PREDICTION OF HARDENABILITY OF S.G. IRONS

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ABSTRACT

The advent of ductile iron has given a boost to the design engineers. Initially it was considered as a wonder metal in the field of metallurgy of cast irons. During few decades it was challenge to make ferritic grade ductile iron in as-cast condition for applications like wind mill and other large castings.

With further developments higher grades of ductile iron such as 500/7, 600/5, 700/3, 800/2, 900/2 are being produced requiring strict control over microstructure and subsequent hardening and tempering heat treatments. The production of these grades involves two steps, viz., consistent control over microstructure such as nodularity, nodule count and matrix structure and controlled heat treatment cycle parameters to achieve optimum mechanical properties including machinability of castings.

KEY WORDS : Hardenability, Ideal critical diameter, Jominey Test fixture, Hardenability Curve

INTRODUCTION

S.G., Iron since its invention, has undergone various developments for the last six decades. In nineteen fifties it was treated as “wonder material” for the design engineers. Let us consider the developments in chronological orders for last sixty years.

(a) Development of Nodularisers – such as elements like magnesium, cerium or calcium containing nodularisers.

(b) Development of various grades of S.G. irons or ductile irons on the basis of mechanical properties such as tensile strength, ductility in the form of percentage elongation in as-cast condition.

(c) Development of ferritic grades to sustain subzero conditions.

(d) Development of Alloy S.G. irons to control matrix structure to improve tensile strength, hardness at the cost of ductility.

(e) Development of S.G. grades to withstand fatigue stresses developed in components like crankshafts of automobiles. This could replace many forged components.

(f) Development of Heat Treatment of S.G. irons for further improvement of mechanical properties like tensile strength, hardness and wear resistance. This was a gift to design engineers to reduce weight of castings, lower weight to strength ratio.

(g) Development of twenty-first century material “Austempered Ductile Iron” (ADI).

(h) Development of “Compacted Graphite Iron” (C.G. iron).

HEAT TREATMENT OF S. G. IRONS

Quite a lot of work has been done in heat treatment of S.G. iron and regularly hardening and tempering, Austorming heat treatments are carried out and are specified by customers in global market scenario.

It is one of the good players in sourcing for S.G. iron of various grades in global market. However Heat-treated grades are not produced on regular scale due to high cost of investment for specific heat treatment shops.

While determining the possibilities of hardening as per design specifications, the most important basic property to be considered is the “hardenability” of metal.

Hardenability is a very conventional term used for selection of various types of steels. Hardenability curves for all types of steels are available for design engineers and for metallurgists.

Hardenability characteristics of various grades of S.G. irons has been discussed in this paper.

HARDENABILITY

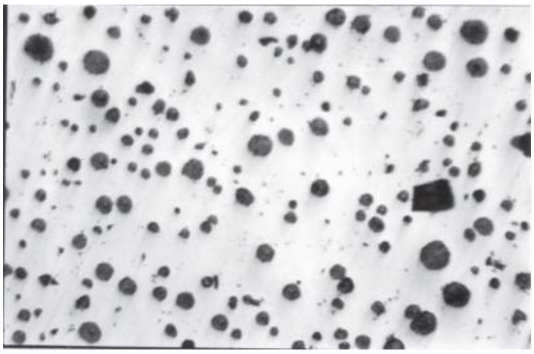
Hardenability of any alloy may be defined as ability of alloy to get hardened upto certain depth during hardening. It predicts whether particular size of component can be “through” hardened. i.e. upto centre of that component.

Hardenability of steel or cast iron can be determined by following methods :

1. Jominey End Quench Test.
2. Grossman Method.
3. Calculation from chemical composition of alloy.

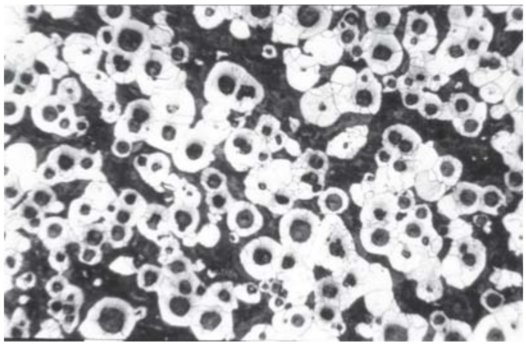
EXPERIMENTAL & RESULTS

The grades used for the project are – 400/12, 500/7 & 700/3. Figure1 shows the as-received microstructures of the three grades and Table-1 lists the microstructural features of these grades.



