



## Heat Treatment and Alloying of Spherulitic Graphite Cast Iron for Intensification of Properties

Yawer Hamid

Department of Mechanical Engineering (M. Tech in Industrial and Production)  
GGGI, University of Kurukshetra, Haryana, India

### ABSTRACT

Spheroidal graphite cast iron or Spherulitic cast iron is described as a high carbon containing, iron based composite in which the graphite is accessible in negligible, round shapes rather than in the condition of pieces. Spherulitic cast iron or spheroidal graphite cast iron is at times implied as adaptable iron, as it has graphite as spheroids (ferritic or pearlitic) embedded in the steel system. These handles of graphite are confined clearly from the liquid in the midst of the technique of solidifying. The handles are more standard, sharp, little and constitute simply little districts of weakness in a steel-like framework. In light of this the mechanical properties of pliable irons are associated clearly to the quality and adaptability of the system show simply like the example of steels. This one of a kind property empowers ductile iron to be utilized for various modern applications. The astounding blend of mechanical properties got in Spherulitic cast iron can additionally be upgraded by the heat treatment. The latest advancement in such manner is the creation of Austempered Ductile Iron (ADI). By adjusting the austempering treatment at first acquainted for steels with DI, it has been demonstrated that the subsequent metallurgical structures cast properties that positively contrast with those of steel while exploiting a close net-shape fabricating process. It upgrades the rigidity, furnishes better wear opposition alongside great erosion obstruction, greynishes commotion and vibration in the segments or parts.

Therefore, flexible iron or spherulitic cast iron is austempered when a blend of various good properties are required. In any case, this sort of treatment is bit dubious and it requires controlled heating and

isothermal holding of the material. So it is fundamental to locate some alluring strategies for property upgrade in Spherulitic cast iron.

### INTRODUCTION

Ductile Iron is likewise ordinarily known as "Nodular Iron" or Spheroidal graphite (S.G) iron was licensed in 1948. With a grandiose climb being produced work in 1950 inside 10 years ductile iron was broadly used as a piece of Industries as a predominant planning material.

Graphite is present as spheroids in the ductile iron which gives it unusual combination of properties. By adding a very small, but specific amount of Mg & Ce or both to molten iron of proper composition this mode of solidification is obtained. Like malleable iron, Ductile Iron exhibits a linear stress-strain ratio; a considerable range of yield strengths and as its name implies ductility. A wide range of sizes with sections which are very thin or very thick in the castings are made by ductile iron.

The mechanical properties and microstructure of heat treated flexible iron with two distinct evaluations, and to contrast these properties and diverse treatment conditions. Carbon instantly diffuses from the spheroids to drench the austenite organize when it is heated into the austenite temperature range. Carbon returns to the graphite "sinks" on direct cooling, by judiciousness of which carbon substance of the austenite gets diminished. To heat treat and to construct the extent of properties in malleable iron openness of excess carbon and the ability to trade it

between the framework and the handles makes it less requesting.

Experiments have shown that proper heat treatment methods can improve the properties of Cast Iron. What's more, sometimes it might even dominate the advantages of steel over Cast Iron. Countless number of researchers are dealing with austempered Cast Iron which demonstrates great combination of properties and in some cases it may even overshadow the advantages of steel over Cast Iron.

Specimen	C %	Si %	Cu %	Mn %	P %	Mg %	Cr %	Ni %	S %
With Cu (N1)	3.52	2.12	0.47	0.21	0.029	0.038	0.018	0.17	0.013

Table 1 Chemical composition of N1

Specimen	C %	Si %	Cu %	Mn %	P %	Mg %	Cr %	Ni %	S %
Without Cu (N2)	3.55	2.32	0.001	0.18	0.031	0.042	0.02	0.23	0.014

Table 2 Chemical composition of N2

The specimen size should be compatible to the machine specifications. The specimens were prepared from the procured samples followed by machining operations like milling, grinding and turning to obtain the required dimensions.

