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SOCIETY OF STUDENT METALLURGISTS

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5th, Met. E.
1981
Soumitra Sinha
Somita Sinha.

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EDITORS
INDRANIL MANNA
DEBOJYOTI BANERJEE

A TECHNICAL JOURNAL

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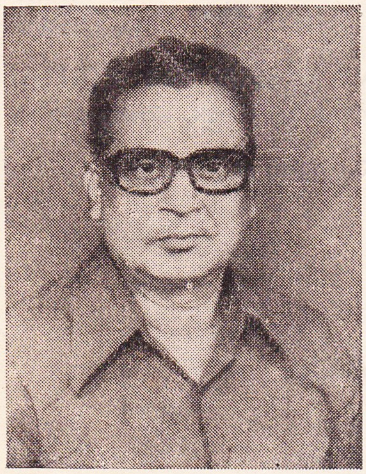

MESSAGE FROM

B

The President, S.S.M.

B. E. College.

D

DEEP

I am very pleased to know that after a lapse of only one year the Society of Student Metallurgists is going to bring out the 18th issue of the S.S.M. Annual very shortly. It is indeed difficult for a small body like the S S.M. with very limited financial resources to publish a technical journal under very trying conditions prevailing at present. That the organisers and the magazine secretaries of the S.S.M. have succeeded in getting over all the difficulties that came in their way, speaks of their hard work, sincerity, resourcefulness and devotion to work.

In the context of the present social condition there is a growing realisation of the urgency for developing character and outlook. Bringing out such a technical journal in these hard days will serve as a method for training of my students in a way that will develop in them, a spirit of selflessness and self reliance and a sense of understanding and adjustment which are so essential for betterment of one's self and for restructuring of the society.

I heartily congratulate the organisers of the S.S.M. for this excellent achievement.

With best wishes,

Sd/-
P. P. Das
President, S. S. M.

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Prof. A. K. Seal,
B. Sc. (Hons.), B E. (Met), Ph.D. (Sheffield), C. Eng.
MIIM (Ind.), MIIF (Ind.), FIM (Lond.), FIE (Ind.),
National Metallurgist, 1965
PRINCIPAL

सत्यमेव जयते

BENGAL ENGINEERING COLLEGE
P. O. BOTANIC GARDEN, HOWRAH-711 103

3rd March, 1981.

MESSAGE

I am happy to learn that the Society of Student Metallurgists, Bengal Engineering College is bringing out this month the 18th issue of its Technical Journal, the SSM ANNUAL.

The members of the Society, in its own limited sphere, are furthering the cause of metallurgy through the medium of this journal and I believe the present issue will continue to maintain, if not improve, the standard and tradition set by the Society. I do hope the student metallurgists will take advantage of this forum to display their literary talents, technical knowledge and organising abilities by improving the format of the journal and enriching its reading contents by their own contributions.

The prohibitive prices of printing and stationery and the dearth of advertisements, not to speak of its own limited financial resources, have all combined to serve as a damper to the Society's enthusiasm to see the journal grow in bulk and variety. I must congratulate the Society for their laudable efforts to bring out this number in spite of these constraints.

I wish the Society of Student Metallurgists, Bengal Engineering College, all the best now and in the years to come.

Sd/-
A. K. Seal
Principal
Bengal Engineering College

MESSAGE FROM

Dr. M. N. Dastur,
Chairman and Managing Director,
M. N. Dastur & Company (P) Ltd.
Consulting Engineers, Calcutta.

I am glad to learn that the Society of Student Metallurgists of the Department of Metallurgy, Bengal Engineering College has completed 18 years of its useful and active service to its members and is bringing out the Annual Journal this year also.

The education and training which the young metallurgists are receiving today in their alma mater will prepare them for their professional life and enable them to make valuable contribution to national development and growth. I wish the young metallurgists and members of the Society all success and prosperity in their studies and future career.

Dr. M. N. Dastur

Calcutta
25th February 1981

EDITORIAL

An old proverb says "Responsibility educates". This is what exactly happened to us in venturing to restore the tradition of publication of the annual journal of the S.S.M. after an unavoidable lapse of one year. We had the minimum idea and experience but were optimally determined. We knew— "Adversity is the trial of principle, without it a man hardly knows whether he is honest or not." So we went ahead under the guidance of our esteemed President Dr. P.P. Das and other office bearers of the S.S.M. and finally had the last laugh when this 18th edition was published at last. In this context quite relevantly, we would like to express our heartfelt gratitude to Sri Amitava Majumdar and Sri Subhasish Sircar without whose active cooperation and constant guidance this venture would never have been successful. We also thank sincerely the first year student members of the Society for their benignent help to ascertain the financial aspect through cellection of advertisements.

At this crucial juncture when India is striving hard to secure stability and prosperity in the economic as well as political field, it is customory for every responsible citizen to exercise his utmost dedication and competence in the discipline he is concerned with to accelerate India's progress. We being attached to the technological and developmental aspects of our country have the most important role to achieve the desired production level and self sufficiency in expertise. In the capacity of metallurgists we ought to shoulder enormous responsibilities concerning the nation's progress.

In this journal our motto is to facilitate the budding metallurgists of this age old institution who would be in the forefront of India's technological horizon in the long run. We believe, the intelligent and scientific expressions of creative ideas in this journal will be highly appreciated and will come to genuine help to everyone engaged in the field of metallurgy.

At the conclusion, let us earnestly hope, this journal unveils a galaxy of promising talents under whose stewardship India will one day see herself in the limelight in the international arena of science and technology.

Indranil Manna
Debojyoti Banerjee.

CONTENTS

SELF LUBRICATING BEARINGS*

INTRODUCTION :

The purpose of any bearing is to bear or to carry the load of a rotating shaft. A frictional force is developed at the interface when a shaft rotates on a bearing and this leads to wear and abration of the bearing and generation of heat at the interface. The last one may cause oxidation and other phase changes. So to minimise the friction at the interface proper lubrication is necessary. Sometimes external lubrication is difficult in some inaccessible region of a machine. In such cases self lubricating bearings are extremely useful. Self-lubrication is achieved by preparing bearings having pores which are connected with each other and also to the surface and impregnating them with oil. The pores with controlled size, shape and size distribution are necessary for efficient lubrication. Powder Metallurgy provides the most suitable method of controlling the above three properties of pores.

ADVANTAGE OF POWDER METALLURGY METHOD OVER CONVENTIONAL METHOD OF PRODUCTION OF SELF LUBRICATING BEARINGS :

The difficulty in producing these bearings by the conventional casting process is that we may not get interconnected pores throughout the mass and the pores at the interior may get separated from the surface.

The pores reduce the mechanical properties of the bearings. Each pore acts as a source of stress concentration. So the ductility and the impact resistance are specially impaired and the compressive strength is below normal. This fact is significant in case of bearings because a minimum level of the compressive strength is necessary for the bearings to carry the load. The hard particles standing out in relief at the surface of the bearing material, embedded in a soft matrix, carry the load.

CHARACTERISTICS OF POROUS BEARINGS :

The main characteristics of these type of bearings are that they must contain over 90% of interconnected pores and must have a pore volume of 10-40% (Average 25%). For a pore volume of 25%, 2 to 4% by weight of oil is necessary. The size, shape and number of porosities change during sintering and the density of compact increases as the total porosity decreases.

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*Manabendra Narayan Bagchi ; 5th Yr. Met. E

BEARING MATERIALS :

1) Bronze bearings :- The most important type is composed of copper and tin alloys in which tin varies from 5 to 12%. Graphite in the range of 0 to 6% is used to impart the damping capacity and to improve the antifriction properties, wear resistance, and resistance to pitting. Copper and tin powder of various grades and pure graphite are mixed in a ball mill. Compaction is done by cold pressing the powder mixture at a pressure of 15 to 35 p.s.i. . Pressing is followed by presintering at a temperature range of 400 to 500°C and then sintering at 800°C Sometime to achieve proper dimensional accuracy sizing is employed after the sintering is completed.

2) Copper Base Bearings other than Bronzes :- Replacement of tin by zinc or lead or iron has met only with a certain amount of success. Brass has a lower wear-resistance compared to bronze.

Copper—lead bearings containing 20 to 40% lead, balance copper, can be used under heavy load application involving speeds upto 3000 r.p.m., oil temperature however not exceeding 135°C. Super high speed and temperature for this type of alloy are not recommended because of scoring and corrosion effect. These effects can be overcome by using bearings materials of copper or copper-nickel alloys impregnated with lead alloys containing 3% each of tin and antimony.

Iron Base Bearing :

These bearings are made from pure iron powder and other alloying elements like copper, lead etc. These bearings have high hardness and strength. In the case of lead-iron alloys containing 2 to 6% lead and 2 to 4% graphite, lead is sprayed in a powdery form on iron-graphite mixture or lead oxide is added. Lead oxide is reduced by furnace atmosphere or excess graphite during sintering. Cold pressing is followed by presintering at 800°C and sintering at 1100°C Iron-copper bearing alloys are produced by mixing iron powder with 2 to 20% copper powder and 0 to 4% graphite and are used for special heavy duty application.

Aluminium Base Bearings :

Aluminium base bearings contain intermetallic compounds such as Al_3Fe (5·9%), Al_3Mn(5%) etc. wich are added to soft aluminium matrix in the form of atomised or pulverised powder. The powders remain very finely and uniformly distributed. Aluminium bearings are light, give resistance to corrosion and they can be heat-treated to get the desired properties.

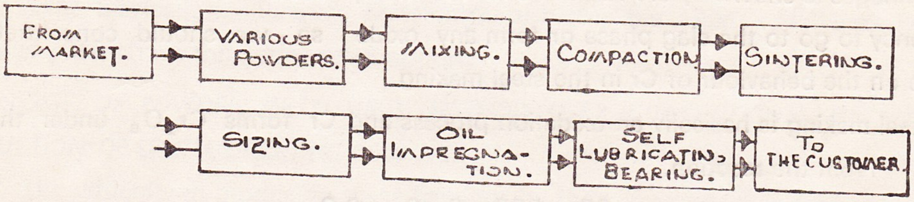
OIL IMPREGNATION :

By this process the lubricating oil gets entry into the interconnected pores when after sintering or final machining the porous bearings are heated in the lubricating oil at a temperature of 80 to 100°C for about 10 to 12 minutes. Air present within the pores is sucked out. The oil remains inside the pores even after cooling because of capillary action.

PRINCIPLE OF SELF LUBRICATION :

When the motor is started, the shaft due to its rotating motion draws oil to the bearing surface. Owing to frictional heat the oil expands and a continuous oil film is furnished by the interconnected pores. The oil forms a protective film thus preventing direct metal to metal contact. When the motor is stopped some oil is reabsorbed into the pores due to capillary action and some remains at the bearing surface which prevents the direct metal to metal contact even when the shaft does not rotate,

FOR THE PRODUCTION PROCESS LAYOUT OF SELF-LUBRICATING BEARINGS :



APPLICATIONS :

Porous self-lubricating bearings are used widely in automobile, tractor, aviation and texfile industries, food mixers, agricultural machines, electrical industry etc.

CONCLUSION :

Powder metallurgy techniques now-a-days are capable of producing porous bearings of close dimensional tolerances in most cases without necessity of machining. Due to self lubricating properties and due to the ease of feed of lubricants, the wear of shaft and bearings is reduced and the design of sub-assemblies can also be simplified. Moreover, these bearings can be produced from materials which are not short in supply. So the powder metallurgy technique has proved itself a competitive and competent process for producing porous bearings.

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ART OF STAINLESS STEEL MAKING*

From the name it is evident that stainless steels are more resistant to rusting and staining than are plain C and low-alloy steels. The superior corrosion resistance is brought about by addition of the element Cr to alloy of Fe & C. Although other elements such as Cu, Al, Si, Ni, Mo etc. increase the corrosion resistance of steel, they are limited in their usefulness. The standard practlces are Fe-Cr and Fe-Cr-Ni steels where Cr is the major element for conferring corrosion resistance.

Stainless steel is generally manufactured from stainless-steel scraps and they are melted in either the electric are furnace or high-frequency induction furnace ; largest tonnages is shown by arc furnace and it is widely used. Ni does not show any tendency to go to the slag phase or form any oxide ; so we should concentrate our views on the behaviour of Cr in the steel making.

Steel making is basically an oxidation process and Cr forms Cr_2O_3 under this condition. From the reaction.

$$2Cr+3CO=Cr_2O_3+3\,C$$

$K=\frac{a_{Cr_2O_3}\cdot a_{C}^{3}}{a_{Cr}^{2}\cdot p_{CO}^{3}}=1$ at 1220°C, where K is the equilibrium const. If steels with low C & high Cr are to be made values of $K<<1$ are required and temp. far in excess of 1220°C. is necessary. The effects of other alloying elements on the behaviour of Cr are not known properly ; only the interactions between Cr & C in liquid Fe have been investigated adequately. So, considering the Cr-C relationship we get the minimum C content at any temp. which can be achieved by oxidation of the melt wtthout also oxidising the Cr. For example with 10 wt.%Cr in the metal the C could theoretically be reduced to 0·05 wt.% at 1800°C but only 0·22 wt.% at 1600°C. The low C is essential to ensure freedom from grain boundary corrosion as a result of C concentration gradient. In non-stabilised stainless steel the preferable value is 0·04 wt.%; but in the stabilised steel it may be 1% or 0·5%. But then the cost to stabilise C

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* Biman Ghosh 5th. Yr. Met. E.

as carbide by adding strong carbide forming element (e.g. Ti, Mo etc.) is too high. So generally, we go for non-stabilised austenitic stainless-steel and high temperature for good Cr recovery is one of the most important factors. As the cost of electricity is high and availability is also a problem and in industry, time is also a critical factor ; so in order to solve all these problems we lance O_2 in the bath. The impurities in the order Si, Mn, C, P. along with some Cr and Fe are oxidised. These are all exothermic reactions, so temperature attainment is very quick. Actually 1·33wt.% Cr loss can increase the temperature by 200°C ; but additional Cr loss is there to raise the temperature of metal and slag and to compensate the heat loss from the system.

We raise the temperature to 1800°C or above. As we have to keep the bath at that temperature so refractory is a problem and we use high alumina (75-80%) refractory for high temperature sustainability. In our Indian condition we should not open the bath at a C content $>$ 0·25. Then we have to expose the bath at high temperature for a long time. Refractory from the furcace roof will spall. In Japan as they have got a very good deposit for excellent refractories they sometimes open the bath at 0·5% concent and then reduce at to 0·06 % to 0·08%. This helps to impart greater cleanliness.

Cr_2O_3 comes in the slag-phase. The solubility limit of Cr_2O_3 in slag is only 10wt.%. If amount of Cr_2O_3 increases in the slag phase it will just make the slag more viscous and unworkable. So, to prevent the oxidation of Cr from the charge, chromite ore is charged along with the scrap. It will saturate the Cr_2O_3 level of slag. When we start from ordinary scrap then cromite ore is charged only after first slagging off to remove P, S etc. If we start from the virgin scrap we try to recover the Cr by adding some deoxidising agent. Generally we use ferro-silicon as the deoxidising agent. This reduces the oxygen potential of the system below that for carbon oxygen equilibrium and allows a new equilibrium to be set up between metal and slag.

Recovery of Cr is better in basic slag than in acidic condition. Again, addition of 'Fe-Si' becomes insignificant due to the high 'SiO_2' activity in slag (close to unity). 'Si' is also added in the form of Si dust. 'Al' shots may be used for deoxidiation. Carbon is never used as there is 100% chance of carbon pick up by the metal and the whole process will lose its rythm. After deoxidation we take a sample from the bath. If the 'C' & 'Cr.' composition is alright then we give a 'pseudo-boil' in the bath to get a cleaner steel. The boil may be given by wooden bamboo or any inert boil is given.

But in case of argon or Nitrogen boil the bath may be chilled. So prior to giving inert boil we should raise the temperature of the bath to higher value, so that chilling does not affect the process There is also arrangement for induction stirring in the bath to have a better slag-metal reaction.

Now depending on the composition of the bath alloying element is added. Generally the size of the alloy is within 2 inches to have a better and rapid solution. 'Cr' is added in the form of ferro-chrome. If addition of 'Ni' is demanded, it is added in the metallic form. 'Ni' obtained in the forms of sheared electrolytic cathodes or as ingots produced from remelted cathodes.

To conclude, the economy of the standard practice must be mentioned. We know that 'Cr' is a ferrite stabilising element and 18% 'Cr' vanishes the austenite field. So to have a good heat treatable property this austenite field must be recovered. So we add Ni (austenite stabilising element) in the stainless steel. Ni also provides good impact property at sub-zero level and toughness and it also increases the corrosion resistance property. But our country is very lean in 'Ni' deposit and we have to spend a huge amount of foreign money to import 'Ni'. But 2% 'Mn' can give the effect of 1% Ni (approx.). Though all the good effect of 'Ni' is not obtained still the major purpose of Ni addition may be minimised by Mn addition. And as our country has got the highest 'Mn' deposit and we are exporting the ore without any use in our country. So to have a better economic advantage we must go for Cr-Mn type of stainless steel.