Unetched 100 X

Grade 400/12	
C	3.6573
Si	2.5839
Mn	0.31242
P	0.01648
S	0.00676
Cu	0.00249
Sn	0.00249
Pb	0.00000



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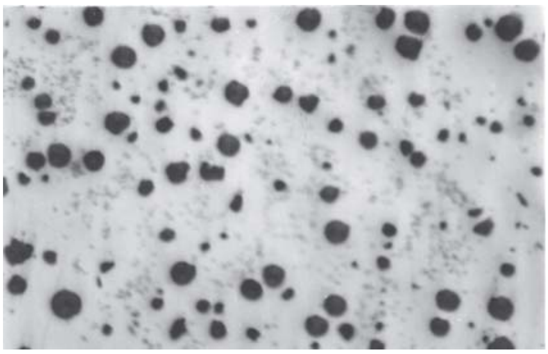

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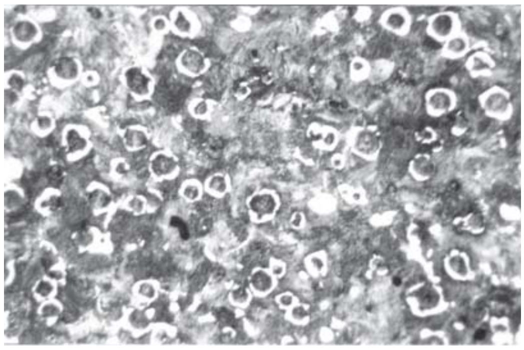
Grade 500/7	
C	3.5780
Si	2.3195
Mn	0.29751
P	0.02050
S	0.00742
Cu	0.54026
Sn	0.00159
Pb	0.00017



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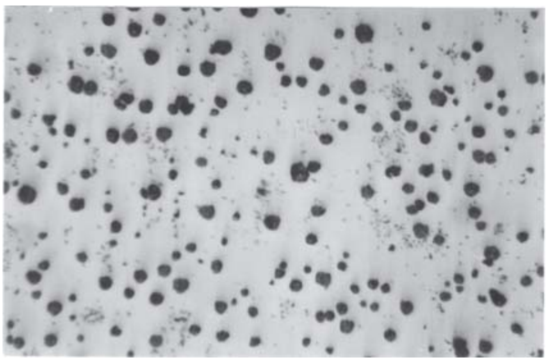

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Grade 700/3	
C	3.6820
Si	2.2425
Mn	0.39887
P	0.01594
S	0.00253
Cu	1.2537
Sn	0.04425
Pb	0.04665

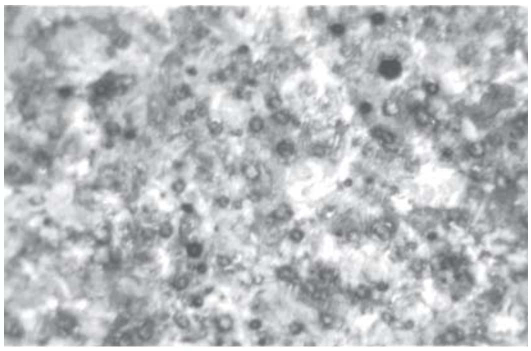

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Fig.1 : Microstructures in as-cast condition.

Table-1

Grade	Microstructure	Equivalent plane carbon steel to Matrix
400/12	Nodularity more than 90% Matrix 50% Ferrite, 50% Pearlite	0.4% Carbon
500/7	Nodularity more than 90% Matrix 25% Ferrite, 75% Pearlite	0.6% Carbon
700/3	Nodularity more than 90% Matrix 100% Pearlite	0.8% Carbon

Jominey End Quench tests of the grades of S.G. irons have been carried out and graphs for variation of hardness from the quenched end has been plotted.

