4. EXPERIMENTAL PROCEDURE:

4.1 Effects of Vibration on the Graphitisation Behaviour of White Cast Iron:

The experimental work carried out to investigate the effect of vibration on the graphitisation behaviour of white cast iron consisted of the following stages:

1. Melting & Casting.
2. Chemical analysis.
3. Preparation of samples.
5. Optical Metallography.
7. Determination of the percentage of different phases by point counting method.
9. Remelting of as-cast sample.
10. Nodule counting of the as-cast and the remelted samples.

4.1.1 Experimental Setup:

The vibrators used in this investigation were of three types. The first one, designed indigenously, is shown in Fig. 3.1. This induces linear simple harmonic motion.
of the bed. Its amplitude is adjustable and the vibrator is driven by 220 volt single phase A.C. motor at 1450 r.p.m. The adjustable amplitude could be measured by a dial gauge fixed to a magnetic stand. The other two types of vibrator are shown in figures 3.2 and 3.3. The vibrator II induces curvilinear oscillation and the vibrator III induces rotation of the moulds.

4.1.2(a) Melting and Casting of alloys in Metal Moulds:

White cast iron of industrial composition was selected as a base metal and the melting and casting were performed in a cupola of 6 tons capacity at Liluah Iron Works, Howrah. Series of castings were made with varying amplitudes and percentage of inoculants in vibrator I. The castings were made in metal moulds of 25 mm. diameter. After reaching proper condition of the melt in cupola the melt was transferred to a ladle of 20 kgs capacity. During the transfer of the melt from cupola to the ladle calcium silicide was inoculated by measured weight and the temperature was recorded very rapidly prior to casting operation. The temperature of the melts were 1450-1470°C in all cases.

For vibrator II and III melts of almost the same composition under the identical conditions of melting were produced in the same cupola. 50 mm diameter metal moulds were used in both the cases. The pouring temperatures were kept between 1380-1400°C.
4.1.2(b) Melting and Casting of the alloys in sand moulds:

A series of castings were made in sand moulds of 25 mm diameter. The castings were made in Vibrator I set at different vibrational amplitudes. The melting and casting procedures are exactly same as that in case of metal moulds vide sec. 4.1.2(a)\[7\]

4.1.3 Chemical Analysis:

The drillings from the samples from each heat were taken for chemical analysis. Care was taken such that the result indicated the average analysis of the bulk samples. This was done by blending well the drillings from several places of the same ingot. The drillings were then analysed by the standard wet analysis method.

4.1.4 Preparation of samples:

From the ingots cast in vibrator I, samples of 25 mm dia x 25 mm height were cut out by an abrasive cutter. All precautions were taken while cutting the samples.

From the ingots cast in vibrators II and III sample slices of 25 mm long were cut out by the abrasive cutter. These slices were then cut to three small pieces to facilitate metallographic work. Usual precautions were taken during cutting.
4.1.5 Heat treatment:

The cast samples were heated to 850°C-900°C and were given first stage graphitisation anneal for various periods of time after which they were cooled in air.

4.1.6 Examination of micro-structures of the as cast and heat treated specimens by optical microscope:

The optical metallography of all these samples was carried out by conventional metallographic technique. The samples were observed in Lietz Microscope at different magnifications and some selected photo-micrographs were taken.

4.1.7 Scanning electron-microscopy:

The samples cast in metal moulds in Vibrator I were observed under a scanning electron microscope to study the changes in details that occurred due to the superimposition of vibration in a solidifying melt of white cast iron. The specimens were etched in 5% Nital for about 40 minutes such that the graphite particles could float. This enabled the graphite particles to appear white in the micrographs.

4.1.8 Determination of percent graphite in the micro-structures:

The percentage of graphite present in each of the variously processed samples was determined by point counting method to study the rate of first stage graphitisation. A minimum of 800 counts in a particular plane were taken to determine the percent graphite. The average of the percent graphite readings in four sectional planes along different directions were taken.
as the representative graphite percent in any sample.

4.1.9(a) Determination of tensile strengths of samples cast in metal moulds:

Selected samples cast in vibrator I in metal moulds were turned to tensile specimens of standard dimensions. These were tested in a universal testing machine of 20T capacity.

4.1.9(b) Determination of tensile strengths of samples cast in sand moulds:

A few selected samples were given annealing treatment to assume complete first stage graphitisation. Tensile testing was then carried out in an Instron testing machine using a cross head speed of 0.05 mm per minute.

4.1.10 Re-melting of as cast samples:

The samples cast in metal moulds in vibrator I were cut to small pieces and were heated in alumina boats to different temperatures above the eutectic isotherm for different periods of time. It was observed that holding for 10 mins. at 1250°C was sufficient to effect incipient fusion of the samples between the liquidus and the solidus lines.

The as cast samples were then remelted for the above time and temperature after which they were cooled in air.
4.1.1. Nodule count of samples:

The nodule counts of the as cast samples were taken under 100 X in an optical microscope. The nodule counts of the remelted samples were also taken in a similar fashion. An average of counts from 50 spots of four different planes was taken to be the representative nodule count. The number of nodules per unit volume was then calculated.

Some photographs of the remelted samples were also taken.

4.2. Effect of Hot Forging on the Graphitisation characteristics of white cast iron:

The experimental work carried out in the present investigation to study the effect of hot forging on the graphitisation behaviour of white cast iron consisted of the following stages:

1. Melting and casting.
2. Chemical analysis.
3. Preparation of samples.
4. Hot forging of specimens
5. Heat Treatment of samples.
7. Optical microscopy.
8. Determination of percent graphite by point counting.
9. Determination of nodule number per unit volume.
10. Scanning electron microscopy.
11. Regression analysis.

