasi
- O Magnesium-inoculant briquettes
  - o M/s Damani Works, Calcutta °
- Thermostatic 31-Metal
  - o Ws Cable Work, Faridabad
- Cast high speed cutting tools
  - o Ws Vora Engg. Works, Bombay
- Copper-clad Al-sheets
  - o M/s Adarsh Mangal Enterprises, Jamshedpur; •
  - o M/s A.J.Electronic, Poona
  - o M/s Special Material, Nasik
- Al-base filler wire
  - o Karnataka Al Ltd, Bangalore

## Know-how ready for transfer

- O Brazing alloys
  - I.
    - o Ag-Cu eutectic alloy
    - o Ag-Cu-Zn alloy
    - o Cu-Ag-Si alloy, rapidly solidified foils as well conventionally cast
- O Heating element
  - o Ni-Cr alloy
- O Cutting tools
  - o High speed cast culling toots
- O Clad material
  - o Mild steel clad with stainless steelV copper/tool steel
  - o Al-clad with stainless steel
  - o Copper clad aluminium
  - o Al clad Al-brazing alloy
  - o Ag clad Ag-base contact alloy
- O Orthodontic stainless steel wire
- CI Contact Materials
  - o Cu-Cr alloy
  - o Ag-Cd0 contact by internal oxidation
  - o Ag-Ni & Ag-W contact by PM ter.hnique
  - o Cd-free Ag-base alloy

Materials Processing Division  
NATIONAL METALLURGICAL LABORATORY  
Council of Scientific & Industrial Research  
JAMSHEDPUR - 831 007  
INDIA

# Metal Casting

## Powder Production

### *Facilities and Expertise*

**M**etal Casting & Powder Production represents one facet of the programmes charted by the Materials Processing Division of the National Metallurgical Laboratory, Jamshedpur. The activities here broadly encompass the following :

0 Melting and casting of ferrous & non-ferrous materials

- Testing, evaluation, and development of foundry raw materials such as sand, binders and special additives

Production of metal/alloy powders

The above activities are pursued as a part of in-house R&D projects; sponsored/ collaborative/interactive/consultancy programmes; or as supporting services for other divisions of the laboratory.

### **Facilities**

#### **Moulding •**

- 0 Sand-Bentonite system
- 0 CO<sub>2</sub> Silicate system
- Resin-Catalyst system

#### **Testing**

- 0 Entire range of testing for moulding materials
- Li Conventional thermal analysis (DSC/DTA/D TG)
- D Thermal properties of sand/metallic materials

#### **Melting**

- a** Vacuum induction Melting & Casting Unit (40 kg capacity)
- 0 Air Induction Melting Unit (1-15 kg capacity)
- Submerged Arc Furnace (500 KVA)
- Direct Arc Furnace (50 KVA, 30 Kg capacity)
- Gas fired Morgan Furnace (50 kg copper capacity)
- Hot Blast Cupola (1 T/hr)

# Achievements

## Sand/Moulding

- ❑ Publishing a Monograph on Indian loirdry sand/ bentonite
- 3 Development of a self-set sand based on residue from pidgeon process (for magnesium production) .

dt Bereficiation of local river sand for appication in Cast Iron & Non-ferrous foundri65

## Alloy development

- 3 Hee,' resistant high aluminium cast iron (Pyrotioy 1000)

## Powder production

- ❑ Design and installationof prototype atomisation units for ferrous and non-ferrous powders
- ❑ Process development for electrolytic iron powder from sponge fines

## Societal mission

- ❑ Appropriate fuel-efficient melting furnace for rural brass & bell metal artisans
- ❑ Mini cupola for small scale sectors
- ❑ Improved material for plough shear
- ❑ Development of hot blast cupola

## Know-how ready for transfer

0 Production of quality SG/CG iron from sponge iron and other indigenous raw materials

0 Heal resistant Al-bearing cast iron

0 Nitraden-bearing wear resistant cast irons

○❑Super plastic (ferrous) material

○❑Life improvement of ingot moulds

0 Substituted stainless steel (Fe-Mn-Al variety) for elevated temperature applications

Low sulphur, low phosphorus pig iron from sponge fines

SG ircn by inexpensive pure magnesium treatment

• Equi-blast and hot-blast cupola

• Upgradation of lean bentonite

0 Filters/Reactive filters for aluminium alloys

0 Modifier for grain refinement of aluminium and its alloys

• Rheocasting technology for light non-ferrous alloys

0 Rapidly solidified ferrous & non-ferrous materials

0 Atomised ferrous and non-ferrous powders

0 Super pure iron powder through electrolytic route from sponge fines

Materials Processing Division  
NATIONAL METALLURGICAL LABORATORY  
Council of Scientific & Industrial Research  
JAMSHEDPUR - 831 007  
INDIA