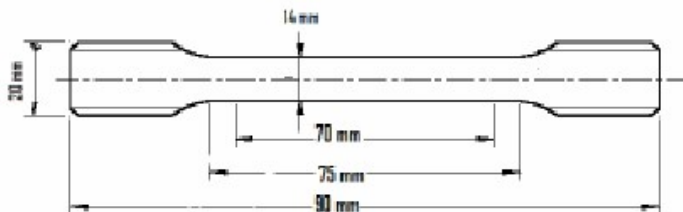
Gauge dia = 14mm

Grip dia = 20mm

Grip length = 50 mm

Gauge length = 70mm.

Then for testing different mechanical properties the specimen was taken to UTS machine after heat treatment.



Tensile test specimen

### Heat Treatment process

For lattice microstructures and related mechanical properties which are not promptly gotten in the as-cast condition in malleable cast iron the essential heat treatment is done. Austenitizing and Austempering

### EXPERIMENTAL TECHNIQUE

The experimental procedure for the project work can be listed as:

Preparation of Specimen, Tensile test, Heat treatment process, Hardness test, Study of mechanical properties and study of Microstructure.

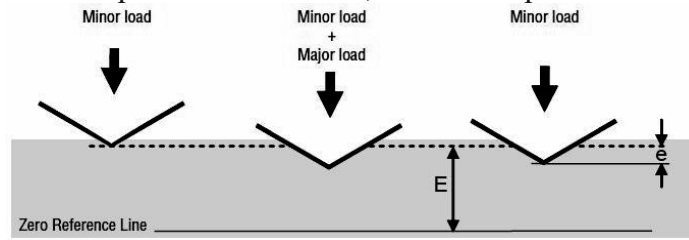
Two evaluations of malleable iron N1 and N2 were utilized one containing copper, while other was without copper whose Chemical creations are tabulated in table 1 and table 2 separately.

are the two phases of heat treatment. Solidifying, normalizing and austempering heat treatment, include austenitization, which is trailed by isothermal response, or a mix of both. The main objective of the project is comparison of mechanical properties after carrying out the heat treatment.

Twenty-six samples from each grade were taken in a group to homogenize the samples kept them in a muffle furnace for one hour at 900°C (austenization), after that, two samples from each grade were normalized by rapid cooling in still air for 30 minutes, and 2 samples from each grade quenched in oil for 20 minutes. For Tempering treatment: After austenization, 6 samples from each grade were tempered at 300°C, 450°C and 600°C for 1 hr, and for austempering, 16 of the samples from each grade were heated at 900°C for 1 hr for anstenzation and then 8 of this sample transferred quickly to a salt bath (salt combination was 50 wt % NaNO<sub>3</sub> and 50 wt % KNO<sub>3</sub>) maintained at 300°C, and the other samples to a bath of 350°C. The samples were kept in the salt baths for different times as: 0.5 hr, 1hr, 1.5 hr and 2.0 hrs.

**Tests Measurements:**

Rockwell hardness test method as defined in ASTM E-18, is the most commonly used hardness test method. The sample was put on the specimen holder and small load of 10kgf was applied by ball indenter. After the small load, an additional load i.e the major load of 100kgf was applied so that the total required test load can be obtained. After holding for a predetermined span of time this major load was then released and the preliminary test force was held for a specified dwell time, the final depth of indentation was measured.



**Tensile Testing Measurement**

The machine used was Instron Universal Testing Machine according to ASTM (A 370- 2002) Process followed:

The details were fed into the testing machine The distance between the jaws was fixed according to the gauge length of the specimen The specimen was gripped by the jaws after inserting into the machine.

Loading was done till the specimen failed (Maximum load =150KN) The corresponding readings generated for Ultimate Tensile Strength, % elongation & Yield Strength were noted.