FIELD ION MICROSPOPE*

INTRODUCTION :

With the invention of microscope by Leeuwenhoek, mankind gradually began to form a percept of the world of tinies, both living and non-living. And this percept was revolutionised again with the advent of electron microscope and the latest—"Field Ion Microscope" the most successful step made yet in making the invisible things visible.

Although the present day electron microscope can resolve non-metallic molecular structures with a lattice spacing of 10Å but the Transmission Electron Microscope (TEM), at hand, fails to resolve a metallic lattice spacing of 3Å. Hence is felt the urge for introducing Field Ion Microscope (FIM), for metallography at the atomic level.

FIM is able to locate individual atom on the surface of a solid metal quite intimately and in its most recent version, to analyse them. It offers a resolution to the tune of 2-3Å, which married with a magnification of 10^6 times, makes it the ultimate metallographic tool for the study of atomic structures with lattice irregularities. It also yields surfaces which are automatically smooth, clean and perfect and on which delicate experiments involving interactions between atoms can be made.

HISTORICAL BACKGROUND :

FIM was first introduced in 1951 as a legitimate modification of the preceeing device Field Emission Microscope (FEM). Both the device owe their birth to the outstanding German Scientist Erwin W. Muller. F. E. M. made use of a fine point-end wire specimen, kept negative with respect to a fluorescent screen on which an image was projected by emission of electrons from the specimen. But the considerably high tangential velocity component of the emitted electrons coupled with a diffraction effect, restrained the resolving power of FEM within the limit of 10-30Å. Muller

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*Debasis Chakraborty & Kinshuk Ghosh 5th. Yr. Met E.

then made the specimen positive with respect to the fluorescent screen and with a small amount of hydrogen image gas, he succeded in projecting an image formed by hydrogen ions which have a greater mass and concurrently lesser tangential velocity component But even then the resolution limit was 5-10$\overset{0}{A}$ because of holding the specimen at room temperature

Then in 1956, Muller and Bahadur operated a F. I. M with the specimen cooled to liquid and solid nitrogen and liquid hydrogen temperature using helium as image gas. Revealation of individual atoms with a resolution of 2-3$\overset{0}{A}$ was then observed on the epoch-making micrographs of Pt, W, Re. in 1958 at Berlin in Muller's papers.

THEORY :

The process of image formation in a FIM is determined by three important parameters.

i) Effect of field in structure of metallic surfaces,

ii) Field ionisation mechanism,

iii) Field evaporation phenomenon.

Since this part of the topic falls completely under higher physics, it would be better to have some idea on the electronic configuration of metals on which (i) depends.

Now the electronic configuration of metallic sufaces under external field is not properly understood yet, except some guesses made on the basis of Harring's electro-model. The electronic energy levels inside the metal are specified by Fermi-Dirac statistics and at absolute zero, all the energy levels upto Fermi level are filled with an energy function $E_{.f}$ The higher levels however, remain vacant and the work function ϕ which represents the energy difference between an electron having Fermi energy and another outside the metal in vacuum is the smallest for least close packed surfaces.

ii; When a valence electron tunnels out from a neutral gas atom into a metal tip, the neutral image gas is ionised. The mechanism is known as field-ionisation mechanism. But this mass dependent tunnelling mechanism was discarded by the fact that hydrogen and deuteron formed similar ions at almost identical fields.

Notwithstanding the few micron pressure maintained in the tube, the image gas atom is attracted to the tip with high kinetic motion due to polarisation in the inhomogeneous field near the tip of the specimen.

iii) It is the process applied for smoothening of the specimen surface with elimination of the oxide layers etc. and also determines the limit of high field operation in the microscope. Evaporation of surface atoms as positive ions under the influence of the high positive field is possible in field-evaporation even at cryogenic temperatures. Continued field-evaporation of such a smooth surface proceeds from edges of the close packed planes and is used to remove repeated atomic layers, whereby bulk crystal structure can be studied.

Muller, Gomer and Swanson (1960-63) have pictured the process of field-evaporation as a desorption phenomenon.

$$\phi_0 = \Lambda + \sum_n I_n - n\phi$$

Here ϕ_0 energy is needed for removal of an atom from a thermionic cycle.

Λ — Sublimation energy

$\sum_n I_n$ — Ionisation energy

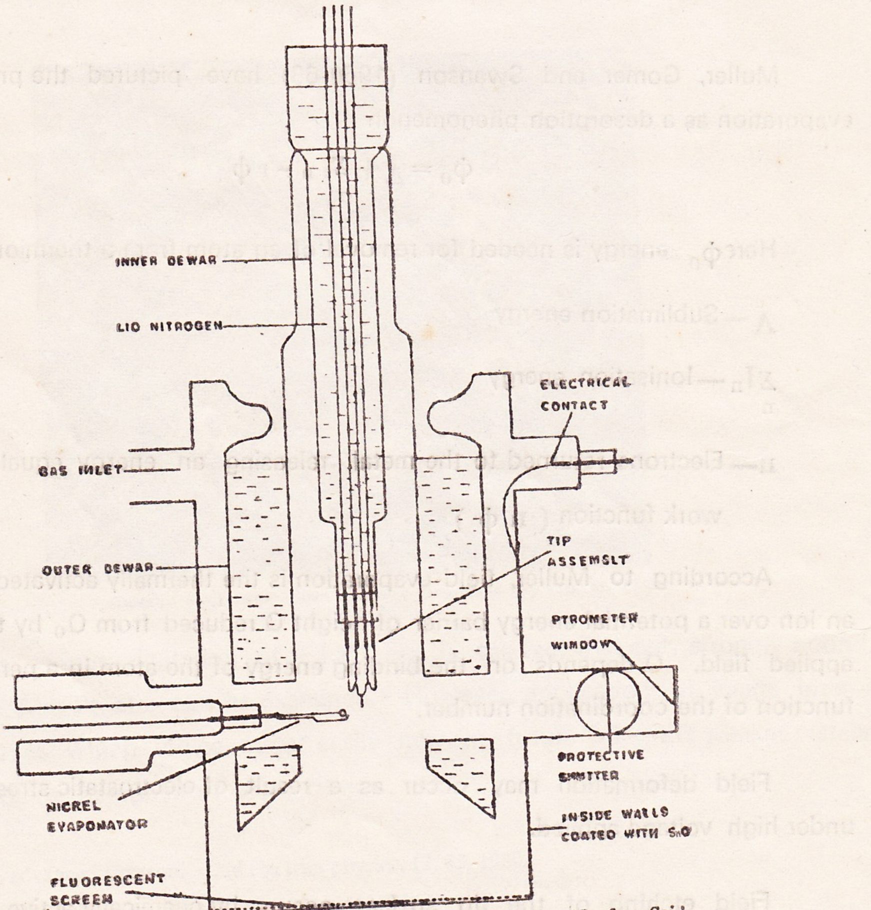
n — Electrons returned to the metal, releasing an energy equal to n' times the work function $(n\phi)$

According to Muller, field-evaporation is the thermally activated evaporation of an ion over a potential energy barrier of height Q reduced from Q_0 by the influence of applied field. Q depends on the binding energy of the atom in a perfect lattice, as a function of the coordination number.

Field deformation may occur as a result of electrostatic stress development under high voltage applied.

Field etching of the tip surface occurs by chemically active species in background vacuum system.

The sectional diagram of a FIM is given in the accompanying figure. The metal specimen in the form of a wire is electropolished to obtain a hemispherical tip at the emission end, with a radius of few 100 Å. The other end is welded to a filament between tungsten cathodes cooled with liquid and solid nitrogen. The whole assembly is mounted on an evacuated (10^{-6}m.m. of Hg) glass chamber to which if introduced a trace of He gas at a pressure of 10^{-3}m.m. fluorescent screen made up of copper activated ZnS CdS phosphor, is located an inch or so away from the specimen tip and records the atomic image of the tip as a pattern of bright spots, each spot being produced by a helium ion, since the specimen is held at a positive potential of 5 Kv with respect to the screen.



(Courtesy: 'Surface Sci.'

The partly exposed positive ions on the tip surface, formed as a result of slight pulling of the electrons by a positive field, are carried to a screen by the gas atoms, for the helium atoms in the vicinity of surface are positively ionised. These gas ions then accelerate down the straight and radial lines of force, radiating from the metal ion to the surface, and faithfully reproduces on the screen the pattern of ionisation centres at the metal tip. Photography of the total image needs an exposure of about 1 minute.

However, ionisation of all surface atoms are not possible in this case, except of only those, which are exposed above the general surface level. Such atoms occur, when close packed planes emerge from the surface and form image on the screen with a magnification of 10^6 times (ratio of screen distance to tip radius).

Intense images can be produced by a sufficiently high voltage, but not that the ions should be pulled off from the surface. Cehesive strength of the metal resists the phenomenon of field evaporation.

PRACTICAL ASPECTS OF FIELD-ION MICROSCOPE :

Vacuum system—Contamination or corrosion of the tip is prevented by keeping a background pressure of 10^{-6} torr by means of a oil diffusion pump backed by a rotary pump which can give a vacuo of 10^{-7}—10^{-9} torr using liquid nitrogen contamination traps.

Pumping speed can be increased by an ion pump with a roughing pump.

Image intensity— By a controlled increase in gas pressure to less than 10^{-2} torr, image intensity can be raised by avoiding undue scattering or ion-atom collision. The point image is then resulted with an image current of 10^{-9} Amps. Expesure time for photographing the image is brought down to 10 sec. at 80 KV instead of 1 min. at 3-4 KV. by an image intensifier, when He is used as the image gas.

Image gas – He is most commonly used for it is ionised at fields above 45 V/A for evaporation.

FIM is capable of imaging :

a) Individual parent and impurity atom, lattice vacancy and interstitial atoms.
b) The atomic structure of grain-boundary.
c) The core-structure of a dislocation.

In Pt, quenched from just below its melting point, were shown the vacancies as dark holes amidst the lines of bright visible atoms by Muller. Point defects have also been seen in Wafter neutron bombardment.

Other applications include the study of alloying effect such as order and disorder in solid solutions and clustering at the early stages of precipitation.

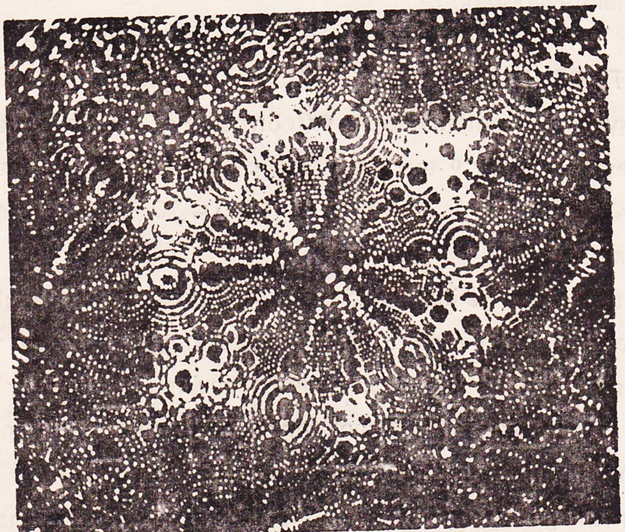
Limitations :

a) Fracture of the specimen and twinning and modification of dislocation content may be caused by sresses of hydrostatic and shear type.

b) Higher melting point metals with high electrical conductivity are suitable for FIM study. And only then, metals which have higher evaporation field than the image field, can be studied by the method.

CONCLUSION

Extensive researches and interest in the area of F.I.M. have been growing exponentially. So day by day new reports are obtained which are not all within our scope.



Tungsten imaged with helium ions, at a temperature very close to 4.2°K
(Courtesy R G Forbes)

But the serious limitation of F.I.M. lies in the fact that only strongly bound metals like W, Mo, Pt, etc. can be examined. However, application of image intensifiers and gases which ionize more easily may in future bring the weaker metals within the scope of the epoch—making device.

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NEW FRONTIERS IN STEELMAKING AND INDIA*

INTRODUCTION

Steel is one of the materials of prime importance in this age. Steel consumption per capita is often considered as a criterion for indexing countries in order of their industrial achievements.

Need for quality steels is on increase all around the world This obviates the necessity for newer and better methods for steel production and modifications of the existing processes so as to increase the output of the plants in operation.

Evolution of the steel making processes will be outlined and their applicability in Indian steel industry will be discussed in this review.

PROCESSES FOR MAKING OF STEEL

As is well known, the steel making processes have been categorized as pneumatic and hearth steel making with the characterization of acid and basic types depending on the nature of the slag.

Pneumatic processes are autogenous in nature In these processes, air, high purity oxygen or a mixture of these or any suitable oxidising gas is passed through, over the, on to the surface of the molten metal charge LD. Bessemer, Kaldo, Rotor converters are pneumatic in operation.

Hearth processes involve heating of the charge with the help of exogenous fuel supply, and greater scrap melting capacities. Open hearth, Electric arc, induction furnaces involve hearth steel making.

From 1950 onwards, there has been a steady increase in the World's crude steel prduction with a gradual change in technology. This is shown in table I. From the table, it is evident that the sixties were characterized by two very important features :

—Steep rise in the world's crude steel production.

—Exponential development in oxygen steel making.

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*Amitava Majumdar, V-th yr. Met. Engg., B. E. College

YEAR	1950		1960		1970		1978	
PROCESS	Production million tons	% of Total prodn.	Production million tons	% of Total prodn.	Production million tons	% of Total prodn	Production million tons	% of Total Prodn.
Open Hearth	147	76.5%	236.5	68 3	230	38.6	164	22.8
Basic Bessemer	20	104%	39	11.2	23	3.8	1.5	0.02
LD+OBM	—	—	13.5	3.9	237	39.8	360	50.2
Electric Furnace	12	6%	37.5	10.8	85	14.2	136	18.96
Others	13	6.7%	19.5	5.6	20	3.3	55.5	7 7
TOTAL	192	100	347	100	595	100	717	100

During the last ten years, the seventies, we see that, as far as the processes are concerned, the electric furnace has continued to increase its production. The seventies are also characterized by rapid decline of the Open Hearth process and disappearence of the Basic Bessemer process. Production of steel by LD/OBM processes has also increased rapidly.

During the last decade, two major inovations in pneumatic steel making are :

— Development of the bottom blown OBM/Q-BOP/LWS processes, offering numerous advantages.

— Development of combined blowing KMS/OBM-S/LBE/LD-OB/LD-KG/STB processes to improve the productivity of the top blowing processes.

LD process, in spite of its metallurgical and economical suitability, has some process-specific disadvantages. Insufficient mixing of bath & slag leads to difficulties in controlling the process. Slopping, temp. gradient in the direction of oxygen impingement, higher S & P contents at lower C contents are also drawbacks. Low carbon steels are difficult to be produced by LD process.

Bottom Blowing With Oxygen :

Oxygen bottom blown (OBM/Q-BOP/LWS) processes are free from the process-specific disadvantages of LD process.

Intensity of mixing is increased to a very high degree, enhancing slag-metal equilibrium and less slopping.

Process control is easy. By injection of powdered lime flux along with the oxygen blow, the removal of phosphorus and sulphur is efficiently achieved with an entirely different mechanism of slag formation. Less oxidation of iron increases the steel yield.

High Mn-recovery, lower oxygen content and very low nitrogen content in steel are features of the bottom blow processes. Ferro-alloy recovery is also better.

L.W.S. process has the added advantage of longer lining life by utilizing double tuyeres, well protected by burning of fuel oils through pipes jacketting the tuyeres.

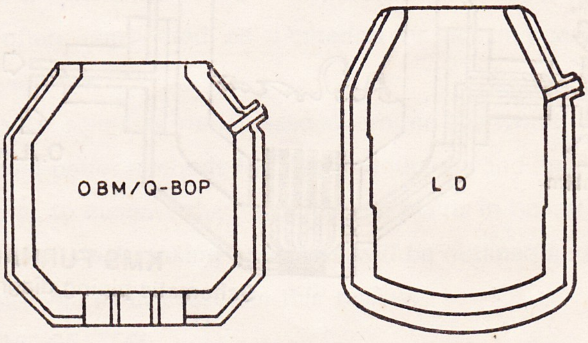


Fig. I

Profile of a bottom blown converter is shown in figure I. The ratio of height to shell diameter (H/D) is closer to unity in this case and another feature is the replaceable bottom.

Inspite of the numerous advantages of the bottom blowing practice, the scrap-rate is abcut 4 percent points lower than in LD process.

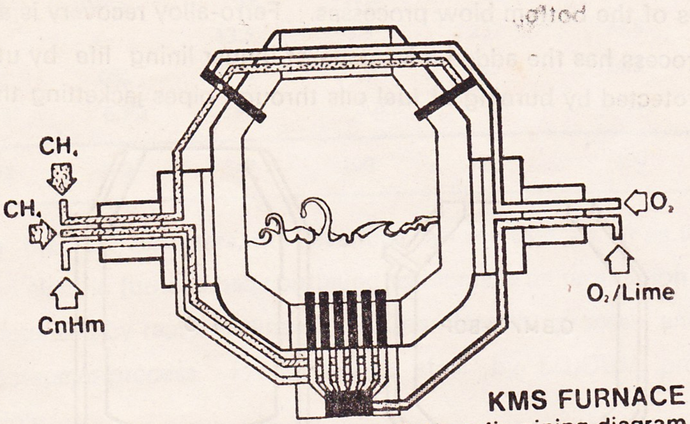
Combined Blowing Technique :

To achive the best of both the top-and bottom-blown processes, several middle-of-the-road techniques have recently been develcped to introduce bottom blowing in top-blown converters. The combination blow leads to calmer bath than that of top-blowing.