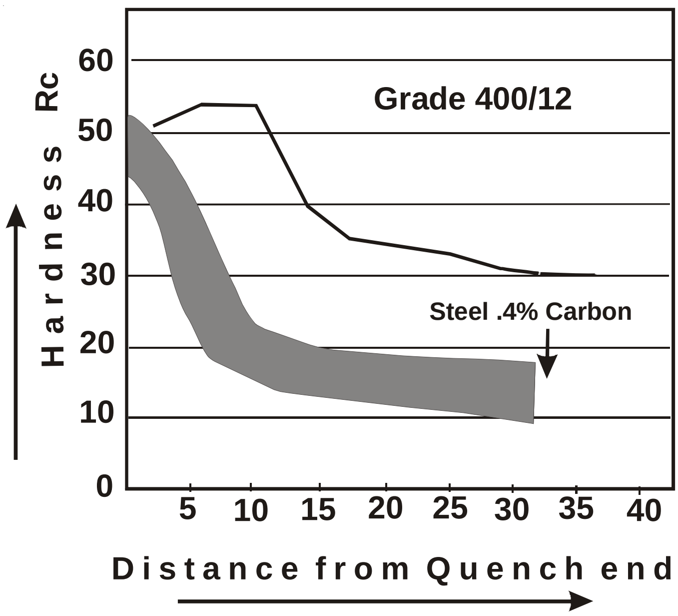


Fig. 2 : Hardenability Curve of Grade 400/12

DISCUSSION

On the experimental Jominey curves of carbon steels, which match the profile of the experimental curve, have been superimposed. Microstructures of end quench experiment upto the distance where hardness becomes constant have also been shown. From Figs. 2, 4 and 6 it can be seen that the hardenability of S.G. iron is comparatively higher than the matrix structure similar to steel and that the Ideal Critical diameter for various grades of S.G. iron increases with increasing grades. This is mainly because of increasing pearlite in the matrix structure, which can be seen from Figs. 3, 5 and 7 respectively.

S.G. iron due to presence of nodules of graphite retains heat for longer time. So, hardness is maintained for larger depths in comparison with hardenability band for steels. It is interesting to note that there is no effect of grain size of Austenite. Higher hardenability may be attributed to alloy Austenite formed containing silicon, manganese. It is observed that the nodule size of graphite is slightly reduced after hardening.

CONCLUSIONS

1. Hardenability of S.G. iron is higher than plain carbon steels.
2. Hardenability of S.G. iron can be predicted by calculation also from composition of S.G. iron.
3. In general the effect of alloying elements on hardenability of S.G. iron is similar to steel. Silicon upto 3% increases hardenability of S.G. iron. Phosphorus reduces hardenability of S.G. iron.
4. Hardenability of any grade is higher than plain carbon eutectoid steel.
5. Hardenability data is very useful for designers and heat treaters.