**RESULTS AND DISCUSSION**

**Mechanical Properties**

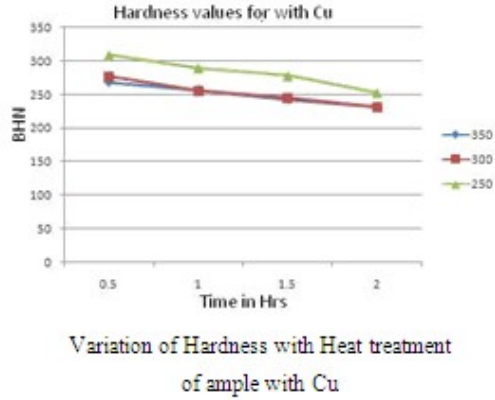
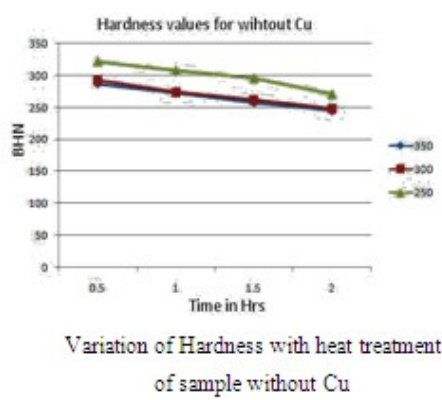
The mechanical properties measured by using Universal testing machine and greyensions of specimen was carried out according to ASTM (A 370-2002), are castn in Table 3 and Table 4 ,lists the mechanical properties of tensile strength, yield stress, elongation and hardness of ductile irons (with and without Cu)N1, N2 respectively.

Table A Tensile strength, yield stress, elongation and hardness of Tempered ductile iron with and without Copper

TREATMENT						
Tempered D.I with Cu (N2)	As Received	Normalized	Oil Quench	Tempered at 300°C	Tempered at 450°C	Tempered at 600°C
UTS ( MPa )	367	374	451	437	402	381
Y.S ( MPa )	191	193	198	205	237	267
%	5.1	4.4	3.5	6.9	10.3	17.85
H (RA)	41	57	71	68	63	59

TREATMENT						
Tempered D.I Without Cu (N2)	As Received	Normalized	Oil Quench	Tempered at 300°C	Tempered at 450°C	Temperd at 600°C
UTS ( MPa )	276	298	387	292	246	213
Y. S ( MPa )	193	201	207	212	207	199
%	13.8	7.3	6.2	8.6	14.9	15.3
H (RA)	43	64	70	69	58	57





Austempered D.I with Cu	TREATMENT					
	As Recieved	Temperature (°c)	Austempered 1/2 Hr	Austempered 1.0 Hr	Austempered 1½ Hr	Austempered 2.0 Hr
UTS (MPa)	370	300	856	1021	1011	1009
		350	654	898	913	902
Y.S (MPa)	322	300	641	841	809	802
		350	478	632	599	601
%	7.9	300	6.4	6.5	6.7	6.9
		350	8.3	8.3	8.9	9.1
H ( RA )	42	300	71	66	61	59
		350	69	61	57	51

austempering of ductile iron with copper

Austempered D.I without Cu.	TREATMENT					
	As Recieved	Temperature (°c)	Austempered ½ Hr	Austempered 1.0 Hr	Austempered 1½ Hr	Austempered 2.0 Hrs
UTS (MPa)	558	300	816	896	901	879
		350	631	788	791	751
Y.S (MPa)	267	300	628	797	718	764
		350	419	558	537	543
%	16	300	6.2	7.4	7.9	7.7
		350	7.9	9.2	9.8	10.3
H ( RA )	39	300	73	69	58	54
		350	68	64	52	49