Lower percentage of iron oxide in slag, less emissions and slopping during melting, increased scrap melting capacity are the salient features of the process.

QMS/OBM-S Process : In this process, oxygen is blown into the converter simultaneously from the top and the bottom. Scrap preheating may be done by bottom blowing of oxygen and fuel oil. The combined effect of oxy/fuel burners, after-burning of CO gas inside the vessel by means of side blowing permits 40% scrap +60% hot metal charging.

2.4.9



KMS FURNACE
Schematic piping diagram

Fig. II

Basically all the combined blowing techniqes are same. They differ only in blow gas composition, blowing arrangements etc. Different combined blowing techniques are summarized in table II, below :

PROCESS	Type	Top Input Gaseous	Bottom Input (Gaseous)	Developed by	Features
KMS/ OBMS	Combined blowing	O_2 + hvdro carbon	O_2 + fuel oil	Klockner	Offer all the advantages of combined blowing
LD/OB	Combined blowing	O_2	O_2	Nippon Steel Japan	,, ,,
LD-KG		O_2	N_2 or Argon	Kawasaki Steel Japan	Less slopping, quiter blow
STB		O_2	O_2 and bubbling of Argon in the later stages	Sumitono Steel Japan	Extra low C Steel may be produced
LDE		O_2	Neutral gas	IRSLD & ARBED	Extra low C Steels.

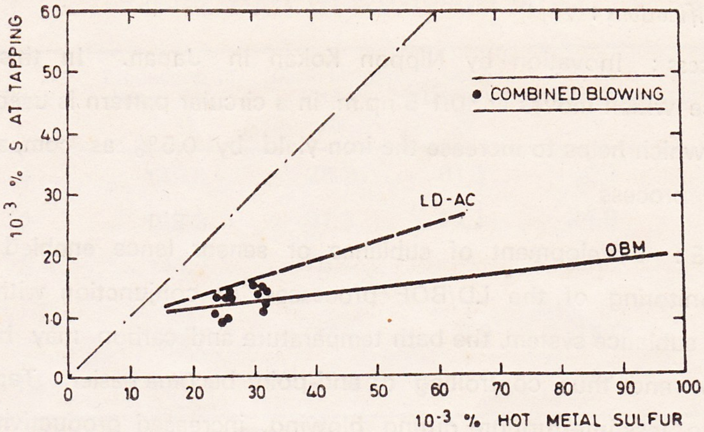


fig. III Sulphur contents in hot metal and tapped steel

Figure III shows that desulphurization effectiveness in the combined process lies between LD-AC and OBM droceses.

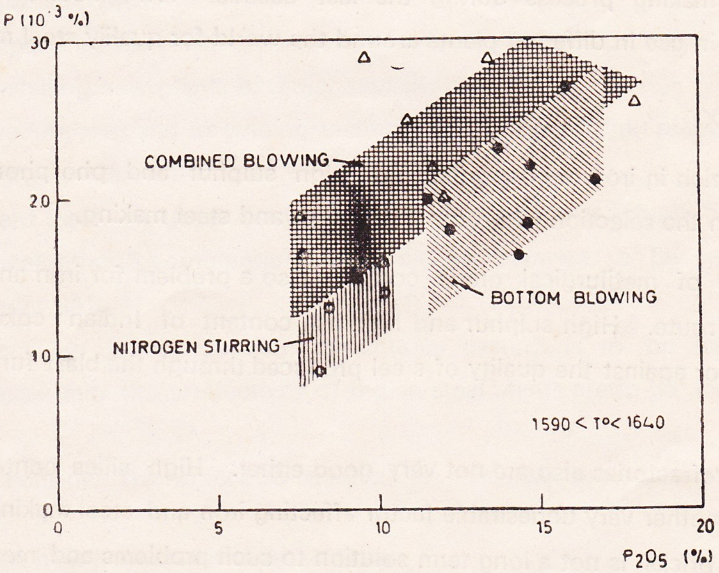


fig. IV Steel phosphorus content vs. slag P_2O_5 content

Figure IV illustrates the relationship between the steel P content and slag P_2O_5 content for the different techniques. It is clear that for a given P_2O_5 content, best results are obtained after nitrogen stirring.

Other Modifications :

LD-CL process : Inovation by Nippon Kokan in Japan. In this process a circling top lance which moves at 0.1-5 r.p.m. in a circular pattern is used to improve oxidn. effciency which helps to increase the iron yield by 0.5% as compared to that in fixed lance LD process

SUB LANCE : Development of sublance or sensor lance enabled in dynamic control and monitoring of the LD/BOF processes in conjunction with computers. With the help of sublance system, the bath temparature and carbon may be measured during the blow and thus controlling of end-point become easier. Tap to tap time decrease due to less interruption during blowing, increased productivity, yield and better refractory consumption is achievable. Sublance has become an essential item of equipnent in modern steel plants

Electric Furnace Steel Making : There are several modifications in the Electric Furnrce steel making process during the last decade. VHP, VUHP, Plasma Melt techniques are in use in different plants around the world for qualiiy steel making.

INDIAN CONTEXT

India is rich in iron ore deposits. But high sulphur and phosphorus contents put restraints in the selection of processes for iron and steel making.

Scarcity of metilurgical grade cock is also a problem for iron and making by blast furnadce route. High sulphur and high ash content of Indian coke is serious restricting factor against the quality of steel produced through the blast furnece-oxygen process route.

Indian refractories also are not very good either. High silica content of Indian magnesite is another very undesirable factor affecting iron and steel making Importing of refractory bricks is not a long term solution to such problems and means are to be worked out for solution of this problem.

At present India is producing approximately 15 million tons of crude steel.

The table shows production of steel by different processes in India and in some other major steel producing countries, as per International iron and Steel Institution reportings.

CRUDE STEEL PRODUTION IN 1979

Country	Rank	Production in million metric tons	Basic Oxygen Process %	Open Hearth %	Electric & others %	Basic Bessemer & others %	Total
USSR	1	149.0	28.2	61.1	10.1	0.6	100 0
USA	2	123 3	61.3	14.1	24.6	—	100.0
JAPAN	3	111.7	76.4	—	23.6	—	100.0
Federal Republic Germany	4	46.0	76.1	9.9	14·0	—	100.0
India	16	10.1	24.2	56.0	18.0	1.8	100.0

From the table we find that, in India, major percentage of steel is still being produced by OH process.

Plans have been drawn to reach a productivity of 25 million tons of crude steel per year at the beginning of the ninties.

This is possible by,

(a) Expanding the existing plants

(b) Installing new plants of larger capacity

(c) Modernizing and upgrading technologies in the existing plants to achieve higher productivity.

At present there are 10 LD converters at work and in near future, 5 more will be set up. In the eighties, 3 continuous casting units are planned to be set up in the steel plants under SAIL.

To boost up the production, continuous casting is to be taken resort to and to feed these units the productivity of Indian steel plants are to be increased to a great extent.

Let us consider the processes suitable to maximize productivity of our steel plants.

The open hearth has some disadvantages

– Longer tap to tap time.

– Less thermal efficiency & high fuel consumption.

But, the open hearth process permitted the use of large amount of scrap charge, and scrap melting capacity of a steel producing unit must be given due consideration specially in a developing country like India, because of cheaper cost of steel scrap.

Again, increasing the scrap melting capacity means increase in output without expanding or over-burdening the working hot metal producing units.

For new installations, combined blowing techniques may be adopted. LWS process is more effective in desulpaurization and dephosphorization but has limited scrap melting capacity. KMS/OBM-S techniques offer a maximum of 50% scrap melting capacity utilising oxy/fuel burning through bottom tuyeres.

Scrap preheating by using fuel oils/oxygen through bottom tuyeres makes the process highly fuel efficient. So, it is evident that, with the KMS method full advantage can be taken of scrap availability and advantageous scrap costs.

Equipment cost for KMS installation is not much higher than the OBM/Q-BOP installations.

If dephosphorization and desulphurization are to be given prime importance, then LD-KG may also be chosen.

We have to consider the existing plants also. Bottom blowing may be introduced in LD converters presently in operation, to increase their scrap melting capacity along with more efficient desulphurization and dephosphorization. Using sublance systems, the tap to tap time may be decreased to some extent. Continuous casting facilities may be installed and this, in conjunction with increased output resulted from high scrap melting capacity, will be very helpful in achieving the aimed productivity.

Of course, the project engineering part is to be considered before selecting a process.

CONCLUSION

Modern steel making processes and their adoptability in Indian steel plants were discussed in a qualitative manner. India is a developing country and steel consumption per capita is increasing with advancement of technology.

It is the high time for the Indian metallurgists to work on the different aspects of modern steel making processes on the basis of Indian resources in order to increase steel production so that India can be at par with the major steel producing countries of the world in near future.

REFERENCE

Reportings, Ihternational Symposium on Modern Developments in Steelmaking, Feb. 1981, Jamshedpur, India.

REQUIREMENT OF PROTECTIVE COATING AGAINST HIGH TEMPERATURE CORROSION*

Metals undergo chemical reaction with their environment producing chemical compounds that are either oxides or salts. The character of these compounds, particularly their solubilities in the surrounding media, their physical properties will have considerable influence on the course of the reactions. Corrosion is a degradation process and is characterized by the dissipation of energy into some other form. The best measure of the tendency of a metal to corrode in thermodynamic terms is the decrease in free energy accompanying the reaction.

The control of corrosion is based upon the prevention of chemical reactions that lead to destruction of the metallic state. The character and extent of preventive measure depend upon the nature of the metal and of the environment to which it is exposed.

- Protective coatings
  - Natural
  - Synthetic
    - Metallic
    - Inorganic (such as vitreous enamel, cement, concrete, clay products).
    - Organic (Paints, Lacquers, enamels, oils, etc.).

So far as the high temperature corrosion is concerned, metallic coatings are most effective. During growth of oxide films at high temperature certain stresses will

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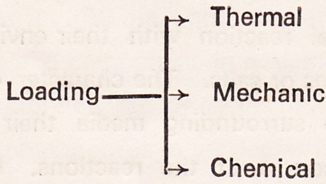
appear. The relief of these stresses may occur principally in two ways. Creep or cracking, and acoustic emission.

A successful use of protective coating depends on weighing the merits and demerits against their costs. The assessment has to be made for every intended application with considerable relief loading on the component and coating.



The thermal stress is due to combustion of gas to 1400°C and material temperature upto 1050°C. During starting up or shutting down of the engine, temperature gradient both in time and space are developed owing to cooling of the components. These are of the order of 100 – 200°C/minute.

Mechanical stress result from centrifugal stress to $170 N/mm^2$, local stress gradients are the cause of extremely complex overstress distribution. This results in cyclic strain of the component. Such strains may lead very quickly to the formation of cracks. These cracks travel and substantially shorten the fatigue life. As a result of high gas velocity, there is also a loading through erosion, foreign object impact and breakaway to products of corrosion.

Finally, the chemical loading is caused by the oxidation in excess air of the combustion gas ($\approx 12\% \ O_2$ by volume), by contamination in the fuel (maximum permissible S is 0·3% by weight) as well as the corrosive constituents of the intake air. Chemical attack can be affected by the pressure (upto 25 bar) and flowrate (upto 600 m/s) of the combusion gases. Chemical attack results in destruction of the surface of the unprotected material and local prevention of corrosion especially along grain boundaries, combined with changes in alloy composition. Roughing the surface causes a drop in efficiency of the engine.

Requirements of protective Coatings

From the service loading and considering the economy, a series of requirements for the protective coatings can be derived : –

(a) When they are produced, the parent material should not be changed in critical areas, e,g. at grain boundaries, either thermally or locally.

(b) There should be little interaction with the parent metal, so that the mechanical properties of the load bearing material are not impaired.

(c) Low susceptibility to cracking i, e, there must be adequate ductility or ductile brittle transition temperature must be low enough.

(d) The viscosity of the coating must be high enough to prevent it being stripped by the centrifugal force.

(e) The coating must be corrosion resistance to prevent it being used up prematurely during the design lifetime.

(f) Uniform, smooth depletion to preserve best possible surface integrity, and to avoid local damage in depth.

(g) The production cost of the coating must be within the acceptable limits.

A comparative study of the coated and uncoated materials have been carried out in the laboratory. The components are heated by a stream of combustion gas to 950°C, and have a uniform temperature distribution across the section where the rupture is expected. The time to rupture for uncoated parts in hot gas lie in relatively narrow scatter band.

In order to stimulate service conditioning in laboratory test the following types of loadings are important in flying engine :—

(a) High velocity combustion gas from aviation fuels as corrosive medium.

(b) Realistic temperature distribution in the component through internal cooling.

(c) Cyclic temperature range from room temperature upto service maximum temperature of 1000°C at the hottest sites of the components in 20 seconds followed, after a holding time of just under 6 minutes, by just rapid cooling to room temperature.

(d) Cyclic stressing synchronously with the temperature changes with maximum value during the holding time, leading to rupture in a test time of acceptably long duration.

In the fig. 1, the ratio of effective stress σ, to some reference stress σ_W, is plotted against the logarithm of service time elapsed. (A typical reference stress σ_W can be taken as the fatigue stress for 100 hrs. endurance at 0.1 cycle/m). Line A shows the time to rupture of the uncoated component in a completely inert atmosphere and without changes in the structure caused by corrosion. For these conditions, line B plots the ratio σ/σ_W while the component is in service. If on the other hand, there is corrossion, the effective stress goes up in the course of time through material consumption over the surface and still more, through damage of grain boundaries (notch effect). Curve C presents the σ/σ_W for the component.

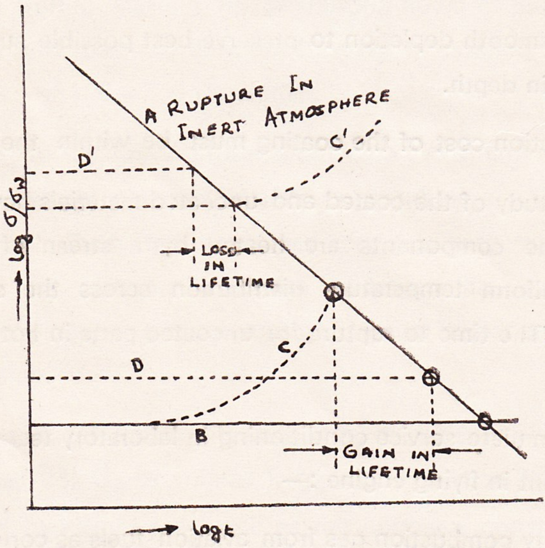


fig. 1

If the componet is given a coating the material may be damaged as a result of the required treatment, σ_w decreases, and, if the coating resists corrosion, curve D now represents σ/σ ratio for the component. Despite the damage to the material the coating has provided a longer lifetime.

However, if the process described in shifted to a higher stress value the situation is reversed, the curve for corrosion C becomes the curve C′, essentially maintaining its shape, and the drop in strength from B to O applies equally for D′, so that the coated component ruptures earlier than the uncoated one.

The various protective coatings which are generally used at high temperature :

(a) Chromium coating (by chromizing treatment) and coating is generally applied upto a temperature of 1400°C.

(b) Aluminium coating (by calorizing) and is used upto temperature of about 1000°C.

(c) Ceramic coating :—There are various types of ceramic coating and they generally applied within the temperature range of 800°—1000°C. The first two are specially applied for aerospace engines.

STRESS CORROSION CRACKING - A REVIEW*

Definition of Stress Corrosion Cracking

Stress Corrosion Cracking may by defined as the spontaneous failure of a metal or alloy resulting from the combined effects of corrosion & static tensile stress.

The term stress corrosion cracking is very specific term and it must be clearly understood that this term is to be applied only when the two effects i.e. stress & corrosive environment are simultaneous. In the absence of the stress the effect of corrosive environment may be relatively small or negligible. The effect of stress is only to accelerate the corrosion.

The importance of the study of stress corrosion cracking

The results of stress corrosion cracking may be dramatic like the explosion of a boiler due to caustic embrittlement & the failure of a ladle-hook in a steel plant. Stress corosion cracking of brass cartridge cases keet in military store houses in the U.S.A. during World War I for only 3 years caused an enormous loss amounting to 7 million dollars.

It may be appreciated from the above instances the importance of the study of the mechanism of stress corrosion cracking & its remedial measures. Lack of knowledge of stress corrosion cracking may become a limiting factor in design. Cracking may occur in metals and alloys in which the mechanism of cracking is not well understood.

Types of Stress Corrasion Cracking

Basically stress corrosion cracking are of two types. (1) Intergranular or Intercrystalline ; (2) Transgranular or Transrcystalline.

