

DR. A-O. I NEGBEYEBOR

CONFERENCE PROCEEDINGS

FIRST AFRICA-USA INTERNATIONAL CONFERENCE ON MANUFACTURING TECHNOLOGY



SHERATON HOTEL, IKEJA,
LAGOS, NIGERIA

JANUARY 11-14, 1993

**FIRST AFRICA-USA INTERNATIONAL CONFERENCE
ON MANUFACTURING TECHNOLOGY**

JANUARY 11-14, 1993

LAGOS, NIGERIA

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Hosted By:

Federal Ministry of Industries and Technology, Nigeria
Nigerian Universities Commission

General Conference Chairman:

Professor Bart O. Nnaji, University of Massachusetts at
Amherst

Advisory Committee: t

Professor Adedeji Bodunde Badiru, University of
Oklahoma

Professor Pius Egbelu, Pennsylvania State University

Professor Bart O. Nnaji, University of Massachusetts at
Amherst

Professor O. Geoffrey Okogbaa, University of South
Florida

Professor Oliver Mobisson, Enugu State University of
Technology, Nigeria

Organizing Committee Chairmen:

Professor Pius Egbelu, Pennsylvania State University

Professor Oliver Mobisson, Enugu State University
of Technology, Nigeria

**International Technical Program
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Professor Adedeji Bodunde Badiru, University of
Oklahoma

Professor O. Geoffrey Okogbaa, University of South
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CONFERENCE BACKGROUND and SIGNIFICANCE

Engineers, Scientists, Managers, Researchers, Chief Executives, Administrators, and Students have come together to participate in the First Africa-USA International Conference on Manufacturing Technology. This conference represents the first international congregation of professionals interested in the advancement of Manufacturing Technology in Africa. Forward and reverse manufacturing technology transfer between the USA and Africa has become imperative for global competitiveness in the new world market place. Some of the problems of developing countries, such as those in Africa, cannot be successfully addressed until these countries are able to implement appropriate new and advanced industrial technologies. Transfer and local adaptation of manufacturing technology are essential to making each country self-sufficient in terms of industrial activities. It is clear that economic, social, and political progress of Africa can be advanced by encouraging the creation of local industries that can employ the growing population, cater to the needs of the population for local consumer goods, establish export products, and stimulate foreign investment and corporate presence in Africa.

This conference provides a forum for the exchange of information and ideas between indigenous professionals in Africa and professionals in the western world. This exchange could form the catalyst for increased dialogue and awareness of manufacturing technology and its role in the

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THE PROCESS OF A NEW WEAR-RESISTANCE STEEL
(AUSAC#1-032)

BY

A.O. INEGBENEBOB,
DEPT. OF MECHANICAL ENGINEERING
UNIVERSITY OF MAIDUGURI,
MAIDUGURI, BORNO-STATE,
NIGERIA.

ABSTRACT

A new wear-resistance steel, was produced for use in the mining industry, the agricultural sector, as well as railway points and crossings.

The iron-manganese-molybdenum alloys, were processed and planned in conventional technology of steel making, so that the optimum amount of manganese was obtained for the wear-resistance properties. This paper discussed the manufacturing technology involved and the exceptional mechanical properties that was obtained. This was due to strain-induced formation of lath martensite during the deformation process. An optimum composition range for this type of steel is indicated.

1. INTRODUCTION

A new wear-resistance steel, was produced for use in the mining industry, the agricultural sector, as well as railway points and crossings.

The Fe-Mn-Mo alloys, were processed and planned in conventional technology of steel making, so that the optimum amount of manganese was obtained for the wear-resistance properties.

This new wear resistant/high strength iron-manganese molybdenum steel was originally intended as a lower cost maraging material (Jones et al, 1982). It was observed that this steel work-hardens very rapidly in the early stage of deformation and simultaneously possesses higher strength than Hadfield manganese steel.

Hadfield manganese type steels (composition around 14% Mn, 1% C) do not transform to lath martensite (White and Honey Combe, 1962), but work-harden very considerably through interaction of stacking faults with interstitials carbon) and formation of epsilon martensite. There can be problem in welding Hadfield manganese steels, however, in this new wear-resistant iron-manganese-molybdenum steel weldability if safeguarded by the low carbon content and costs are reduced since it can be used in the hot-rolled condition.

The strengthening effects with the work-hardening of this alloys caused by an increased dislocation density and stacking fault population due to the strain-induced formation of lath martensite.