*R & D Support is our Motto*

## MATERIALS CHARACTERISATION

Characterisation of materials is related to their structural, physical, mechanical and chemical attributes. For the same chemical composition, the parameters which determine the attributes are microstructural features and flaws in the material. The techniques for materials characterisation use methodologies which are influenced by these parameters. In the recent times, emphasis has been placed to develop and use non-destructive test techniques and to improve the laboratory techniques for better materials characterisation so that the safety and reliability of a component is improved and quantitative life assessment of a component is possible. The Materials Characterisation Division of NML aims to cater to these needs.

Facilities	Expertise
<ul style="list-style-type: none"><li>• Transmission Electron Microscope. Philips EM400 with associated equipment for specimen preparation.</li></ul>	Assessment of structural integrity - on-line and off-line.
<ul style="list-style-type: none"><li>• Scanning Electron Microscope. JEOL JEM 840A, with EDAX facility.</li></ul>	Experimental stress analysis. Failure analysis.
<ul style="list-style-type: none"><li>• Optical(Carl Zeiss &amp; Leitz) microscopes with image analysis facility</li></ul>	Structure property relationship.
<ul style="list-style-type: none"><li>• Portable X-ray diffraction based residual stress measurement.</li></ul>	Non-Destructive Testing for flaw detection/assessment.
<ul style="list-style-type: none"><li>• Portable barkhausen noise analysis system for residual stress measurement and assessment of microstructures.</li></ul>	Non-Destructive Testing for the assessment of microstructures and damages due to mechanical deformations.
<ul style="list-style-type: none"><li>• Equipments for magnetic property determination.</li></ul>	Soft and hard ferrites.
<ul style="list-style-type: none"><li>• X-ray diffraction system for crystal structure determination and phase identification</li></ul>	High strength soft magnetic materials. Alnico magnets.
<ul style="list-style-type: none"><li>• Ultrasonic and eddy current equipment for flaw evaluation.</li></ul>	Insitu microscopy
<ul style="list-style-type: none"><li>• Portable metallography and hardness measurement systems.</li></ul>	High Strength ceramic magnet.

MATERIALS CHARACTERISATION DIVISION  
NATIONAL METALLURGICAL LABORATORY  
JAMSHEDPUR 831 007

---

*QUALITY BY CHOICE AND NOT BY CHANCE*

TAURKSIVP  
ON  
TAILORING OF PROPERTIES THROUGH MECHANICAL  
PROCESSES -- A PRACTICAL APPROACH (PROMPT-94)

COMMITTEE STRUCTURE

Organising Committee

Prof. P.Ramachandra Rao, Director, NML	C.	Chairman
Dr. C.S.Sivaramakrishnan	..	Coordinator
Mr. Sukomal Ghosh	..	Member
Dr. V.Rao	..	Member
Mr. B.N.Ghosh	..	Member
Mr. S.K.Choudhury	..	Member
Mr. Kishori Lal	..	Member
Mr. N.K.Das	..	Member
Mr. S.P.Chakraborty	..	Member
Dr. N.G.Goswami	..	Member

Technical Committee

Mr. B.N.Ghosh	..	Chairman
Mr. S.P.Chakraborty	..	Member
Dr. V.Rao	..	Member
Mr. S.K.Choudhury	..	Member

Finance Committee

Mr. N.K.Das	..	Chairman
Dr. A.K.Ray	..	Member
Dr. C.S.Sivaramakrishnan	..	Member
Mr. Kishori Lal	..	Member

Hospitality/Registration/Accommodation Committee

Mr. Sukomal Ghosh	..	Chairman
Mr. P.K.De	..	Member
Dr. G.Mishra	..	Member
Mr. R.G.Ganguly	..	Member
Mr. M.L.Bhagga	..	Member