In intergranular stress corrosion cracking, selective corrosion occurs at the grain boundaries or closely adjacent materials without appreciable attack on the grain

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interiors. The basic mechanism probably involves a difference in potential between the grain boundaries and the grain interior. Examples of this type may be found in Silver-Gold alloys, Copper-Gold alloys, α-brass.

In transgranular cracking, the attack occurs in the body of the grain. Here the stress greatly modifies the corression available points to smooth continuous crack propagations in one instance and discontinous crack propagation in others. Tppical examples may be found in β-Brass, austenitic stainless steel and in magnesium alloys.

It has been substantially proved that whether cracking would be intercrystalline or transcrystalline is independent of the equilibrium structure of the metal or alloy.

The following roles have been observed for the occurence of the various types of cracking.

(1 Intercrystalline cracks occur in the agents that react with the less noble component of the alloy, while the more noble component remains completely passive.

(2) Transcrystalline cracks occur only in the agents that corrode the more noble component of the allo, as well as the less noble or can, at least, ionise it transionetly during the decomposition of the solid solution lattice.

Characteristics of Stress orrosion Cracking

Basically these emperical characteristics govern stress corrosion cracking.

(1) Stress corrosion cracks grow in a planne perpendicular to the operative tensile stress regardlese of the nature of the applied or residual stress regardless of the nature of the applied or residual stress system.

(2) Stress corrosion cracking is apparantly a brittle type of failure (i. e. little plastic deformation) which can occur in highly ductile materials.

(3) From microstructural point of view, stress corrosion cracking may take place either in an intergranular or transgranular path depending on the alloy and rhe medium. The intercrystalline cracking is, in many cases, associated with some stage of of precipitation reaction and it is then heat treatment dependent. Transcrystalline cracking generally occurs in the more highly alloyed materials, such as the brasses, austenitic stainless steel and Cu-Au alloys and it is not normally very sensitive to heat treatment.

(4) The chemical conditions leading to cracking are highly specific and characteristic to the alloy system.

(5) The crack propagation is normally a discontinuous process, with slow stages of chemical activity interspersed with rapid brittle crack propagation.

(6) The velocity of the propagation of stress corrosion crack is very slow and it is of the order of 1 cm./hr.

Mechanism of Stress Corrosion Cracking

The mechanism of stress corrosion cracking consists of two stages ; a period of localised electro chemical corrosion (crack initiation) followed by stress corrosion cracking stage (crack propagation).

The initiation of the crack is essentially electrochemical in nature and the first and the foremost requirement is the creation of some anodic sites with the remaining regions as cathode, forming the electrolytic cell. The anodic regions may form on the preexisting precipitated phases or segregates, or they may form due to rupturing of surface films by the dislocations created during the stress corrosion test etc. Due to the formation of anodic sites, there happens a localised decrease in the resistance to corrosion and thus trench like fissures are produced which have extremely sharp radii of curvature.

The propagation or cracks may occur along intergranular of transgranular paths. The environment determines the manner of cracking path. Among many such crevices, one usually predominates over others and grows deeper. As the fissures grow deeper and sharper, a stress concentration is developed gradually at the tip, until localised plastic deformation and yawning of the crack occurs due to higher applied stresses. This deformation at the apex of the notch initiates the crack. The crack propagates continuously unless arrested sometimes, by the presence of unfavourably oriented grain boundaries some form of lattice discontinuity or non-metallic inclusions etc. During propagation clear metallic surfaces are formed and the corrosive agent is soon drawn into the crack by capillary action and of course, the corrosion rate increases, aiding penetration of the crack. The rate may sometimes decrease due to polarisation and reformation of protective films.

Due to lateral corrosion at each point of arrest. branching occurs. Fracture progress may also stop when it extends into a stress field, where there is no significant component of tension, normal to the fracture path and then further deformation requires new initiation of crack.

It is reasonable to believe that the tensile stress is more important factor that causes the propagation of crack than the electrochemical attack. The propagation of crack may be observed in motion picture microscopy.

The above is a generalised theory of stress corrosion cracking though the exact manner of failure may differ from system to system and a no. of theories to explain the specific failure modes are found in literatures.

Aluminium Alloys

Pure Aluminium is quite resistant to stress corrosion cracking but Al-Zn alloys containing more than 12% Zinc & Al-Mg alloys containing more than 6% magnesium are susceptible to stress corrossion cracking even under mild corrosive conditions. The cracking is intergranular. The grain boundaries are anodic to the grains in solution to produce cracking.

Brass

Perhaps the best known example of stress corrosion is the season cracking of brass and is so called as it resembles these in seasoned wood. Exposure to moist atmospheres containing traces of ammonia is particularly drastic in producing cracking.

Ammonia and ammonia compounds are believed to be potent agencies, but H_2O and O_2 are necessary. CO_2 is a contributing effect-susceptibility to cracking increases with increasing Zn content. Usually intergranular cracking is prevalent but transcrystalline cracking has been reported.

Other Alloys

Compared with brasses, other Cu alloys, such as tin-bronze, Al-bronze, Si-bronze and Arsenical copper show little tendency to season crack.

'shot'. This is important since shot significantly increases the thermal conductivity of Ceramic fibre. Bulk Fibre at the outset contains about 5% unfibrised particles by weight. To make long staple fibre a zirconia containing mixture is spun into fibres having lengths upto 250mm and diameters upto 18 microns. These long fibres are used for textile manufacturing process.

Normally Ceramic fibres are classified into grades depending upon the temperature rating as below :—

1. Standard Fibre : continuous service rating upto 1260°C.
2. High Duty : continuous service rating upto 1400°C.

CHEMICAL COMPOSITION

	Standard Fibre %	High Duty Fibre %
Al_2O_3	43—47	52—56
SiO_2	53—59	43—46
Fe_2O_3	0.02—0.08	0.02—0.08
TiO_2	0.02—0.05	0.02—0.05
MgO	0.01—0.04	0 01—0.04
CaO	0.02—0.04	0.02—0.04
Alkalis as Na_2O, K_2O	0.05—0.4	0.05—0.4
B_2O_3	<0.02	—
Trace inorganics	—	—
Leachable chloride	20 ppm*	20 ppm*

(* can be manufactured to lower limits if required).

PHYSICAL PROPERTIES

	Standard Fibre	High Duty Fibre
Specific gravity (ASTM C135)	2.56	2.70
Specific heat capacity (J/(KgK)(980°C)	1070	1070
Melting point (°C)	1760	1825
Tensile Strength (MN/m^2)	1400	1400
Young's Modules (MN/m^2)	1.2×10^5	1.2×10^5
Hardness (Mho's Scale)		
(Knoop Scale)	700^6	700^6
(100 loading)		
Packing Density range (Kg/m^3)	50—250	50—250

AVAILABLE FORMS

Ceramic Fibre is processed into wide range of forms starting from bulk fibre—over 40 are Commercially available :

- Bulk Fibre
- Blankets
- Board
- Strips
- Wet Felt (Pieces of Blankets treated with hardner)
- Mastic
- Mesh Enclosed
- Modules for veneering etc.
- Paper
- Rope and Braided rope
- Cement and Hardner.
- Shapes

KEY PROPERTIES

1. Completely asbestos free.
2. Very low thermal conductivity—about one third better than insulating firebrick and upto $2\frac{1}{2}$ times better than asbestos products.
3. Resistant to thermal shock. No matter how fast they are heated or cooled, the product forms will not crack or spall.
4. Remarkably low heat storage due to low density. In furnace applications this means faster cycling times and savings in fuel.
5. Light weight—about one sixth of the weight of insulating firebrick, and about one third the weight of asbestos board. Equipment insulated with Ceramic Fibre can be made smaller and lighter, with savings in structrucal steelwork and transportation costs.
6. The blown fibres enable Blanket to be made which is completely inorganic and binder-free.
7. The Converted Products can also be wholly inorganic Board and Shapes.
8. Bulk Fibre, Blanket and Wet Felt are 100% inorganic and totally incombustible. (Other product forms can contain an organic binder which burns off in service).

9. Good acoustic properties enable ceramic fibre to be used for noise reduction in high temperature environments. Also, due to the inherent resilience, it will withstand and absorb vibration.

10. All product forms are easily handled and most can be quickly cut with a knife or scissors, reducing installation costs in many applications. Some converted products may require cutting with a bandsaw or similar medium.

11. High chemical purity, including very low chloride content.

12. Good chemical stability—unaffected by oil, water, and steam ; resistant to most chemicals except hydrofluoric and phosphoric acids and many alkalies.

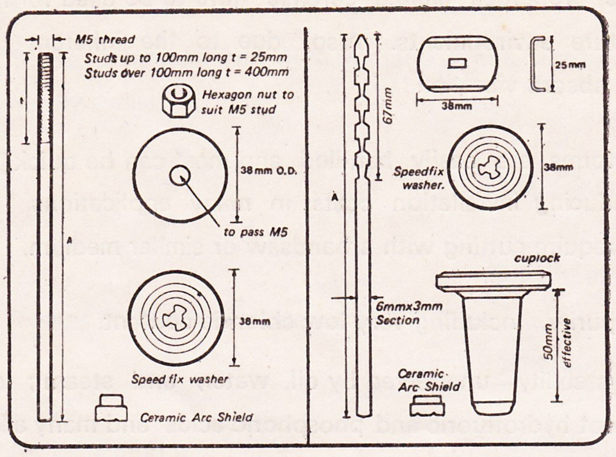
13. The continous service rating is quoted as a general guide only. In certain applications, e.g. expansion joints and once-only usage, the rating may be exceeded. In other cases, e.g. furnace hot-face linings, where high stability is required over long periods, it is desirable to impose a lower service limit.

LINING TECHNIQUE WITH CERAMIC FIBRE

A very important consideration for Ceramic Fibre is the right design and installation technique. The primary factors to be considered for the design of a Fibrewall furnace lining system are :—

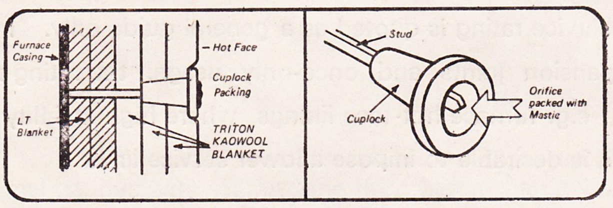
1. Peak operating temperature.
2. Desired cold face temperature.
3. Gas velocity inside the furnace.
4. Furnace atmosphere and type of fuel.
5. Hot face and Skin temperature.

The usual method of installing Fibre Blankets on furnace casing made of mild steel, usually, is to weld SS/Inconel studs and roll the blankets over the studs. A typical anchoring system appears in figure-1.



M5 threaded anchor

Twistlock anchor



Typical lining section showing position of cuplock.

Threequarter view of cuplock

Fig I

There are different stud pattern's adopted, and some of these are shown in said figures. The Blankets are fixed on to the studs starting with back up lining with low density blanket followed by Needled High Density Blankets. The joints between the blankets need to be overlapped as Ceramic fibre shrinks with temperature increase. Directional gas flow can cause a problem but by overlapping the blanet layers in the direction of gas flow, this can be overcome. Some areas such as vertical or a circular joint are critical areas and require special attention.

Having fixed the blankets, ceramic cuplocks are fixed on to the studs and the exposed portion of the stud through the cuplock hole is covered by injecting ceremic fibre mastic.

If necessary, spray hardening of the hot face surface can be carried by spraying ceramic fibre hardener in the blanket surface.

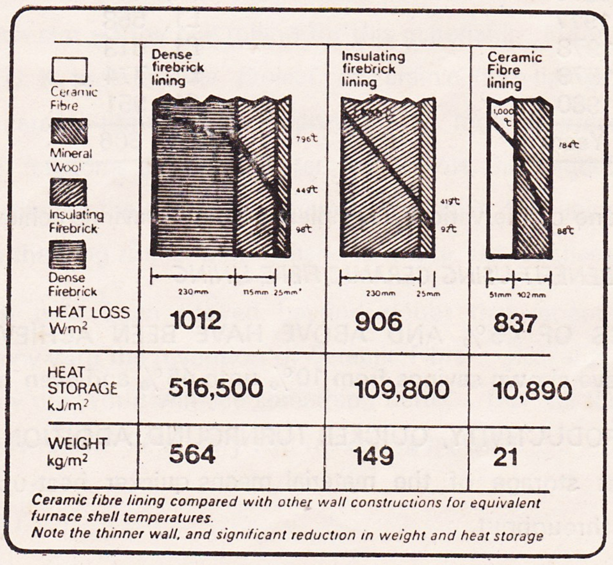
VENEERING

Where the existing furnace lining is in sound or in a easily repairable condition, veneering with Ceremic Fibre Modules can lead to considerable fuel savings. The installation is a simple procedure. After brushing the existing lining free of dust and oxides, fibre cement is applied to the Module which is fixed on to the existing lining. The existing lining also needs to be buttered with Fibre Cement. Adhering is better when the furnace wall is cold. Therefore, water may be splashed on to the lining to cool down, if the lining is hot. The module is to be applied to the lining with a flat board and held under pressure for 20 seconds. Then the subsequent modules can be applied taking care to butt each one against its neighbour. Veneering with 50 mm modules on curved walls down to 300 mm radius is also possible.

Yet another important application of ceremic fibre in furnace applications, is the kiln car insulation. Effective insulation of Bogies have proved very effective in preventing heat conduction through the kiln car to the rails which leads to buckling of the rails and subsequent derailment of the bogies.

USERS' EXPERIENCE/CASE HISTORY

Before giving any result from the case history, let us glance at figure 2 which gives you an idea about the substantial reduction in wall thickness, heat storage and weight.



	Dense firebrick lining	Insulating firebrick lining	Ceramic Fibre lining
HEAT LOSS W/m²	1012	906	837
HEAT STORAGE kJ/m²	516,500	109,800	10,890
WEIGHT kg/m²	564	149	21

Ceramic fibre lining compared with other wall constructions for equivalent furnace shell temperatures.
Note the thinner wall, and significant reduction in weight and heat storage

Fig. II

Ceramic fibre furnace linings have been giving excellent service in oil, gas and electric furnaces over eight years and above, in the U.K. and other countries. A furnace lined with ceramic fibre at the British Steel Works, Distington, England during 1972/73 has been working since then and the savings obtained are listed below :—

HEAT TREATMENT GROUP	No. of treat-ments	BRICKS	CERAMIC FIBRE			SAVING	
		Time	Galls	Time	OIL	TIME	OIL
STRESS RELIEF "GENERAL ENG. PRODUCTS	25"	199	7002	181	6300	9.5%	10%
STRESS RELIEF LARGE VESSELS	10	28	1172	20	882	26%	24%
FULL ANNUAL S. G. IRON MOULDS	14	19	941	15	840	21%	11%

Monetary Savings :

Year	Saving
1973	£ 832
1974	£1, 172
1975	£1, 289
1976	£1, 417
1977	£1, 558
1978	£1, 613
1979	£1, 774
1980	£1, 951
8 Years	£11, 606

This is just one of the various examples of energy savings achieved.

SO HOW CAN YOU BENEFIT USING CERAMIC FIBRE LINING

1. FUEL SAVINGS OF 45% AND ABOVE HAVE BEEN ACHIEVED— studies of installations have shown savings from 10% upto 45% and even higher.
2. INCREASED PRODUCTIVITY, QUICKER TURNROUND, ADDITIONAL CAPACITY —the low heat storage of the material means quicker heat-up and cool-down cycles-quicker throughput.
3. LOWER MAINTENANCE COSTS—the elimination of thermal shock damage minimises costly repair work. Local repairs can be effected without disturbing the rest of the lining.

4. SERVICE LIFE—case histories of units operating efficiently for 8 years and more are available.

5. REDUCED DOWNTIME, MINIMAL LOSS OF VALUABLE PRODUCTION—should the lining become damaged, it is quickly and easily repaired.

6. EASE OF INSTALLATION—no need to rely on skilled labour. The flexible, easily-cut materials can be installed quickly, minimising wasteful plant downtime.

CONCLUSION

Ceramic fibre application as an insulting refractory material goes back to the days of world war II. At that time some distinguished research establishment in U.S.A. was working on top priority defence projects, first tested Ceramic Fibres as an insulation material in the engine rooms of the US Navy's submarines and warships. But matters were left at that for a decade or so until the early fifties when Babcock & Willcox of USA first took up the prospects of Ceramic Fibre linings as a refractory material. There was in need a pioneering effort which however was confined to the American continent in the trial stage. Post-war Europe recovering from the ravages of the war took to rapid industrial growth and with it the energy crisis came simultaneously which started the ball rolling for this material in Europe also. At that point Morgans of U. K. took up the project of ceramic fibre linings for the European market of course, ceramic fibre is to be imported into India at present, and with the higg precentage of customs duty on this item of import, the added cost is on the higher side. Nevertheless the economy offered by ceramic fibrelining is amazing and the cost savings in the long run is more than to make up for these initial costs

It has been now been proved beyond doubt that yet another step is taken towards fuel economy with the invention of Ceramic Fibre. Research will march ahead and may be one day the World will see something better. But till then, Ceramic Fibre shall remain the best known Refractory and Insulating material.