Austempering of ductile iron without copper

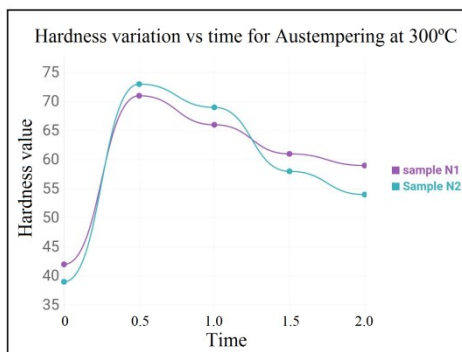


Fig 1

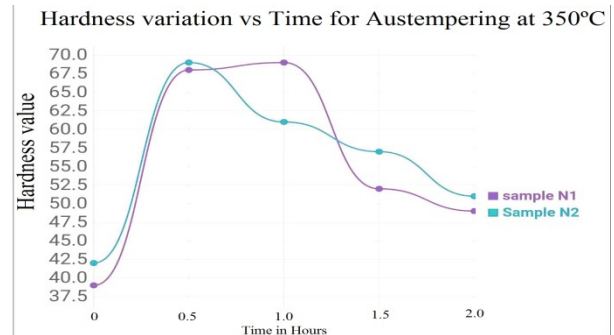


Fig 2

Hardness of plain ADI (N2 specimen) is slightly lower than the Cu enriched ADI(N1 specimen), and hardness reduces proportionally with increase in austempering time. This decrease in hardness is due to the disappearance of martensite phase. Lower austempering time yield a finer structure and therefore higher hardness was obtained. But as the holding treatment time increased further, the hardness values

were again decreased due to the occurrence of coarse plate-type structure (of bainitic) matrix phase.

**Resultsof Elongation, Tensile Strength Elongation, Tensile Strength**

In case of tempering elongation, ultimate tensile strength and yield stress variation with temperature, of two different grades are shown below in fig x, fig y and fig z respectively.

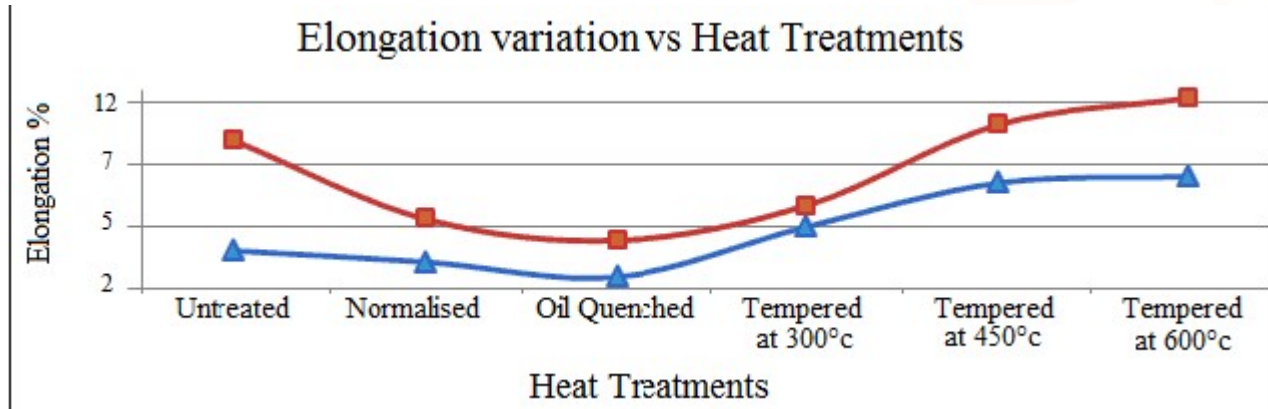


Fig X( Elongation with treatments)