2. MANUFACTURING TECHNOLOGY

During the course of the investigation, a large number of experimental low carbon steels have been produced but this paper is limited to a consideration of only a few of the alloys.

Electrolytically pure materials were cast in a vacuum induction furnace to produce a series of iron-manganese-molybdenum alloys. The iron used was Japanese electrolytic of the following composition:- Fe = 99.9%, Si = 0.002%, Sn = 0.001%, C = 0.004%, Mn = 0.001%, P = 0.0018%. The required higher carbon content in the cast was achieved with additions of low carbon steel En3B. The manganese content of the charge took account of the manganese present in the added En3B. Weighed amounts of electrolytic iron and molybdenum were placed in a crucible situated inside a molybdenum heating coil. A weighed amount of flake manganese slightly more than that required for the target composition to allow for manganese volatilisation loss was placed in a hopper situated above the crucible. The melting chamber was pumped down to a pressure of 10^{-4} to 10^{-5} torr and the alloying elements in the crucible melted. The furnace chamber was isolated from the diffusion pump and high purity argon was introduced to a pressure of approximately 300mm of mercury. This argon pressure was maintained in the furnace chamber to prevent excessive loss of manganese through volatilisation. Following melting and casting, the ingots were subjected to a homogenization treatment at 1200°C for 24h. Subsequently, the ingots were heated to 1100°C and hot-rolled into 13mm thick bar in five passes with about a 4% reduction in eduction in each pass.

The finishing rolling temperatures were monitored by using an infrared pyrometer, and these are shown with the chemical analysis of the alloys in Table 1. Each bar was machined into Hounsfield specimens for tensile testing and thereafter sealed in silica tubes under vacuum (to minimize carbon and manganese loss) for solution treatment at a range of temperatures (850, 950, 1050, and 1150°C) for 1h and were then air-cooled.

TABLE 1. CHEMICAL ANALYSIS AND THE FINISHING ROLLING TEMPERATURE.

Alloys			Finishing Temperature
C(%)	Mn(%)	Mo(%)	($^{\circ}\text{C}$)
0.050	11.30	3.61	862
0.020	11.85	2.65	862
0.025	12.85	2.70	850
0.003	8.60	1.99	900
0.070	11.90	1.93	817

All tensile tests were carried out at a constant cross-head speed (0.5mm/min.) corresponding to an initial strain rate of $8.33 \times 10^{-5} s^{-1}$.

The phase content of the steels was determined using a commercial "Ferritescope" which quantified Ferromagnetic phase contents by monitoring magnetic reluctance in-situ.

3. RESULTS

Table 2, shows the mechanical properties of the alloys under studied both of hot-rolled and solution treated samples.

TABLE 2. MECHANICAL PROPERTIES.

Alloy	Elastic limit (MPa)	0.2% P.S (MPa)	T.S (MPa)	Elong. %	Red. in area	"n"
Fe-9Mn-2Mo**	500	549	882	16	65	0.319
Fe-11Mn-4Mo*	33	364	1470	18	54	0.550
Fe-12Mn-2Mo*	422	472	1480	24	50	0.683
Fe-12Mn-3Mo*	415	455	1276	20	25	0.634
Fe-13Mn-3Mo*	234	256	1392	18	10	0.447

*Hot-rolled condition **Solution treated 950°C for 1 hour.

The volume fraction of lath-martensite in the higher manganese alloys which transformed was found to increase as the plastic strain increased (Fig. 1) which can be compared with the results of other workers (e.g Olson and Cohen, 1972 and Hecker et al, 1982).

Examples of the true stress/true plastic strain curves of some of the higher manganese alloys and tensile work-hardening rate/true plastic strain curves obtained at early stage of deformation are given in figs. 2 and 3. The overall flow stress levels and trends of the curves show how, as the transformation progressed the work-hardening of the steels increased rapidly. This phenomenon has resulted in the exceptionally mechanical properties as shown in the table.

4. DISCUSSION

The changing of phase content along the stress-strain curve may be linked to the model of Olson and Cohen (1975). This analysis provides a rationale for the formation of martensite with plastic strain and how this is affected by stacking fault energy and strain rate.