ACKNOWLEDGEMENT

The author is grateful to M/S Morganite Ceramic Fibres Ltd, UK, for providing useful information through trade literature and write up.

INOCULATION OF CAST IRON*

The process is distinct from alloy addition to the molten iron for the sole purpose of affecting the chemical composition of the melt. In fact, normal inoculation treatment is concerned with the introduction of quantities of material, usually of about 0.1—0.3% which exerts little or no influence on the chemical analysis. The addition is made to the molten metal for the purpose of modifying its microstructure and, as a result improving the mechanical and physical properties to a degree not explainable in terms of compositional change. Apart from chemical composition, there are a number of factors which influence the properties of cast iron.

FACTORS OF INFLUENCE

Even if chemical composition remains steady within fixed limits, the following factors will affect the strength machinability and other characteristics—

1) Amount of super heat
2) Degree of oxidation
3) Moisture in air blast
4) Charge make-up
5) Weight of charge
6) Speed of cooling in moulds—section thickness
7) Pouring temperature.

They can exercise their effects either singly or in combination.

Much of the required control is achieved by standardisation of melting practice in accordance with correct technique. However, atmospheric moisture is usually variable, and components of charge vary in proportion, composition and properties.

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* Subrata Chatterjee, 3rd Year-Met, E,

Cooling speed depends on casting design, section thickness and the effect of mould and cores. Thus, there are a number of factors that can exert an important influence on the properties of casting which can not be brought under full control. Fortunately the technique known as inoculation provides a means of counteracting and minimizing the effects of these variable factors.

INOCULATION TREATMENT

Since calcium silicide was developed as the first inoculating agent many other materials are known to function in a similar way. Those commonly employed are ferro-silicon, aluminium, graphite, zirconium and combination of these. It is known now that ferro-silicon acts as a good inoculant only when it contains 1—2% Al and upto 1% calcium. There is a risk with Al containing inoculants that the molten cast iron may pick up H_2 from moisture in the mould, those by encouraging the development of subsurface pinholes in the castings.

A good inoculant should posses the following charactertistics :—

1) Slow fading of reversion with constant result from a standard addition.

2) Enter the molten Fe readily with no adverse effects from an over addition.

3) Produce maximum inoculation and chill reduction from minimum addition.

4) Leave little residue and that easy of removal.

5) Reduce section sensitivity to a minimum.

The last point above has reference to the extreme change in properties and stricture which results between thin and thick sections in uninoculated grey cast iron. Very thin sections may be chilled, brittle and unmachinable while the thick section may be of open grain, soft and of very low strength. A properly inoculated grey cast iron will not show these extremes.

How Inoculation Works

During solidification of grey cast iron graphite grows from eutectic cells and each eutectic cell grows from a nucleus. Inocluation treatment increases the number of nuclii in the molten cast iron and, therefore, creats a large number of eutectic cells with their clusters of graphite flakes. In any given volume of cast iron, the larger number of eutectic cells, the smaller their size must be. Thus inoculation treatmet is also a means of controlling grain size and density of structure. As eutectic cell count increases and size diminishes so does the flake size of A-type graphite becomes smaller. These changes are accomplished by an increases in mechanical properties coupled with improved machinability.

Adding the Inoculant

Grading or particle size must be suitable according to the means of introduction and the volume of Fe to be treated. Crushing between 1/8' & 1/2' in mesh, free from fines and dust, covers most requirements. Maximum inoculation effect occurs immediately after the addition is made and becomes less with the passage of time. So, the treatment should be applied to the molten Fe at as late stage as possible prior to casting. This requirement is fulfilled by adding the inoculants at the furnace spout as the iron runs into the pouring sadle.

Contact with molten stream should be made at a point as near the tap hole as possible where the flow becomes smooth. Delivery should be at controlled rate through a steel pipe allowing a minimum vertical fall of 4 ft. or 1m. This gives the inoculant sufficient energy to penetrate the surface of the metal stream rather than float on its surface. An inch or two of molten metal (Fe) should be allowed to enter the ladle before inoculation commences and treatment should finish by the time their quarter of the volume of iron to be inoculated has entered the ladle. The molten iron must be delivered from the furnace through slag and of good temperature. Also the ladles must be clean and free from slag build-up on the litnings.

A device in the form of a hopper with vibratory control is illustrated in Fig. (1). This dispenses the incculant to the spout delivery tube pictured in Fig. 2 The fading

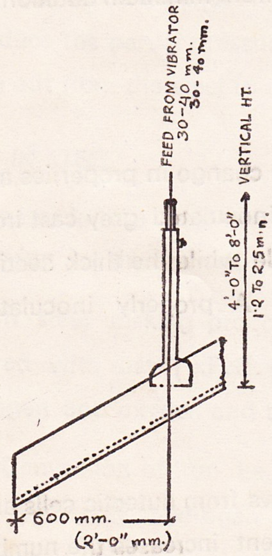

Fig. 2

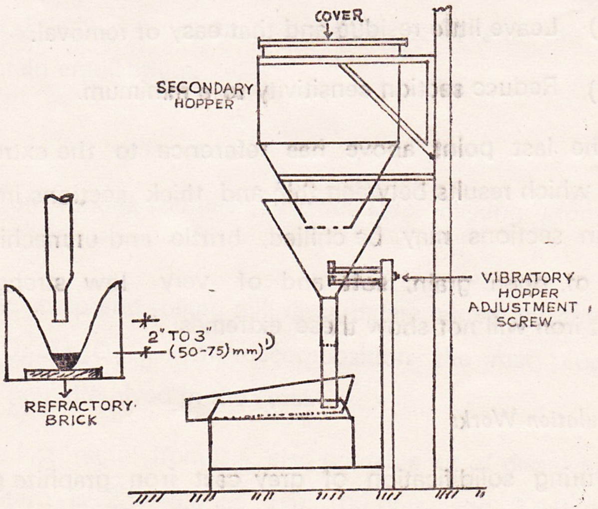

Fig. 1

effect on chill reduction is strongest at the moment the inoculant has dissolved in the melt. Fading time or reversion period vary with the different inoculating agents and foundry conditions, between 15 to 30 mins. with a view to avoiding the fading effect mould inoculation has been applied.

Mould inoculation involves the placing of an appropriate small quantities of inoculant inside the mould, usually at the base of the down runner. It can be used independently or as a last second boost to laddle inoculation. Some means must be found of getting the inoculation effect distributed uniformly through out the iron entering the mold. An attempt towards the end, which has achieved some success contains the inoculation agent with a fluxing material into a small pellet. These pellets containing a controlled weight of inoculant are inserted into the the running system.

Improved inoculation

From time to time attempts are made to increase the potency of inoculants and to lengthen the period of time over which the treated iron can be held molten without reversion taking place. Barium-coating inoculants have been introduced for which less rapid fading is claimed. On the other hand it has been shown that the inoculating power of Al free ferro-silicon can be increased by a small percentage addition of Strontium. The simulaneous presence of a significant amount of calcium nullifies the effect of Storntium and it is important that the Ca content of any Strontium Inoculant should be as low as possible. Particle tests show the superiority of the Strontium-containing inoculants in reducing chill and Increasing eutectic cell number particularly in thin section.

Dawson's work shows that for nodular iron the Strontium must be alloyed with ferro silicon although for flake graphite iron it is effective when added as mixture with ferro-silicon. Strontium containing ferro-silicon is very effective in preventing chill in nodular iron casting of thin suction but only when Cerium is absent. Very little residue is formed from the of Strontium ferro-silicon which dissolves readily in the melt. The reduced slag formation is attributed to the low content of Al & Ca in alloy.

VACUUM DEGASSING OF STEEL*

INTRODUCTION

Modern engineering makes ever higher demands on the properties of steel. Contamination with non-metallic inclusions excludes possibility of obtaining the required strength. On the other hand, manufacture of a steel free of non metallic inclusions is out of question by normal methods. Hence new methods of making steel are devoloped, one of which is to use vacuum during melting in the furnace or to refine the metal outside the furnace.

Vacuum refining after tapping may be an additional link in the operation of deoxidation, degassing and removal of non metallic inclusion from steel and makes it possible to use to the full extent the advantage of carbon & hydrogen as deoxidising element over other de-oxidiser.

So, vacuum degassing is a refining process of steel. Here a vacuum is created to reduce the partial pressure of dissolved gases in the molten steel and the gases come out from the steel to maintain equillibrium.

GASES IN STEEL

The gases in the steel come from various sources in various steel making processes. Following are the sources :—

(i) In steel making proccesses scrap and rolling mill discards are added and they are covered with rust ($xFeO.\ yH_2O.\ zFe_2O_3$). On decomposition the rust produces hydrogen and oxygen and they gets dissolved in the steel.

(ii) Conversion of iron i.e., the hot metal from B.F. also contains lot of dissolved gas in it. Generally hydrogen content is 2.5—3.0 c.c. per 100 gms. and 3—8 p.p.m. nitrogen.

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* Soumitra Sarkar, 5th Yr. Met. E and Arun Ghosh, 5th Yr. Met. E.

(iii) Various ferro-alloys that are added contain lot of gases in it and the Table I below shows it.

TABLE—1

Sl. No.	Ferro Alloys	Hydrogen, cc/100 gm.	Oxygen %	Nitrogen %
1	Nickel from Mond's Process	85—100	0 017	0.003
2	„ after long storage	12—17	0.023	0 003
3	Fe - Si	8—38	0.019	0.005—0.01
4	Silico-Calcium	38	—	0.03
5	Fe - Cr	6—16	—	0.012—0 043
6	Fe - Mn	13—35	0.002	0.02—0.05
7	Silico-Manganese	40—80	—	0.019—0.039
8	Fe - Ti	46	0.155	0.008
9	Fe - Nb	20	0.169	—
10	Fe - W	12	0 208	—
11	Fe - Mo	6—10	0.039	—
12	Aluminium	—	—	0.001

(iv) Synthetic slag that are added in diffusion deoxidation are also gas sources.

(v) Metal absorbs gases from furnace atmosphere and the combustion products of fuel.

EFFECT OF GASES ON THE PROPERTIES OF STEEL

Gases may remain in the steel in following forms a) as in solid solution b) as bubbles c) as hydrides, nitrides and oxides.

Oxygen : Total oxygen at the end of a melt is made up (a) of that in the steel (b) of that in the oxide inclusion formed through oxidation reaction. The effect of inclusions on the properties will vary according to their location. Most harmful are oxides distributed as chain, thread or film along grain boundry. Less harmful are those oxides formed at high temperature and located within the grain.

High oxygen content renders a steel prone to ageing, impairs electrical resistivity and lowers its magnetic properties. High percentage of oxygen in steel makes it redshort even at normal sulphur content.

Hydrogen : During the solidification, hydrogen is liberated and it produces very fine fissures, shrinkage-discontinuities and pores at the boundary between non-metallic inclusions and the metal. It also produces flakes, hairline cracks and lappiness in the steel.

Nitrogen : It increases brittleness and reduces the magnetic permeability. It gives rise to stresses in the crystalline lattice as it is finely dispersed as solid nitride. It encourages aging, impairs plastic property, increases hardness, coercive force and hysteresis loss.

Solubility of gases in steel : The gases of the furnace atmosphere (e.g. H_2, N_2, and O_2 etc. are soluble in metal. They may be present as separate atoms or ions or combined chemically with certain impurities or the metal itself. The absorption of gases through the formation of chemical compound is substantially higher than that through formation of interstitial solutions. The process of dissolution of gases in the metal from the furnace atmosphere take place in the following ways.

The particles of gaseous phase collide with the surface of the liquid so that adsorption and dissociation of their molecules into atoms occur. Atoms of the gases then pass across the gas-metal interface and get dissolved in the metal. The rate of passage into metal increases with increase of bath temperature.

In most cases the dissolution of a gas in metal is an endothermic process so that the solubility co-efficient increases with temperature.

The dependence of the solubility of an atomic gas in the metal on temperature is expressed by the formula $S = C. \exp. -Es/2KT$.

Where S — Solubility of gas in the metal,

C — constant,

Es — It is the heat of formation of a solution or chemical compound of the gas with impurities in metal.

K — Boltzmann's constant.

T — Temperature in absolute scale.

Sivert's Law : Sivert's Law states that the solubility of a gas in the metal at a given temperature is proportional to the square root of its partial pressure in the gaseous phase.

It is a deviation from Henry's law. This can be explained as follows :

(i) N_2 (gas)$\rightleftharpoons$2N (gas) ; $K=[N]^2 / P_{N_2}$

(ii) H_2 (gas)$\rightleftharpoons$2H (gas) ; $K=[H]^2 / P_{H_2}$

Here 'P' is the partial pressure of a given gas in the gaseous phase in equilibrium with iron. Consequently, the selubility of nitrogen in iron, $\% [N]_{Fe} = K\sqrt{P_{N_2}}$ and that of hydrogen. $\% [H]_{Fe} = K.\sqrt{P_{H_2}}$

Vacuum Degassing Proeesses : Several methods have been developed since about 1950 for degessing large quantities of liquid steel. Follwoing are the different vacuum degassing processes :

(a) Ladle degassing
(b) Stream degassing
(c) D-H (Dertmund Horder) process.
(d) R-H (Ruhrstahl Heraeus) process.

(a) Ladle degassing : In ladle degassing method the ladle of metal is placed in a heat insulated vacuum chamber, which is then sealed with a tight lid and evacuated. Due to evacuation, the gases in the metal escape with an accompanying boiling action. The boiling occurs at the upper level of the molten metal in the ladle and more intense boiling was observed near the lining of the vessel. This disadvantage with this method is that the metal at the bottom are not degassed due to high metalostatic pressure at the bottom.

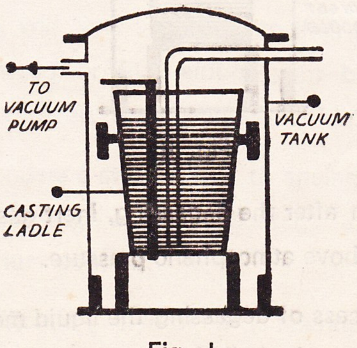

Fig. I

In ladle refining of 25 ton capacity, refining time is 10-15 minutes and temperature drop is 45—60°C. Residual pressure is 5-10 mm. of Hg. Hydrogen content falls by 60% and amount of hydrogen that remain in metals is 2 c.c./100gms of metal.

Promisng result have been obtained by simultaneous vacuum refining and blowing of inert gas (argon). Argon blowing gives good agitation and makes it possible to use larger laddle of 80-100 ton capacity. Sometimes electro-magnatic heating is done to agitate the bath.

Stream Degassing :—A second method is to treat the metal is vacuum while pouring it from one to another. Here one preheated ladle is taken into a vacuum chamber and evacuated. The ladle containing molten steel is placed on the evacuated chamber. The aperture of the ladle is then opened and the metal falls into a chamber as tiny droplets. The dioplet or stream form as the pressure of the metal suddenly falls and this breaking up of stream ensures rapid degassing due to higher surface expose. The rate of pouring is 5-10 tons per minute, temperature drop is 30-60°C. The hydrogen content falls by 50% and final hydrogen content is 2 c c./100gm. of metal. Residual pressure is 5 mm. of Hg.

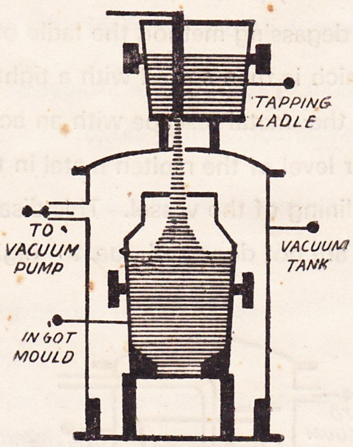

Fig. II

To avoid the exploration after the degassing, inert gases are introduced to fill the chamber at pressure slightly above atmospheric pressure.

D-H-Degassing :—In this process of degassing the liquid metal is sucked from the ladle to an evacuated chamber. Here the ladle is immobile and mobile part is the evacuated chamber and it is hung from a crane . Movement of the chamber is up and down and the pipe at the bottom of evacuated chamber is properly refractory lined.

In D-H process first the top chamber is dipped into the ladle and then the evacuation is done. After this, the vacuum chamber is taken out by upward movement but the refractory pipe is never brought out from the metal. Usually for D-H type of degassing the metal circulation stroke is 0 6 m. This results in about 10-15% of the metal in the evacuated chamber. Normally 30-50 such cycles are necessary. The full treatment of heat takes 20 minutes. Residual pressure is 1-10 mm. of Hg. and amount of hydrogen in final products is 2.0 to 2.5 cc./100gm. of metal. The retention time of metal in the vacuum chamber for each cycle is 30 seconds. There is an electrical resistance heating arrangement. Following changes occur during the operation (1) hydrogen is removed (2) carbon content is lowered by reaction with oxygen in steel forming carbon monoxide (3) some loss of manganese. These changes are also found other degassing processes. There is always a provision for adding alloying elements.