Further Reading

1. A.S.M. Handbook, Vol. I.
2. A.S.M. Handbook, Vol. II.
3. A.S.M. Transactions, 63, 116, 1955.

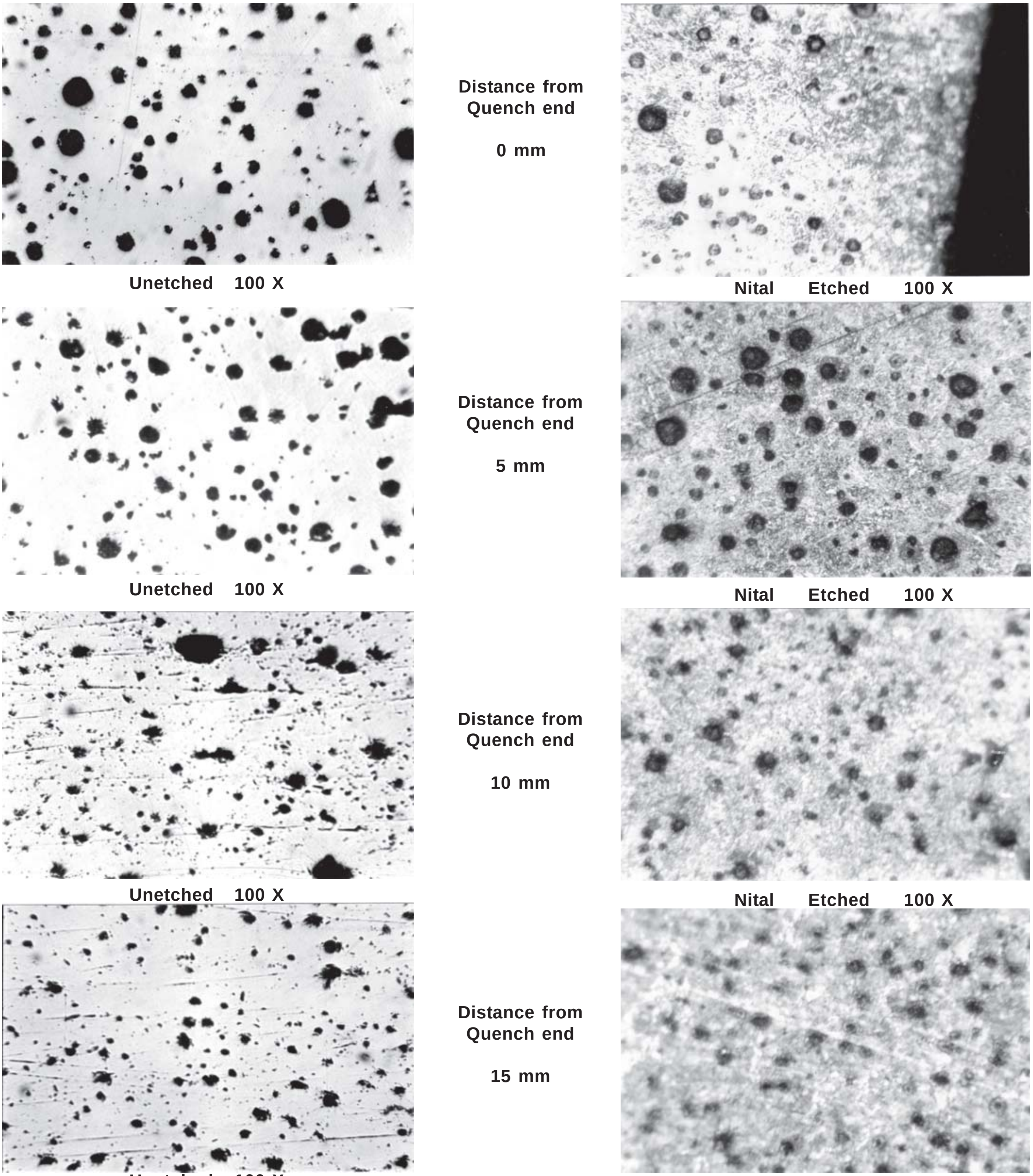


Fig. 3 : Microstructures of Jominey specimen of Grade 400/12