During strain-induced transformation, plastic deformation of the parent phase creates the proper defect structures, which act as embryo for the transformation products. This will result in higher dislocation density in the end product. Therefore, this rapid work-hardening in this low strain region will reflect the continuous transition from a plastic deformation mechanism involving transformation induced lath-martensite, residual stresses and mobile dislocations to plastic deformation by a dislocation generation/dislocation glide mechanism. It could also be argued that the irregular nature of the curves in Fig. 1 seems to suggest a transformation "burst" phenomenon (Guimaraes, 1987) during plastic deformation. This might be associated with the "brickwork" martensitic structures which forms in these steels as a result of the fragmentation of the original austenite on (111)_γ planes by thin layers of epsilon phase. This is an intermediate in the transformation to lath martensite as the structure undergoes strain-induced transformation as reported by Bogachev et al, (1975) and Jones et al, (1982). What happens is that the nucleation of one lath triggers off the formation of another lath in an adjacent region as plastic strain increases. From the mechanical properties of a large number of experimental steels, Inegbenebor et al, (1988), have established the ideal composition range for wear resistance application for use in the mining industry, the agricultural sector as well as railway points and crossings as:

11-12.5% Mn, 2-4% Mo, 0.2% C Max., 0.4% Si Max., 0.02% S Max., 0.03% P Max., balance Fe. This range covers air and vacuum melts.

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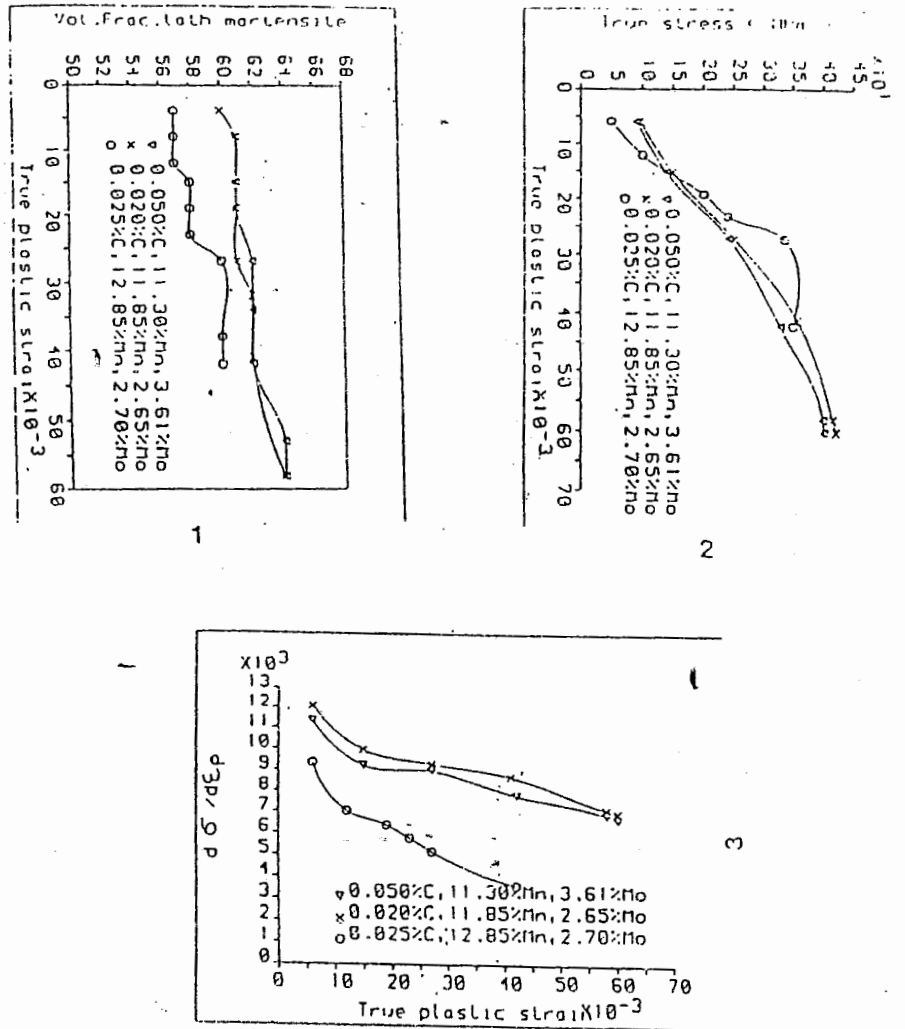


Fig. 1 Volume fraction of lath martensite vs. true plastic strain

Figs 2-3 Tensile true-stress and work-hardening rate vs. true plastic strain, s.t. at 950°C for 1 hr.