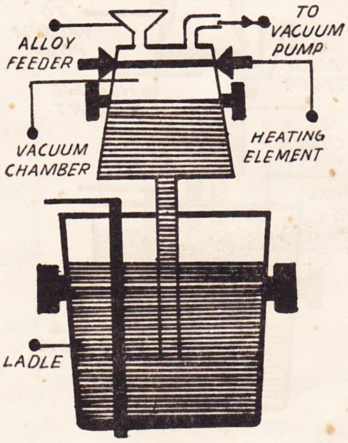

Fig. III

R-H Degassing :—The most effective and widely used method of degassing is R-H method. The equipment consists of a vessel equiped with two tubular extensions. One extension is provided for an inlet for the injection of an inert gas. The vessel is lowered until the ends of two extensions are submerged beneath the liquid steel in a ladle, after which the vessel is evacuated. Atmospheric pressure causes the molten steel to rise through the extensions. Argon is injected into the one extension at low pressure and, in effect, decreases the density of column of liquid metal in that extension and causes a "pumping" action resulting from the inbalance between that column and the denser column of liquid metal in the other extension. As the liquid metal rises into the evacuated chamber through the extension into which argon is injected, absorbed gases leave the metal with a boiling action, and the degassed metal returns to the ladle by way of the other extention. The circulation of metal from the ladle into the evacuated chamber is continued until the desired low level of gas content in the steel is achieved.

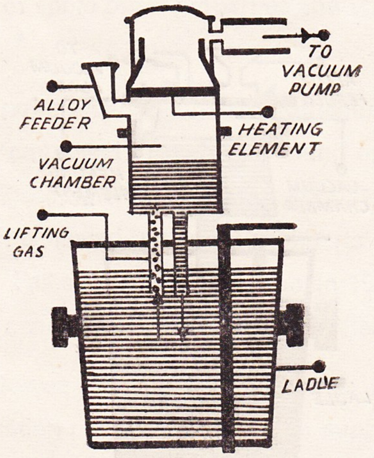

Fig. IV

R-H degassing makes it possible to reduce the hydrogen content of steel by 40-60%, that of oxygen by 50-70% and that of nitrogen by 5-10% and it also reduces the percentage of non-metallic inclusions.

Comparison of Degassed and Non-degassed steel : Comparison of internal soundness tested by ultrasonic tests in degassed and non-degassed bloom in R-H method at A. S. P. Durgapur.

TABLE—2

	Non degassed bloom	Degassed bloom
Percentage of defect with ultrasonic test.	13.4%	3.4%

CONCLUSION

The application of vacuum degassing plant increased rapidly after initial development period from around 50 plants in 1958 and 340 plants today all over world.

Initially degassing was applied only for hydrogen removal from large ingot and stream degassing into a second ladle or simple ladle degassing has not proved entirely satisfactory where alloying is required mainly because of high temperature losses and the problem of achieving mixing. Because it is possibe to introduce heat into the degassing vessel, the application of the DH and RH process has therefore tended to expand rapidly.

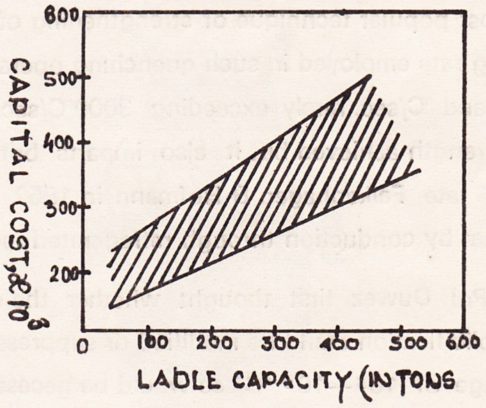

Fig. V

The heat size handled has also tended to increase and there are new plants capable of treating ladle capacity of 300 tons and over.

RAPIDLY SOLIDIFIED ALLOYS*

INTRODUCTION

Improved physical, chemical and mechanical properties of metals have been the target for research workers. In most cases improvement of a specific property is associated with deterioration of some other properties and vast all round improvement has not been achieved.

The oldest and most popular technique of strengthening of metals is quenching in solid state. The cooling rate employed in such quenching operations vary from a few hundred to a few thousand °C/sec, rarely exceeding 3000°C/sec. Higher the cooling rate the greater is the strength achieved but it also imparts brittleness. In an effort to achieve still higher rate Falkenhagen & Hofmann in 1952 quenched directly from liquid state removing heat by conduction through refregerated metal mold surface.

In 1959, Prof. Pol Duwez first thought whether the normal solidification or crystallisation type of solidification could be modified or suppressed and estimated the cooling rate in the range of 10^5—10^6 °C/sec would be necessary to produce rapidly solidified alloys.

Rapidly solidified alloys are actually the alloys obtained by the special cooling methods suggested by various workers. It is clear that the greater the cooling rate the less will be the diffusion controlled growth of the nuclei and at the extremely slow cooling rate there will be no diffusion and super cooled liquid structure (metallic glass) will be obtained at room temperature.

PROPERTIES

General improvement achieved in rapidly solidified alloys are :

1) Extreme grain refinement (even down to 100 A°)
2) Extention of liquid state solubility in solid state
3) Generation of new non-equilibrium crystalline phases.

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* Pradip Patra & Bikash Chandra Roy, 5th Year Met. E.

4) Formation of metallic glasses i.e. amorphous alloy by diffusionless solidification and supression of normal solidification process i.e. supercooled liquid at room temperature.

The striking degree of grain refinement obtainable in rapidly solidified alloys may make some special applications of these materials possible though commercial utilisation is yet to find ground

Extension of solid solubility can give rise to very high strength/highly precipitation hardenable alloy where solid solubility is very less in equilibrium condition (e.g. Aluminium alloy containing iron or similar elements).

Non-equilibrium crystalline phases (e g. Al-Cu, Al-Zn) are also very strong and may occasionally be super-conducting. On aging a supersaturated solid soliution there may be formation of transient metastable phases ; but their practical applicability is restricted by their thermal instability.

Production of metallic glasses requires a cooling rate of the order of 10^6 to 10^8 °C/Sec. They have no crystallinity hence there are no imperfections like dislocation, grain boundaries and stacking faults in them. So even if they flow plastically it will not be by movement of dislocations as in crystalline metal. So their strength properties are tremendously higher than the common alloys (e g. 7.5 of metallic glass $Fe_{80}B_{20}$ kg/mm^2 compared to 304 stainless steel's 54 kg/mm^2.)

Metallic glass also shows very good magnetic and corrosion resistance properties. So among the rapidly solidfied alloys, metallic glasses have drawn the greatest attention.

Most valuable property of metallic glasses seem to be ferromagnetism for immediate large scale application as these are free from magnetocrystalline anisotropy and to utilise this magnetic property the section thinness is not a major obstacle. Magnetic properties of $Co_{70}Fe_5Si_{15}B_{10}$ are superior to those of the well-known super permalloy.

Any non-unifotmity in a material may be responsible for its low corrosion resistance. In a crystalline material non-uniformity in :

a) Structure (e.g. multiphase alloy),

b) Grain orientation,

c) Composition,

d) Energy content (e.g. energy content of imperfect zones are higher) etc.

leads to enhancement of corrosion. But metallic glasses have no such non-uniformities and so their corrosion resistance is tremendously high.

Corrosion resistance of Fe-Cr, Fe-Ni-Cr-P, Fe-Cr-B-X (C, Si or P) etc. are studied. In amorphous alloys containing high Cr rapid formation of a highly protective and absolutely uniform passive film leads to further high corrosion resistance Phosphorous included in large amount in these alloys accelerates active dissolution of the constituent elements prior to passive film formation. The corrosion resistance of amorphous alloys has been found to be dependent on the metalloid content and also minor metallic alloying elements present in them These alloys are almost immune to the corrosive action of NaCl, HCl, H_2SO_4, $FeCl_3$ etc.

Many theories are presently under development for predicting the composition suitable for producing metallic glass Extremely pure metals require higher cooling rate for metallic glass production than the cooling rate achievable at present. Some metallic alloys and some metalloid alloys are suitable for this.

The thermal stability of the metallic glasses also varies over a wide range. Most of them lose their stability through crystallisation in the 400—500°C range ; but metallic glasses based on W, Ta, Nb and Ir have even higher crystallisation temperature (e.g. 950°C for W_{35} $MO_{20}Cr_{15}$ Fe_5 Ni_5 P_6 C_5Si_3 alloy).

APPLICATION

Commercial production of rapidly soildified alloys have already started. Allied chemicals, Morris Town, U. S. A. is now marketing some brazing alloys and magnetic shielding materials made of rapidly solidified metallic glasses. This firm is also selling to research laboratories spools of metallic glass ribbons or tapes up to 1/10 mm. in thickness and a few cm. in width under the trade name of METGLAS.

SOME TECHNIQUES OF PRODUCTION

I. The Gun Technique

Here the melt from a graphite cruicible is ejected through an orifice at a high velocity and spreads on to a copper substrate maintained at very low temperature.

Cooling rate obtainable is 10^6 to 10^8 °C/sec. Alloy foils of thickness upto 15 μm can be produced.

2. *Piston-and-Anvil Technique*

Here a falling molten drop is pressed between a fixed anvil and a fast moving piston—both being made of highly conductive material. Maximum achievable cooling rate is 10^6 °C/sec. and foil upto 100 μm can be produced.

3. *The Plasma-Jet spray Technique*

Fine powder of the alloy is injected into a high temperature plasma and the molten droplets impinge at a high velocity on a copper substrate. As no container is used, both reactive and refractory metal can be quenched continuously at cooling rate of order of 10^7 °C/sec.

There are also some other techniques e.g. the Centrifuge, the Torsion catapault roller quenching method etc. which are still in their developmental stage.

CONCLUSION

The practical applicability of rapidly solidified alloys are very much limited due to their very low thickness. So we are unfortunate not to be able to utilise the potential of tremendously improved physical, chemical and mechanical properties.

But the attractive properties of these alloys have made a great impact in research for finding new economic and all round improved alloys.

If such an alloy can be found which itself has very high thermal conductivity then thicker alloy may be produced. We should be proud that in Benaras Hindu University in India, a lot of work has been done successfully and is being done in this field.

Presently attempts are made to grow controlled amount of crystallinity in metallic glasses to have a combination of high strength, ductility, corrosion resistance etc. and it may be possible to produce cans for highly reactive liquids.

REFERENCE

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MANGANESE SUBSTITUTED ALLOYS*

INTRODUCTION

Amongst alloys, high nickel alloys occupy very important position. Stainless steels, high strength maraging steels, TRIP steels, Ni-base superalloys are a few belonging to this class. These alloys contain Ni in the range of 12-25%. But due to worldwide scarcity of Ni, attempts were made to find proper substitute for Ni in these alloys without any serious detriment to their properties. Manganese was found to be the best allround alternative. So for countries like ours where there is no Ni deposit worth mentioning and Mn is abundant, such substitution can bring about a great relief to the economy and lead to growth of industries.

Alloys

There are four prinicipal alloys which contain nickel in high concentration. We by way of our discussion review each of them briefiy, pointing out the change in properties illustratively wherever possible and whenever necessary and advantages and limitations that come by in the bargain

(A) TRIP Steels : These steels are known in the abbreviated form of 'Transformation Induced Plastic Steels'. They are characterized by their very high fracture toughness. The nominal composition of conventional (1) and Mn substituted (2) TRIP steels are given in Table-1. Table-II illustrates the mechanical properties of (1), (2),.

Table– I

Alloy No.	Normal Compn.%						Modified Compn.%					Alloy No.
	C	Si	Mn	Mo	Ni	Cr	C	Mn	Cr	Ni	Mo	
1	0.25	1.96	2 08	4.04	7.60	8.80	0.55	2.52	9,20	5 80	4 25	4
2	0.31	1.92	2.20	3 80	7.31	8.89	0.56	3 73	9.25	5,85	4.26	5

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* Debasish Chatterjee 5th Year Met. E.

Table—II

Alloy No.	% Redn. in Area	Temp. (oF) of Rolling	Cooled to .....(oF)	Y. S. in p. s. i. x 1000	T. S. in p. s. i. x 1000	Elongn %	Mn in wt%	Temp. (oF) of Rolling	σS in kg/mm.2	U.T.S. in kg./m2	δ in %
	Normal						Modified				
1	10	840	320	103	173	58	2.5	450	185	250	10
2	20	840	320	122	168	81	3.7	550	185	230	20

The substitution so far reported is to the extent of 5.43% Mn. (2). However studies are being made to increase this level further.

(B) *Maraging Alloys* : In the maraging alloys also attempts are made towards the partial replacement of Ni by Mn. There is some controversy in doing so as to the effect of Mn addition in place of Ni (3).

Decker showed that Managanese addition is undesirable and rapidly promotes the embrittlement effect. Patterson and Richardson, however, obtained favourable strength and toughness and were able to establish the minimum (Ni & Mn) combination to get any given hardness. The last analysis is given in the Fig. 1. (4)

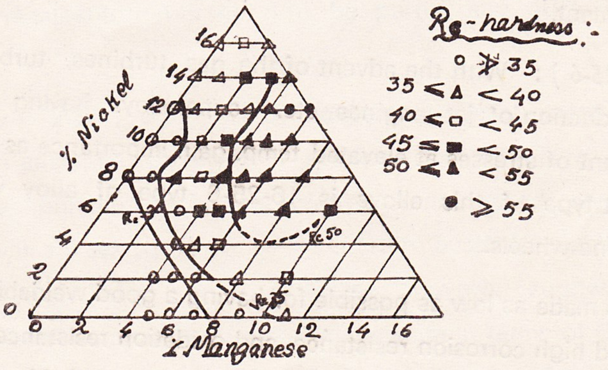


Fig. I

Tanaka working with Fe-12% Ni; Fe-6% Mn; Fe-9%Ni-5%Mn and Fe-7%Ni-6%Mn found no detrimental effect and suggested that this is due to the coherent precipitates or zones in the matrix, mainly. Kardonsky, however, contradicated Tanaka's views by reporting that the properties of the alloys are due to the precipitation of Ni_3Mn super-lattice, a f. c.c. structure. Goldman and Manence showed that with an alloy of Fe-12% Mn-5% Ni-4% Ti, the hardening comes by from appearance of an ordered cubic phase, ordered tetragonal phase and Fe_2Ti. Later electron microprobe analyses revealed that the fine dispersed precipitates hitherto known as Fe_2Ti is $(Fe\,Ni\,Mn)_2Ti$. They concluded that Mn-substitution suppresses Ni_3Ti precipitate and results an equilibrium phase Fe_2Ti with some substitution of Mn for Fe and Ni.

The composition and mechanical properties of both the normal and the modified varieties are given in Table-III and Table-IV.

Table—III

%	Normal	Modified
Ni	18	12.5
Mn	–	3
Co	6.9	8.0
Mo	2.9	4.0
Ti	0.17	0.20
Al	0.11	0.10
V	—	0.20

Table— IV

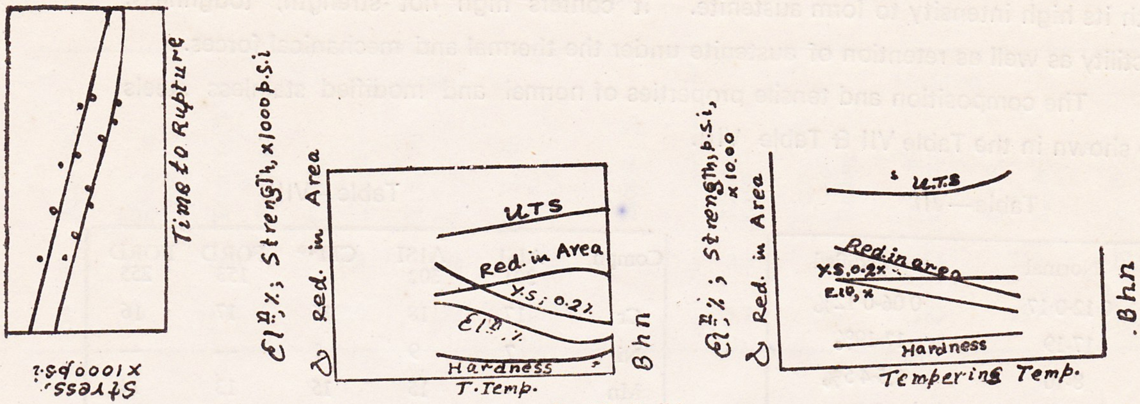
Mech. property	Normal	Modified
El. %	8.5	6—7%
Redn. % in area	68	53-60
YS k. s i.	175	2,14,000-2,25,000
T. S. k. s. i.	184	2,27,000-2,71,000
N. T. S. k. s. i.	284	3,44,000-3,67,000

Here also, we find that the substitution is partial and studies are aimed at higher level of such replacement.

(C) *Superalloy (16-25-6)* : With the advent of the gas turbines, turbosuperchargers, along with mass production of jet engines etc. superalloys having high ability to withstand high amount of stresses at elevated temp. gain importance as time rolls on. One of the important type of this alloys is 16-25-6 type of alloy which finds its principal use in turbine wheels.