Secretarial Assistance

Mr. P.N.Swamy  
Mr. K.Narayanan

## **Faculty**

<b>Banerjee, Mr.P.K</b>	Chief Quality Manager Tinplate Company of India Ltd Golmuri, Jamshedpur 831003
<b>Biswas, Dr.P.K</b>	Scientist National Metallurgical Laboratory Jamshedpur 831007
<b>Das, Mr .N.K</b>	Scientist National. Metallurgical Laboratory Jamshedpur 831007
Dev, Mr.S.0	Scientist National Metallurgical Laboratory Jamshedpur 831007
Ghosh, Mr .B.N	Scientist National Metallurgical Laboratory Jamshedpur 831007
<b>Kutumbarao, Dr.V.V</b>	Professor Head (Dept.of Met.Engineering) Institute of Technology Banaras Hindu University Varanasi 221005
<b>Lal , Mr .K</b>	Scientist National. Metallurgical Laboratory Jamshedpur 831007
<b>Lunawat, Mr .C.B</b>	Divisional Manager Quality Assurance Tube Division Tata Iron & Steel Company Ltd Jamshedpur 831007

**Mitra , Mr .N**

Director  
Bureau of Indian Standards  
Namdih Road  
Jamshedpur 831007

**Pandit, Mr.S**

Deputy General Manager  
Technical Services  
Foundry Forge Plant  
Heavy Engineering Corporation Ltd  
Ranchi 834004

**Rao, Dr .V**

Scientist  
National Metallurgical Laboratory  
Jamshedpur 831007

**Sharma, Mr.S.R**

Divisional Manager (Design & Dev.)  
Forge Division  
Tata Engineering & Locomotive Co.Ltd  
Jamshedpur 831010

**Singh, Dr.M.P**

Professor  
Metallurgical Engineering Dept.  
Regional Institute of Technology  
Adityapur, Jamshedpur 831013

**Singhal, Mr.0**

Divisional Manager  
Roll Technology Services  
Tata Iron & Steel Company Ltd  
Jamshedpur 831001

**TOdi, Mr.V.N**

Thbe Division  
Tata Iron & Steel Company Ltd  
Jamshedpur 831007

**Viswanathan, Dr . M**

Chief Technical Manager  
Indian Copper Development Centre  
27-B, Camac Street  
Calcutta 700016

Workshop  
on  
TAILORING OF PROPERTIES THROUGH  
MECHANICAL PROCESSING -- A PRACTICAL APPROACH  
(September 23-24, 1994)

**LIST of PARTICIPANTS**

1. Bandopadhyay,  
AF/Extrusion (P.NO.837144)  
Ministry of Defence  
Ordnance Factory  
Ambajhari  
Nagpur 440021
2. Bandopadhyay, Mr.P.S  
Works Manager  
Ordnance Factory  
Ambarnath 421502
3. Banerjee, Mr.S  
Senior Engineer (R&D)  
Tinplate Company of India Ltd  
Golmuri  
Jamshedpur 831003
4. Basu, Ms.Sarbari  
Metallurgist (R&D)  
Indian Aluminium Company Ltd  
39, Grand Trunk Road  
Belurmath  
Howrah 711202
5. **Bhattacharya, Mr.P.K**  
Technical Adviser (W.M)  
Indian Steel & Wire Products Ltd  
Indranagar  
Jamshedpur 831008
6. **Bhide, Mr.Rajesh A**  
Assistant Works Manager  
Ordnance Factory  
Ambarnath 421502

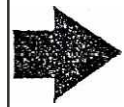


7. **Chandran, Mr.Ravi**  
Deputy Manager (R&D)  
Tata Iron & Steel Co.Ltd  
Jamshedpur 831001
8. **Choubey, Mr.S.M**  
Manager  
Bharat Aluminium Company Ltd  
P.O: BALCO Township  
Korba 495684
9. **Choudhury, Mr.S.P**  
Scientist  
National Metallurgical Laboratory  
Jamshedpur 831007
10. **Das, Mr.L.K**  
Engineer  
India Government Mint  
Alipore 700053
11. **Das, Mr.Shantanu**  
Quality Assurance  
Usha Martin Industries Ltd  
Jamshedpur 831001
12. **Dey, Mr .N.K**  
Assistant Works Manager  
India Government Mint  
Alipore 700053
13. **Goswami, Mr.S.B**  
AF/IMS (P.No.887158)  
Ministry of Defence  
Ordnance Factory  
Ambajhari  
Nagpur 440021
14. **Hajela, Mr.P**  
Manager  
Bharat Aluminium Company Ltd  
P.O: BALCO Township  
Korba 495684
15. **Haider, Mr.S.H**  
Deputy Manager (Metallurgy)  
Bokaro Steel Plant  
Steel Authority of India Ltd  
Bokaro Steel City  
Bokaro