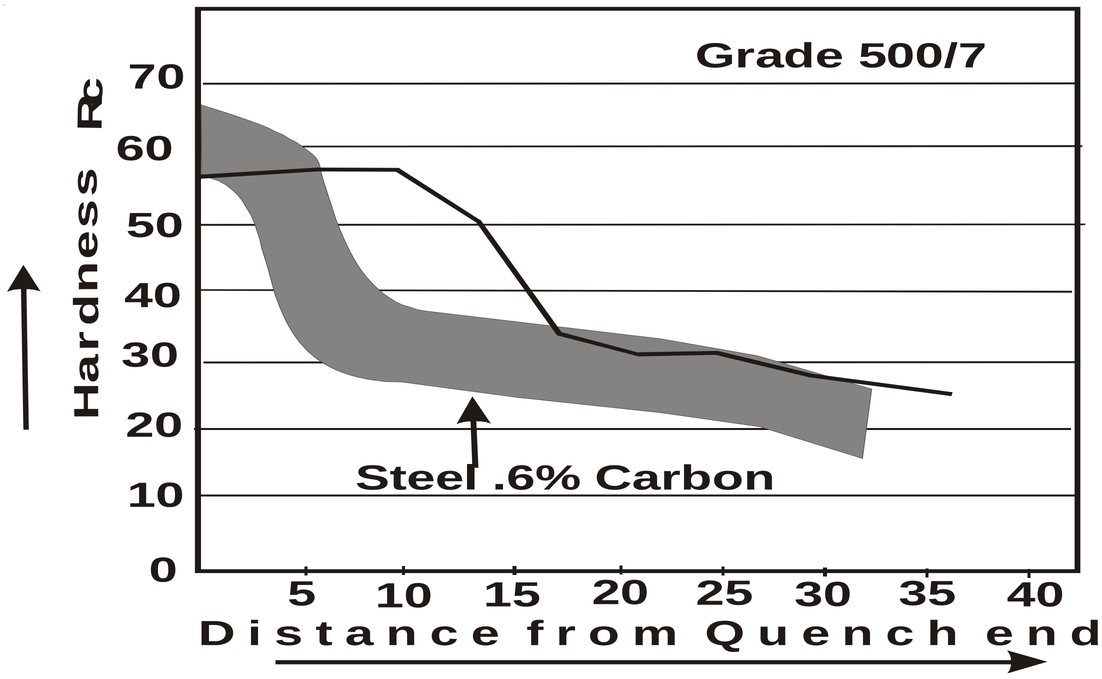


Fig. 4 : Hardenability Curve of Grade 500/7

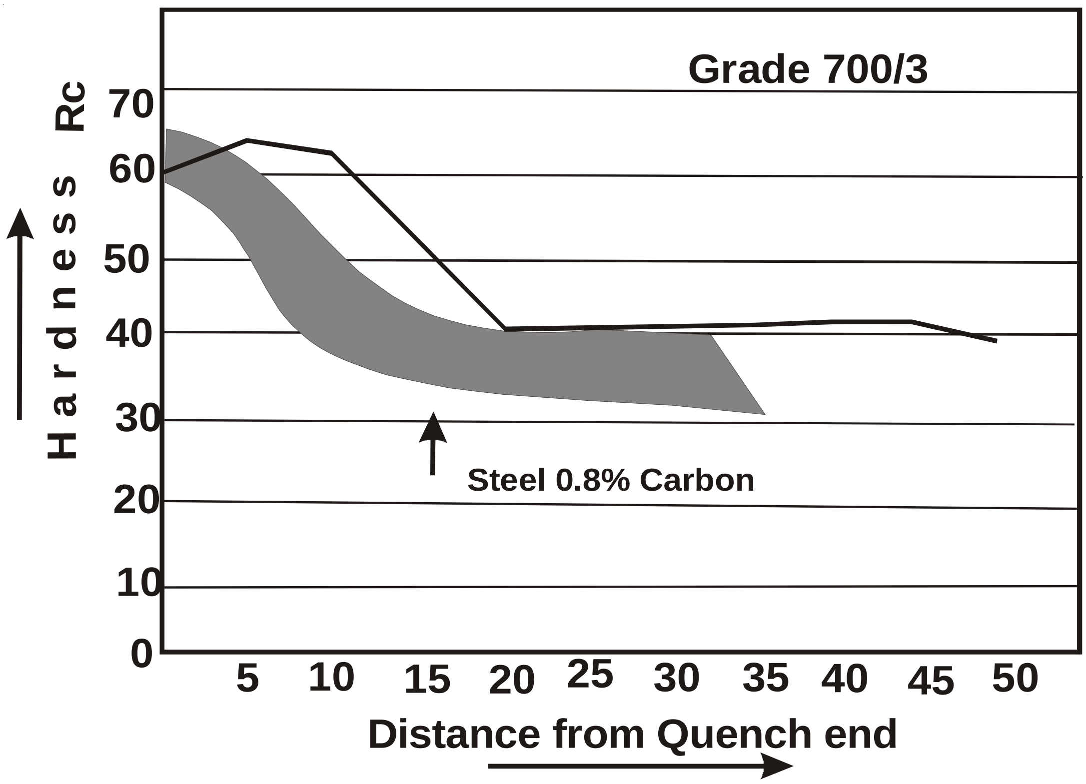
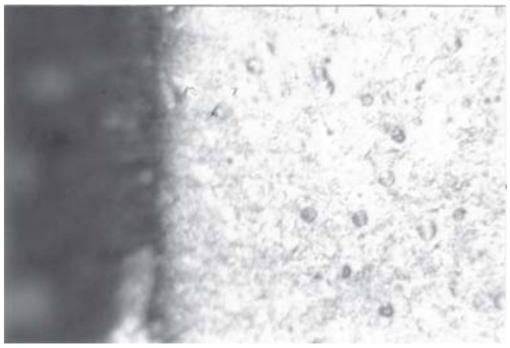