The carbon is made as low as possible for having a good weldability. Cr-16% to maintain the required high corrosion resistance, and oxidation resistance at the service conditions, Ni-25% to have a proper austenitic structure and Mo for its simplest approach to its high hot strength and toughness.

The usual and modified compositions are given in table-V. The mechanical properties of heat treated alloys are shown in fig. II fig. III & fig. IV. The high



Figs. II, III & IV

temperature properties are also listed in the Table-VI. The ppt. hardening experiments also showed great contribution to high strength without hampering the ductility.

Table—V

	Normal	Modified
C	0 13% max	0·08% max
Mn	2·00% max	6·5-8·5% max
Cr	15-17.5%	15-17 5% max
Ni	24-27%	14-17%
Mo	5·5-7.0%	5·5-7.0%

Table—VI

Material	Temp. in ......oC	Stress in ..p s.i.	Time to rupture in hrs.	El n., %	Redn. in area, %
16-25-6	595	5,000	226	9	16·7
16-15-6	595	5,000	549	13·5	15·6

Here also, the substitution is found to be partial and 10% Ni is substituted with 6% Mn.

(D) *Stainless Steels* : With the purpose of conserving nickel, comprehensive studies have been made on austenitic Cr-Mn-Ni-N steels. The aim is to provide a stable austenitic structure, optimum mechanical properties and good corrosion resistance. The Manganese gives a week performance in regard to austenite stability in comparison to that of Ni. Chi-Mei-Hsiao and E. J. Dulis6, however, suggested an empirical formula to determine Mn content to get stable austenite in terms of C, N, Cr content of the alloy. They showed that with 12·15% Cr, Mn content be 18-12% or for an alloy containing-Cr-15%, 12% Mn is called for stabilising the austenite. Still extensive studies show that it is virtually impossible to build sufficient hot strength in Cr-Mn steels, for which we must almost always use Mo. Nitrogen for this reason comes in with its high intensity to form austenite. It confers high hot strength, toughness, ductility as well as retention of austenite under the thermal and mechanical forces.

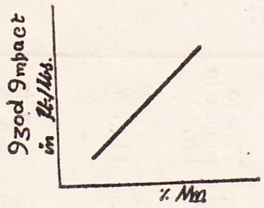
The composition and tensile properties of normal and modified stainless steels are shown in the Table VII & Table VIII.

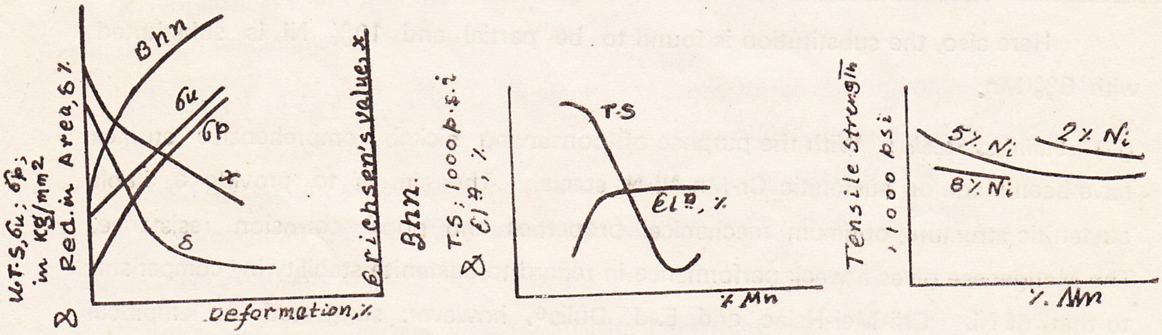
Table—VII

	Normal	Madified
C	0·12-0·17	0 06-0·12%
Cr	17-19	17-19%
Ni	8-10	3.5-4·5%
Mn	2·00	7-9%
N	—	0·12-0·18·/.

Table—VIII

Compn.	AISI 301	A1SI 302	CM**	FORD 153	FORD 255
Cr	17	18	16	17	16
Ni	7	9	1	—	—
Mn	—	15	15	13	14
Mo	—	—	—	2·5	2
N	—	—	—	0·75	0·6
Cw%	40	60	40	25	33
Y.S. in p.s.i × 1000	1,50,000	1,80,000	1,45,000	1,76,000	1,83,000
T.S. in p.s.i × 1000	2,00,000	1,95,000	1,85,000	2,05,000	2,07,000
Eln %	10	3	5	11·5	13





Figs. V, VI, VII & VIII

The mechanical properties including tensile properties, impact properties coupled up with corrosion resistance etc. have been given in fig. V-fig. VIII. The effect of Nitrogen on tensile properties are shown in fig. IX in the next page.

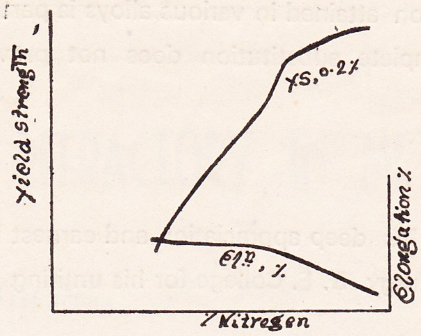


Fig. IX

General properties obtained through substitution are :

1) Good workability, if the initial working temperature is fixed within 1225°C.

2) Good hardness and toughness comparable to that of 18 : 8 type.

3) Good weldability - weld metal posseses good tensile and yield strength with good ductility in the as-welded condition, indicating less fissuring in weld metal.

4) Room temperature impact values are guite high to an extent of 52-55 or as high as 66 ft. lbs.

5) The corrosion data show that despite slight loss due to substitution of Ni by Mn, the modified steels show fair corrosion properties.

6) Mn retards notch sensitivity at low temp. Steels of this type containing $C < 0.08\%$ are prone to intergranular attacks.

SUMMARY

The analysis on the substitution of Nickel by Manganese in some prominent high nickel alloys shows the feasibility of the substitution from the view point of properties. It is clear from various reports that the Manganese substituted alloys are comparable, if not better, than the high nickel varieties for various mechanical properties point of view excepting a slight decrease in toughness and a marginal loss in cost involved and an increased chance of workhardening rate. Manganese lowers the stacking fault energy of the system, thus hindering the cross slip to occur and results in improved workhardening ability.

The level of substitution attained in various alloys is partial in nature, as it has been well established that complete substitution does not provide such good and comparable properties.

ACKNOWLEDGEMENT

The author expresses his deep appreciation and earnest regards to Mr. Monoj K. Mitra, Asstt. Prof. of Metallurgy, B. E. College for his untiring useful guidance.

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ROLE OF REFRACTORY IN METALLURGY*

Introduction and definition of refractory

The material which can withstand high temperature without fusion and resist the action of slags, matte, etc. are called refractory. In any pyrometallurgical or chemical operations the refractories are supposed to withstand thermal shock, abrasion, wear and chemical attack. Hence given the definite technological parameters, proper choice of refractory is one of the most important factors in justifying the economy of the process.

Classification of Refractories

According to their chemical behaviour, the refractory materials which are mainly oxides of metals or non-metals or their mixtures are classified as follows :

Refractories

Acid	Basic	Neutral	Special
	Dolomite	Carbon	Forsterite (m.p. 1600°C)
Silica Silicate	Magnesite	Carbides	Cordesite (m.p. 1700°C)
SiO_2 is the major constituent	Burnt lime	Chromites	Thoria (m.p. 2800°C) Zirconia (m.p. 2700°C)

The general properties of good refractory material

In most of the pyrometallurgical operations the refractory materials come in contact with the liquid metal, slag and gaseous medium. They may undergo partial melting during the operation also damages due to the thermal

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* Bidyut Chakraborty, 5th Year, Met. E.

effects, mechanical damages during changing. All these factors are interconnected and contributing towards the failure of the lining. That is why the refractory materials used for pyrometallurgical processes should be of higher refractoriness, thermal resistance, chemical stability, mechanical strength, low thermal conductivity and low expansion and contraction properties at temperature variations.

Indian availability of refrctories

Accepting the fact that a good refractory is a must for the technoeconomic success of a metallurgical process it is worth while to go for a brief survey on the availability of different kinds of refractories in our own country. This is presented below :

Mineral	Composition	Temp. limit for use in °C	Occurrence
Fireclay	45.9% Al_2O_3 54.1% SiO_2	1730-1740°C	Hazaribagh and Jharia (Bihar), Rajkot (Gujarat), Jabalpur (M.P), Sambalpur (Orissa), Shimoga (Karnataka), Kumardhubi (W.B.)
Silica	96% SiO_2 Rest FeO, CaO Al_2O_3	1750°C	Hyderabad (Andhra), Dhanbad, Gaya and Hazaribagh (Bihar), Ratnagiri (Maharastra).
Bauxite (Alumina)	Al_2O_3 — 50.90% SiO_2 — 3.25% Fe_2O_3 — 1/2 — 12% H_2O — 10-30%	1850°C	Ranchi and Palamau (Bihar), Kutch and Saurastra (Gujarat), Raisi & Poonch (Kasmir), Jabalpur, Balaghat, Mandla and Bilaspur (M. P.), Salem and Nilgiris (Tamil Nadu), Kelhapur and Kolaba (Maharastra), Sambalpur (Orissa), Belgaun (Karnataka).

contd ......

Magnesite MgO — 98% (Magnesia) $CaCO_3$, Al_2O_3, SiO_2, and Fe_2O_3—rest.	2500°C	Almora (U. P.), Salem (Tamil Nadu), Kadakola (Karnataka), Singhbhum (Bihar).
Dolomite $MgCO_3$ — 35% SiO_2 — 1% max. FeO & Al_2O_3 — 1.5% $CaCO_3$ — rest.	1900°C	Birmitrapur and Sambalpur (Orissa), Hirsi (M. P.), Shimoga (Karnataka), Kurnool (Andhra), Nagpur (Maharastra).
Graphite C—90% V.M.—1-8% Ash—1-32%	3000°C	Bolangis and Dhenkanal (Orissa), East Godavari (Andhra), Trivandram (Maharastra).
Chromite 32% FeO 68% Cr_2O_3	2180°C	Jojonatu and Kittaburu (Bihar), Krishna (Andhra Pradesh), Salem, Ratnagiri, Keonjhar and Jaipur (Orissa).
Kyanite 63% Al_2O_3 37% SiO_2	1800°C	Lapsa-Buru (Largest deposite in the world), Singhbhum (Bihar), Hassan (Karnataka), Jaipur (Rajastan).

Selection of refractories

The general trends of lining is of same nature as that of the slag produced in the furnaces. As per example in acid convertor where acid slag is produced fireclay or silica bricks are used. However, there are some exceptions in this rule that cement is a basic substance (CaO-60% Al_2O_3-8%, MgO-4%, K_2O & Na_2O-2%, SiO_2-20%). But an exceedingly satisfactory brick in cement kiln is found to have an acid composition (SiO_2-73%, Al_2O_3-18%, Fe_2O_3-7%). The reason for the success of such a brick is attributed to the fact that it fuses on the surface and forms with cement clinker, a protective coating. So the question of protecting coating may also be an important one in judging the refractory material.

Zinc retorts are externally heated so that the charge inside it is heated up by heat conduction. So the refractory material which is used to make the retort must be highly heat conductive and at the same time it possesses high strength at elevated temperature. In such case, fireclay with coke or graphite is used to rise the thermal conductivity of fireclay. But normally silicon carbide is used in zinc retort making.

Some material like copper and silver are absorbed by chromite bricks largely and these absorbed copper and silver can not be recovered from the bricks. So the use of chromite bricks is prohibited, in cases where the material like Cu, Ag comes in contact with the brick.

Production of steel in our days serves as a symbol of progress for all countries. So let us focus our attention on the refractories of steel making furnaces specially.

In our country, there are three major processes of steel making. They are Open Hearth steel making, Electric furnace steel making and Basic Oxygen convertor process.

When we propose a refractory for a certain purpose, we must keep our attention that how many years it will last—because the lining of refractory is not only costly but also it hampers the normal production and also relining of any furnace take a lot of time.

Considering these facts, the hearth and the walls of the open hearth furnace should be made of magnesite bricks with the following characteristics :

Chemical composition : MgO 91.0% & CaO 3.1%
Cold crushing strength (Kg/cm^2) : 400
Refractoriness under 2 kg/cm^2 pressure : 1500°C
Bulk density (gm/cm^2) : 2.6

The arch of the furnace is made of the magnesite periclase spinnal brick (used in U.S.S.R.) of the following composition ;

Cr_2O_3—8.9 – 12.4%
SiO_2—4.6 - 5%
MgO—64.2—70.5%
Al_2O_3—4.5%
Fe_2O_3—8.5%
CaO - 2.1%

Cold crushing strength—500 . 600 kg/cm^2.
Porocity — 15%
Refractoriness under load — 1600°C.

Next electric furnace comes to the picture. Refractory material used for the lining of these furnaces are of the same type as used in the open hearth furnaces.

The last one is refractory used for Basic Oxygen steel making process. In this respect tar bonded dolomite bricks are thought to be most suitable and in U.S.S.R. it is a widely used refractory brick.

The composition and properties of tar bonded refractories are :

Composition in %				Properties			
SiO_2	Al_2O_3	Fe_2O_8	MgO	Bulk density gm/cm^3	Porosity	Cold crushing strength kg/cm^2	Refractoriness under 2 Kg/cm^2 pressure.
2.4	1.2	1.0	57.0	29	—	550-600	1650°C to 1700°C.

CONCLUSION

From the above discussion it is apparent that the overall economy of a process on the long term basis is much dependent on the quality of the refractories chosen for the process. Lining life is the most profit-bearing parameter of a steel industry that can be effectively increased only if the procurement of a high quality magnesite is possible. Indian refractory materials have the inherent draw-back of high silica content in magnesite. Hence the lining life of steel melting furnaces of our country is well below the lining life in other countries. Import may be a shot-range solution. Means are to be found out to produce the good quality refractory materials to achieve a long term benefit on the national economy. Magnesite from sea-water is not a very profitable proposition in our country, as its high installation cost does not justify itself to meet the small requirements of refractory of our country. It is probably wiser to put an effort to upgrade the quality of refractory at a lower cost.

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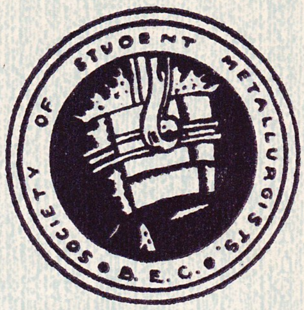
International Symposium '80.



S. S. M. REPORTS
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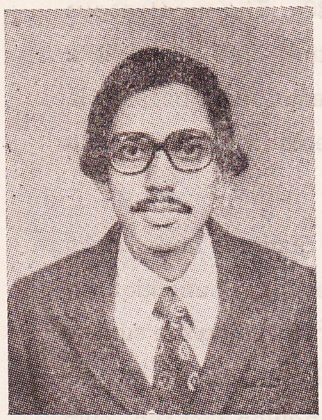
FROM THE GENERAL SECRETARY'S VIEW POINT



"When winter comes, can spring be far behind". After enjoying the most eventful part of our life at the premises of Bengal Engineering College and the cordial atmosphere of the Society of Student Metallurgists, time has arrived to bid farewell and enter into a greater sphere of life. Though it is inevitably painful, still we ought not to forget to welcome the younger generations to come. I specially feel extremely elated to have been offered the privilege of expressing the sentiments and reporting the annual activities of the society through this column.

At the onset, let me extend my heartiest congratulations and thanks to the joint magazine secretaries of the society for their tireless endeavour to revive the tradition of publication of the Society's Annual Journal after an unavoidable lapse of one year. I feel extremely elated and proud for their utmost effort, because, this year the society is able to publish this Journal inspite of the particularly stringent and adverse conditions. In this connection I feel it is customary to remind our members that it is practically impossible and inhuman to shoulder the entire resposibility of publishing this traditional Journal by the selfless attempts of only a few office bearers.

The activities of the society for this session commenced on the 28th August, 1980 with the election of the present office bearers under the stewardship of Dr. P. P. Das, our esteemed head of the department. Apart from the tight schedule of regular sessional and lecture classes, the series of guest lectures by eminent metallurgists, though informative and interest-provoking, restricted further activities of the society.

I am specially enlightened to congratulate the triumphant team of our department which had taken away the Anupam Memorial Inter-Departmental Quiz competition this year also. Out of six contests arranged so far, that our department could achieve this distinction no less than four times, speaks of the great promise and potential of our students.

The society was also successful in arranging an outing cum picnic at the bank of the river Ganges at Batanagar on the 23rd December, 1980. The spontaneous participation of all the members of the students & members of the staff made it a memorable occasion. This function seems as important as academic study because it provides the ample scope of knowing each other among students as well as the members of the staff in a most friendly atmosphere.

As a part of my responsibility, I must extend my heartfelt gratitude and thanks on behalf of the S.S.M. to Dr. S. K. Sengupta of Torsteel Research Foundation in India and Mr. A. Guha of Liluah Iron Works for their generousity in donating the sum of Rs. 250/- each to the society. The society has arranged two annual scholarships out of this amount for the needy final year students in every year on condition that the sum would be reimbursed after the receipients get absorbed in jobs.