16. **Kambli, Mr .R.S**  
Works Manager  
Ordnance Factory  
Ambarnath 421502
17. **Kunar, Mr.A**  
Deputy Manager (Technical Services)  
Heavy Engineering Corporation  
Ranchi 834004
18. **Lunawat, Mr.C.B**  
Divisional Manager (QA)  
Tubes Division  
Tata Iron & Steel Company Ltd  
Jamshedpur 831007
19. **Mahajan, Mr.R-C**  
General Manager (Works)  
Indian Steel & Wire Products Ltd  
Indranagar  
Jamshedpur 831008
20. **Mahanti, Mr.R.K**  
Scientist  
National Metallurgical Laboratory  
Jamshedpur 831007
21. **Mhlhotra, Mr.A.K**  
Deputy General Manager  
Rourkela Steel Plant  
Steel Authority of India Ltd  
Rourkela 769011
22. **Mishra, Mr.A.K**  
Senior Engineer (QA)  
Tinsplate Company of India Ltd  
Golmuri  
Jamshedpur 831003
23. **Mishra, Mr.Sandeep**  
SSS Industries  
Adityapur  
Jamshedpur 831013
24. **Parida, Dr.N**  
Scientist  
National Metallurgical Laboratory  
Jamshedpur 831007

25. Rao, Mr.P.R.G  
Divisional Manager (Plant Engineering)  
Ribes Division  
Tata Iron & Steel Co.Ltd  
Jamshedpur 831007
26. Roy, Mr.Soumitra  
Metallurgist (R&D)  
Indian Aluminium Company Ltd  
39, Grand Trunk Road  
Belurmah  
Howrah 711202
27. **Sharma, Mr.M.K**  
Deputy Manager  
Heavy Engineering Corporation  
RanChi 834004
28. **Singh, Mr.Charanjit**  
WRM Production  
Usha Martin Industries Ltd  
Jamshedpur 831001
29. **Sinha, Mr.R.K**  
Scientist  
National Metallurgical Laboratory  
Jamshedpur 831007
30. **Sisodia, Mr.S**  
Manager (Metallurgical Services)  
Salem Steel Plant  
Steel Authority of India Ltd  
Salem 636013
31. **Tiwary, Mr.S.K**  
Assistant Manager (R&D)  
Tata Iron & Steel Co.Ltd  
Jamshedpur 831001
32. **Vasudevan, Mr.S**  
Senior Manager (Project)  
Salem Steel Plant  
Steel Authority of India Ltd  
Salem 636013

# TECHNICAL PAPERS



WORKSHOP  
ON  
TAILORING OF PROPERTIES THROUGH  
MECHANICAL PROCESSING -- A PRACTICAL APPROACH

September 23-24, 1994

List of Papers

- "Evaluation of Hot Workability through Processing Maps"  
(V.V.Kutumba Rao)
- it( "Quality Aspects of Special. Forgings of Low Alloy Steels"  
(S.Pandit)
- 3,1 "Tailoring of Properties through Squeeze Casting Technique"  
(P.K.Biswas)
- L,1 Forging Technology -- As Applied to Automobile Industry"  
(S.R.Sharma)
- "Wire Drawing -- Influence of Manufacturing Practice on Wire Quality  
and Properties"  
(M.Viswanathan)
- 6'1 "Roll Qualities and Economic Utilization of Rolls"  
(Umesh Singhal)
- "Roll Cladding and Property Developments"  
(S.C.Dev and B.N.Ghosh)
- g.1 "Mechanical Processing in Magnetic Materials"  
(V.Rao)
- "An Overview of Manufacturing Methods of Tin Mill Black Plate (TMBP)  
and its Quality Requirements"  
(P.K.Banerjee)
- lod "Technology of Steel Tube Making"  
(V.N.Todi and C.B.Lunawat)
- 11'1 "Role of Indian Standards in Tailoring the Properties of Wrought  
Steels"  
(N.Mitra)
- 12A "Processing of Non-ferrous Alloys through Extrusion"  
(K.Lal and S.C.Dev)
- 131 "Thermo-mechanical Processing for Tailoring Properties in Steels"  
(B.N.Ghosh and N.K.Das)
- 14\_1 "Superplastic Forming of Metals"  
(M.P.Singh)

EVALUATION OF HOT WORKABILITY THROUGH PROCESSING MAPS

V.V.Kutumba Rao  
Professor & Head  
Department of Metallurgical Engineering  
Banaras Hindu University  
Varanasi 221005