4.2.1. Melting and Casting of Alloys:

Melting was carried out in a high frequency induction furnace at an initial 20 KVA power rating which was decreased to 10 KVA at the later stages of melting. Clean mild steel scraps were recarburised by the addition of petroleum coke. Three different compositions were prepared. Nickel and chromium were added after the completion of recarburisation to the desired extent. The melts were held for five minutes after alloy addition to avoid inhomogeneity in composition. The pouring temperature of the melts was around 1450°C as measured by immersion thermo-couple. Each heat contained five kgs of melt. The liquid metal was poured in a metal mould of 25 mm diameter.

4.2.2. Chemical analysis of the alloys:

The drillings from the samples from each heat were taken for chemical analysis. Care was taken such that the result gave the average analysis of the bulk sample. This was done by blending well the drillings from several places of the same ingot. The drillings were then analysed by the standard wet analysis method.
4.2.3. **Preparation of Specimen.**

From the ingots, samples of 25 mm diameter and 25 mm height were cut out by an abrasive cutter. All precautions were taken while cutting the samples.

4.2.4 **Hot Forging of Sample.**

The specimens were heated to 1080°C and were soaked well. The specimens were then forged between open dies. The degree of reductions given to the specimens were 20 per cent, 40 per cent, 50 per cent and 70 per cent and above. The high forging temperature was standardised by trial such that the heat of impact led to semifusion of the mass to heal the cracks which might have originated within the specimens.

4.2.5 **Heat Treatment of the Samples.**

The as-forged samples of each composition for each per cent deformation were heated at 900°C and were given the first stage graphitisation anneal for two, four, six and eight hours after which they were quenched in oil. The samples were then tempered at 200°C for two hours.

4.2.6 **Chemical Analysis for Graphitic Carbon.**

The drillings from all the as-forged and heat-treated samples were taken out carefully. These were then analysed chemically for graphitic carbon by using standard procedure.
4.2.7. **Optical Microscopy**

The optical microscopy of all the samples were carried out carefully by standard metallographic technique. The samples were observed in a Lietz microscope at different magnifications and some selected photomicrographs were taken.

4.2.8. **Determination of per cent graphite**

The per cent graphite in each sample was measured by standard point counting method. A minimum of 1000 counts in a particular plane were taken to determine the per cent graphite. The average of the per cent graphite readings in four sectional planes along different directions were taken as the representative graphite per cent in any sample.

4.2.9. **Determination of nodule number**

The nodule count of each sample was found out in a way similar to 4.1.11.

4.2.10 **Scanning electron microscopy**

Scanning electron microscopy of various samples was carried by the same procedure as in 4.1.7.

4.2.11 **Regression analysis**

The data for per cent graphite at various conditions of mechanical and thermal treatment were analysed by usual mathematics and partial regression analysis was carried out by a TDC 316 Computer.
4.3 Effect of Vibration on the Characteristics of Grey cast iron:

The experimental work carried out to study the effect of oscillation (vibrator IV) on the solidification behaviour of grey cast iron essentially consisted of the following steps:

1. Melting and casting.
2. Chemical analysis.
3. Preparation of samples.
4. Tensile tests.
5. Measurement of eutectic cell size.
6. Optical microscopy.
7. Scanning electron microscopy.
8. Regression analysis.

4.3.1. Melting and Casting of Grey Cast Iron:

Melting was carried out in a cupola of capacity 4T/hour in a typical Indian industrial condition. The molten metal was taken in a small ladle of 20 kgs capacity. This hot metal was poured in metal moulds of 30 mm diameter and preheated to 400°C. The eutectic cell sizes of solidified castings were varied by altering the carbon equivalent of the alloys with the steel scrap addition and ferro-silicon inoculation. Also the amplitudes of vibration were varied to effect a variation in the eutectic cell size. The pouring temperatures...
in all cases were kept between 1380°C-1400°C by measuring it with the help of an immersion thermocouple.

4.3.2. Chemical analysis:

The drillings of each casting were collected in the usual way described earlier (vide 4.1.3.). The drillings were analysed chemically by the usual wet analysis method.

4.3.3. Preparation of specimens:

The specimens of 30 mm x 25 mm long were cut out carefully from the stock-ingots by means of an abrasive cutter for the purpose of metallographic observation. Tensile test specimens conforming to I.S. : 210-1978 were made.

4.3.4. Tensile Tests:

The tensile tests were carried out in a universal testing machine of 10T capacity.

4.3.5. Measurement of eutectic cell size:

The eutectic cell size of the castings were determined by the normal metallographic technique of polishing and viewing the structures of the specimens under optical microscope. The intercept method was used to calculate the cell size. Not less than twenty locations were viewed to get the average cell size values. The eutectic cell size values were determined by cell size = (Total distance/Number of eutectic cell) x 1/magnification.
4.3.6. **Optical Microscopy**

Optical microscopy of all the samples were carried out with the Lietz optical microscope at various magnifications.

4.3.7. **Scanning Electron Microscopy**

The samples were observed under scanning electron microscope to study the detailed changes that occurred due to superimposition of vibration in a solidifying grey cast iron melt. The samples were prepared conventionally to observe the graphite flakes as black areas.

4.3.8. **Regression Analysis**

By usual mathematics and with the help of computer (TDC 316 model) the linear regression analysis was carried out to relate the tensile strength of grey cast iron with its eutectic cell size.