The Society feels relieved at the joining of Mr. Moloy K Banerjee & Mr. Monoj K. Mitra as assistant professors to reduce the acute staff shortage to some extent. The Society aiso sincerely hopes that the students of this department will be greatly benifited by their illustrative teaching approach and helpful advices.

I, on behalf of the Society, express the deepest gratitude to Mr. R P. Ganguly for being available in the capacity of visiting lecturer even after his retirement.

We deeply mourn the sudden demise of Dr. B. K. Chatterjee of the chemistry department, B. E. College & Dr. S. Ray of Metallurgy department, Jadavpur University (Ex-Student of B. E. College) remembeiing their most cordial & parential attitude towards the student community.

Last, but not the least, I on behalf of the S.S.M., would like to extend my heartfull thanks and gratitude to Dr. P. P. Das, for his constant inspiration and advice throughout each and every proceedings of the society, failing which, successful completion of the calendar activities would have been a far fetched idea.

SUBHASISH SIRCAR
Gen. Secy., S.S.M., 1980-81

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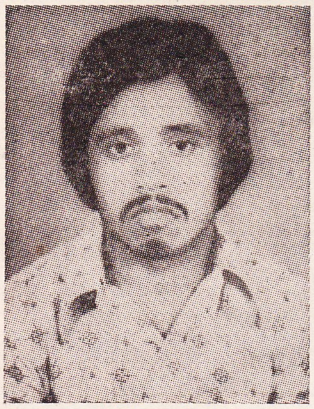
& Sri Amitava Mazumdar ... . *for their invaluable guidance.*

Also, we acknowledge the magnanimity of our patrons, friends and well-wishers who extended their cooperation and sympathy to a great deal for making this venture a success.

Budding Metallurgists of 1981



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An examination is a nightmare to him in a different way.

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A specimen from the other planet—admitted to B. E. College on a reserve list & more so to Metallurgy department.

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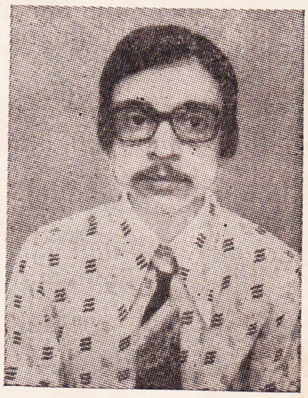
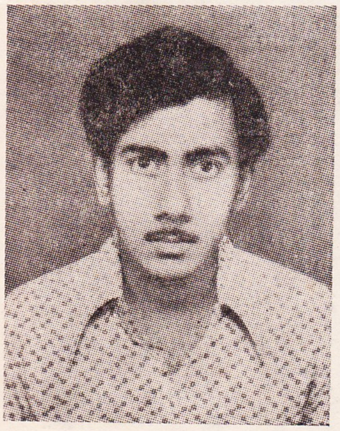


Completes his sessional work before the session has started.



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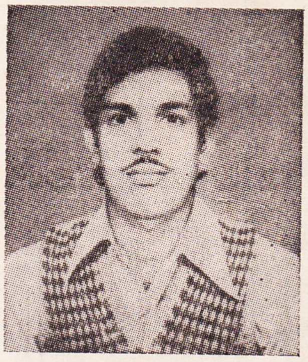
23/4/1, Abinash Banerjee Lane,
Howrah-711104

Newton of modern age—but "bad luck" almost 100% of what he speaks is non-sense.

Debashis Chatterjee
'Mahua', Saradapally,
Hooghly.



Classrooms are out of bounds for our "Great Bachal."

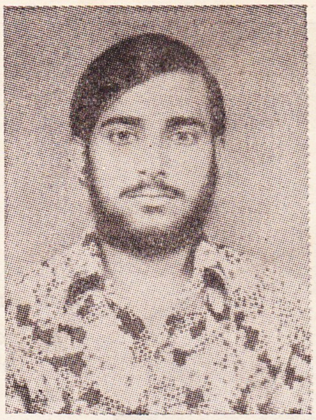
Sushil Das

Vill : Udayan Palli (Mullick Bagan),
P. O. Batanagar, 24-Parganas,
Pin-743313

The more you give him Entero Quinol tablets the happier he is.

Arun Ghosh

B-6/195, Kalyani,
P. O. Kalyani, Nadia,
Pin-741235

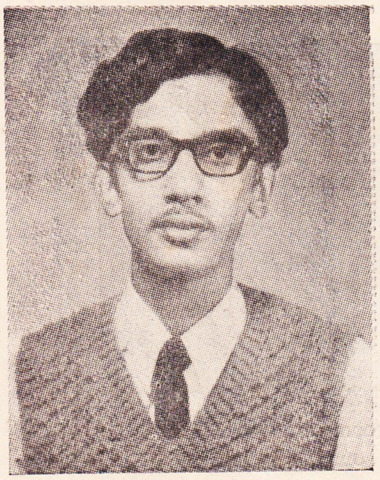


Our "Nata" is not so short as to swing his legs sitting on the edge of a foot path.

Biman Ch. Ghosh

24, Jnan Ch. Mukherjee Lane,
Krishna Nagar,
Pin-741101

A warrior of many battles—lost more than won ; because.........



Kinshuk Ghosh

BB—59, Salt-Lake,
Cal-700 064.

"Frailty thy name is Kinshuk"

Pradip Goswami

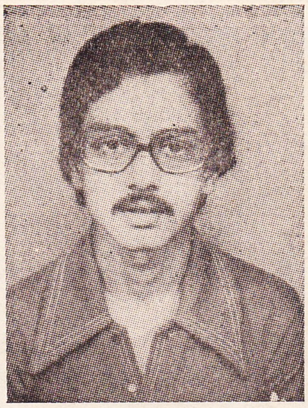
C/O Sri Bidhan Bhusan Goswami,
'Purabi', Chowk Bazar,
P. O. & Dist -Hooghly

He lives more in Australia & London than in India.

Biswajit Hazra

132/EF, Traffic Colony.
Asansol, Burdwan, W. B.

Palmistry says that he would prosper in life and that is all.



Amitava Majumdar

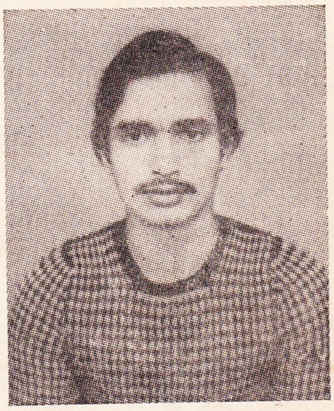
C/o. S.P. Majumdar,
Asst. Chief Engineer,
P.W.D., Design Division
P O. & Dist —Jalpaiguri, W.B.

His aim in life: Straight from 5th Year, Metallurgy to a top Executive of a firm.

Pinaki Ranjan Nag

100/1/1A Dr. Lal Mohan
Bhattacharjee Road,
Calcutta-700014.

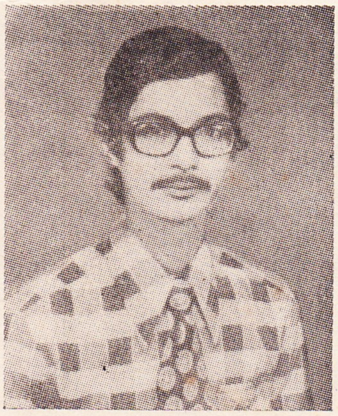
Let us hope that his over enthusiasm in secret matters does not lead him to destruction.



Pradip Kumar Patra

C/o Mr. Madan Mohan Patra,
Vill. Raghunathpur, P.O. Pilkhan,
—Via Gourhati, Hooghly.

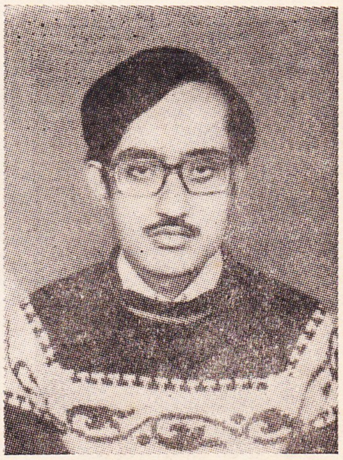
Metallurgy & health are the two things that intrigue him most.



Bikash Ch. Roy

C/o. Sri Brojo Gopal Roy,
110, Santi Nagar Road,
P.O, Bhacrakali, Dist. Hooghly.

Every body may escape ticket-less but never can he.

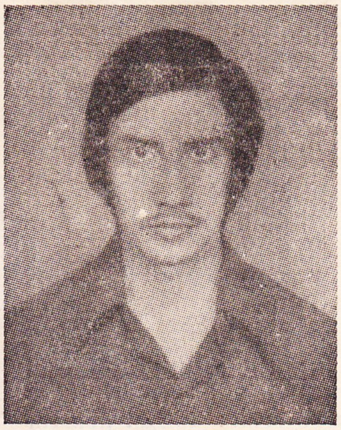


Subhashis Sanyal

43/6, Ram Charan Seth Road,
Santragachi,
Howrah-4.

2627 - 1857

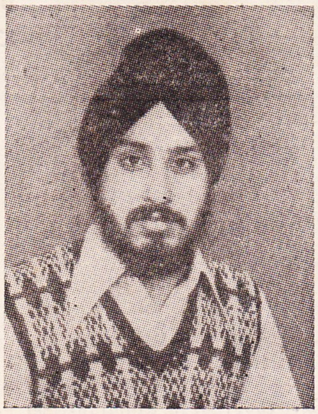
A three dimensional specimen—which cannot be conceivied by human beings.



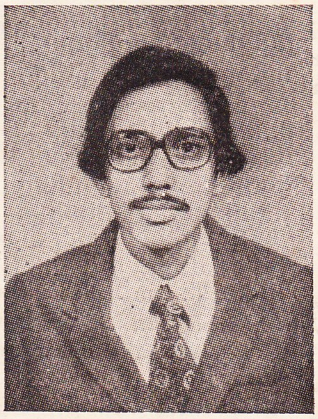
Soumitra Sarkar
3, Post Office Road,
Jamshedpur-12,
Pin-831012.

Whenever we run after a bus we are reminded of Soumitra—college's best sprinter.

Gurprit Singh
C/o. Mr. Hardayal Singh,
16, Debai Pukur Road,
Hindmotor, Hooghly.

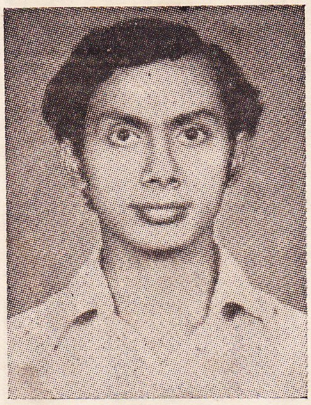


The trouble with him is that he finds more things to laugh at in Punjabis than anyone else.



Subhasish Sircar
18/30, Dover Lane,
Calcutta-700029,
Ph.-47-7522.

Is there an electronic brain behind his over-enthusiastic activities ?



Saumitra Sinha
C/o. Dr. S. K. Sinha,
P-35, Kanungo Park,
P.O. Garia,
Pin-700084,
Ph.-72-4146.

A shuttle cock flying between B. E. College & Garia—without any rest at all.

Mrinmay K. Sinha Babu
C/o. Pramathanath Sinha Babu,
Vill- Sinhajora,
P.O.- Lakshmisagar,
Dist.- Bankura.

Five years are too short a time to understand his characteristics.

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With the best compliments of :

MA Steels Micro-Alloyed
for Macro-Economy

Durgapur Steel develops SAIL-MA, high strength Micro-Alloy steells with excellent notch toughness, fatigue properties, easy weldability promoting cosiderable economy in steel consumption.

SAIL-MA is the right kind of steel to construct transmission towers, substation structures, high rise buildinss, ship superstructures, railways, flyovers, offishore plateforms, E.O.T. and mobile cranes, mining equipment, etc.

This high strength steel has been developed at Durgapur Steel Plant in collaboration with the R&D Centre of SAIL. It is produced in semi-killed variety depending on customers' requirements.

For further information & technical assistance please contact :

1. Chief Superintendent Production Planning & Control Department Durgapur Steel Plant Steel Authority of India Ltd. Durgapur-713203, India
2. Research Manager Product Development Group Research & Development Centre for Iron & Steel, Steel Authority of India Ltd, Ranchi-834002, India

For trade enquiries please contact :

General Marketing Manager
Central Planning & Products Division
Central Marketing Organisation
Steel Autority of India Ltd.
2, Fairlie Place
Calcutta-700 001, India

STEEL AUTHORITY OF INDIA LTD.
DURGAPUR STEEL PLANT

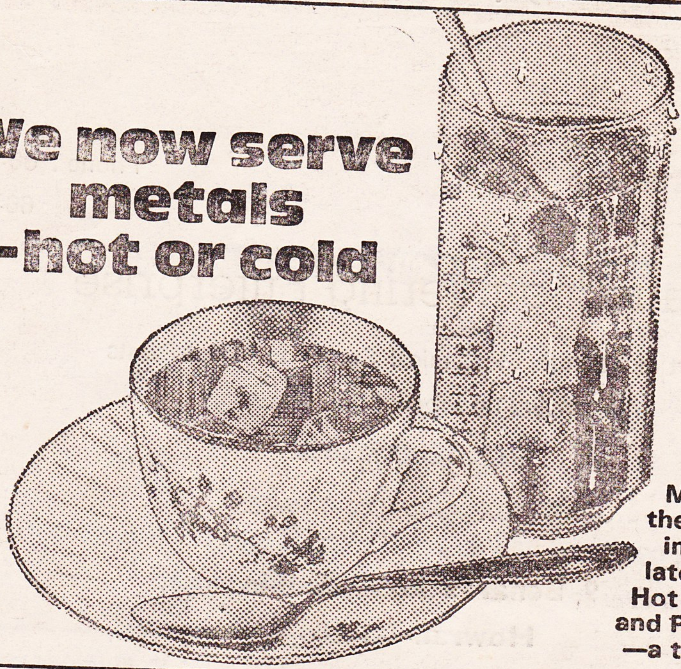
With best compliments :

ORISSA SPONGE IRON LIMITED

4, GOVT. PLACE (NORTH)

CALCUTTA-700 001

We now serve metals -hot or cold



SAA/MECON/106A2

MECON is now serving the steel and non-ferrous industries with the latest technology for Hot and Cold Rolling Mills and Processing Lines —a total turnkey service.

For Mishra Dhatu Nigam Limited, Hyderabad—India's first Super Alloys Project—MECON has designed, supplied and erected
One Bar Rolling Mill
and one Wire Rod Rolling Mill.

The Bar Mill has been commissioned in May 1980 when 100 mm x 100 mm stainless steel hot billets rolled down to 30 mm rounds with excellent tolerance. The Wire Rod Mill has been commissioned in August 1980 when hot bars were rolled into wire rod coils with close tolerances. We feel humble at the success at MIDHANI and we salute MIDHANI for the confidence reposed in MECON for these TWO HOT ROLLING MILLS.

MECON scored a 'DOUBLE' with the successful commissioning in February, 1980, of the Cold Rolling Mill Project of STEEL STRIPS LIMITED, Chandigarh. Located at Jitwal Kalan, a backward area in Punjab, this project has already started supplying quality Cold Rolled Strips in the market. MECON rendered complete consultancy and engineering services—from concept to commissioning—besides designing and supplying the 4-High Reversing Cold Rolling Mill—the heart of the project.

A similar Cold Rolling Project was conceived and commissioned by MECON in June, 1977, for NAGARJUNA STEELS LIMITED, at a greenfield site at Patancheru, a backward area in Andhra Pradesh. Today NAGARJUNA STEELS is a name synonymous with quality Cold Rolled Strips in the Indian market. MECON proudly shares the success of NAGARJUNA STEELS LIMITED and of STEEL STRIPS LIMITED for their Cold Rolling Mill Projects.

And that's not all...

- MECON is revamping the Hot Strip Mill at the Rourkela Steel Plant on turnkey basis. The mill will incorporate most advanced technological features like Hydraulic Automatic Gauge Control for the Finishing Stands, Thyristor Power Supply System, New Vertical Mill Stand, upto-date Strip Cooling System.
- For the Silicon Project at Rourkela, MECON is designing and supplying an advanced 4-High Reversing Cold Rolling Mill. MECON is also designing decarburising and tandem annealing lines for the same project.
- At Bokaro Steel Plant—MECON is designing and supplying most sophisticated cold rolling mills like 5-Stand Tandem Mill, a Twin-Stand 4-High Double Cold Reduction/Temper Mill and a Single-Stand 4-High Temper Mill.

  MECON is also designing a number of high-capacity continuous strip processing lines for this steel plant.
- A modern 2-High Hydraulic Skin Pass Mill is being designed and supplied by MECON for stainless steel application for Salem Steel Project.

Yes, with its expertise and experience, MECON is on the move—helping the steel and non-ferrous industries to roll out better products and ensure greater productivity.

Metallurgical & Engineering Consultants (India) Limited
(A Government of India Undertaking)
Ranchi-834 002

MECON
मैकान
-Committed to total consultancy

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