Fig.6 Hardenability Curve of S. G. Grade 700/3

Distance from Quench end

0 mm



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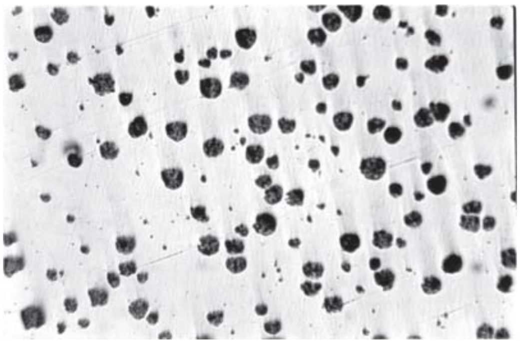
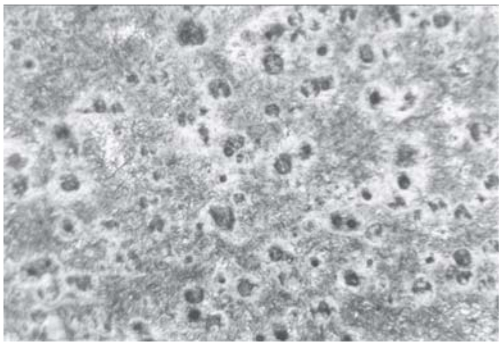


Distance from Quench end

5 mm



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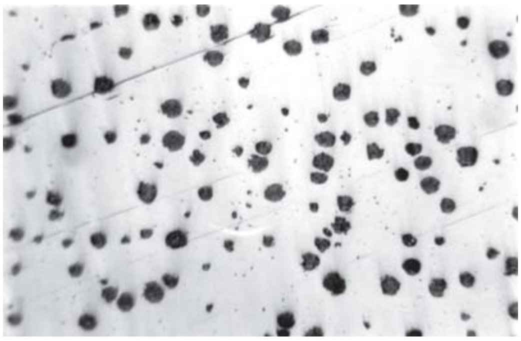
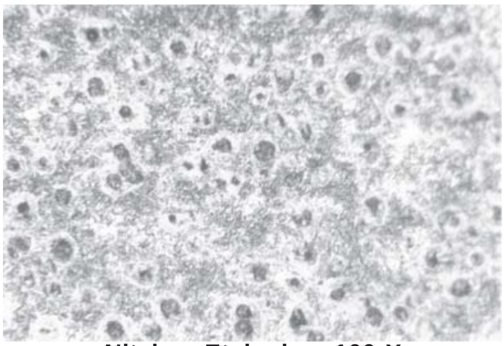


Distance from Quench end

10 mm



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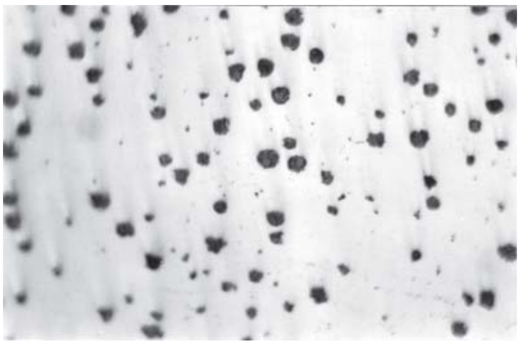

Distance from Quench end

15 mm

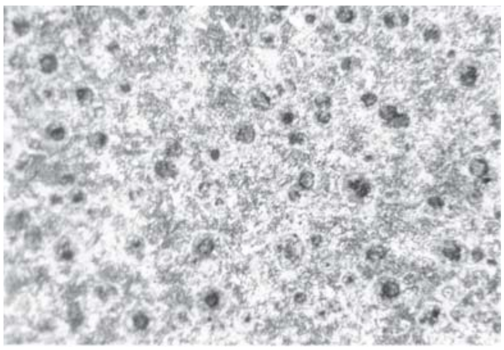

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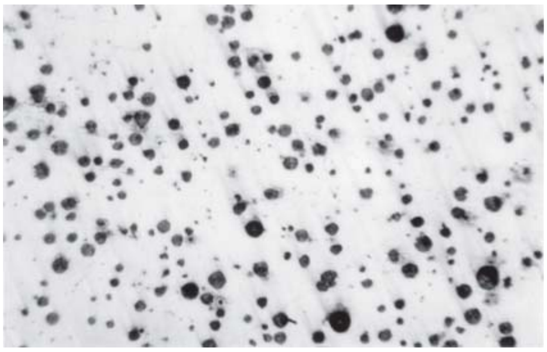
Fig.5 Jominey Microstructures of Grade 500/7

Unetched 100 X

Distance from Quench end

0 mm

Nital Etched 100 X



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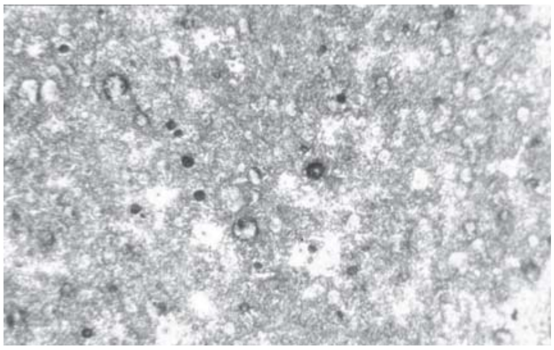
Distance from Quench end

5 mm



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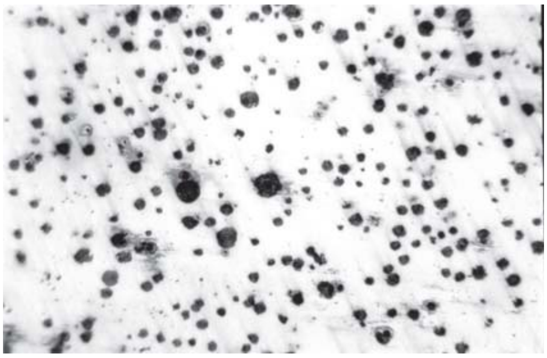

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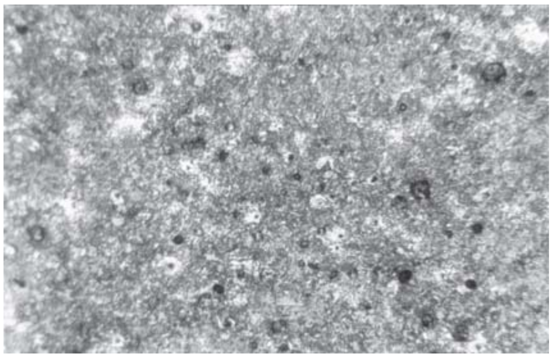
Distance from Quench end

10 mm



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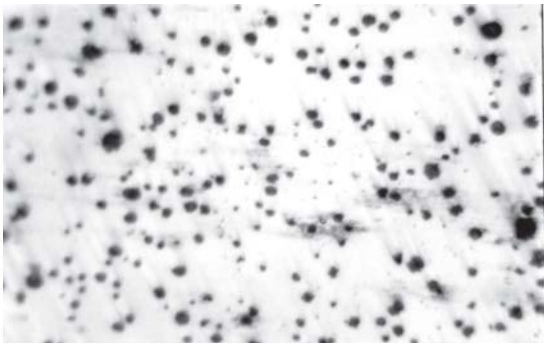

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Distance from Quench end

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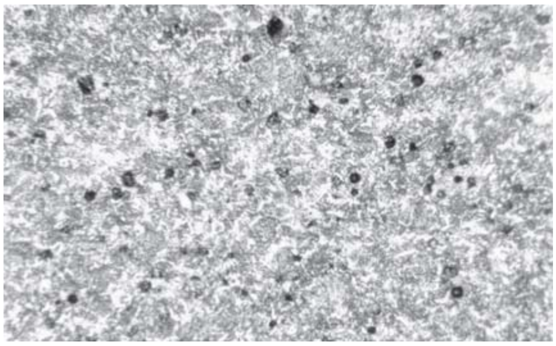

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Fig.7 Jominey Microstructures of S. G. Grade 700/3