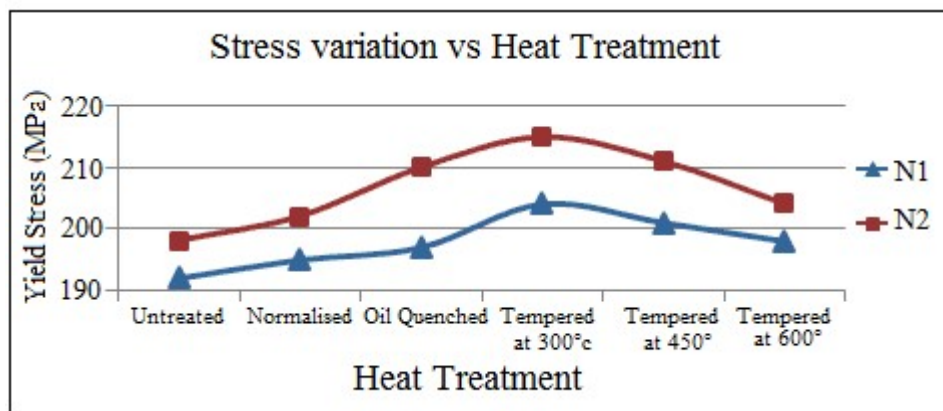


Fig Y (Yield Stress vs Treatment)

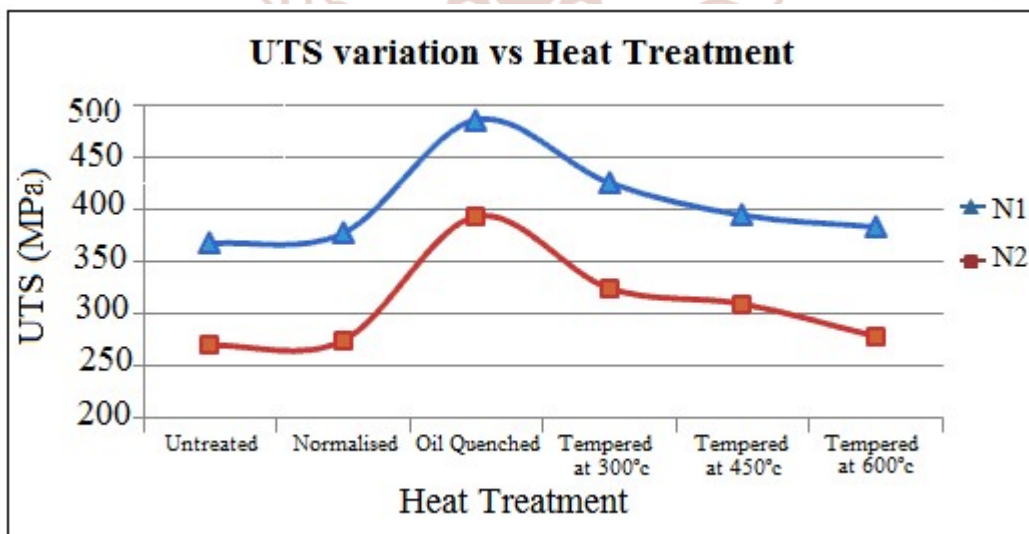


Fig Z (Ultimate tensile strength with treatment)

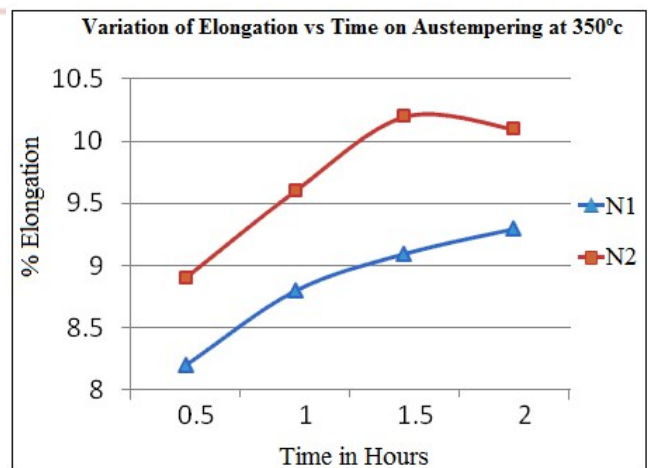
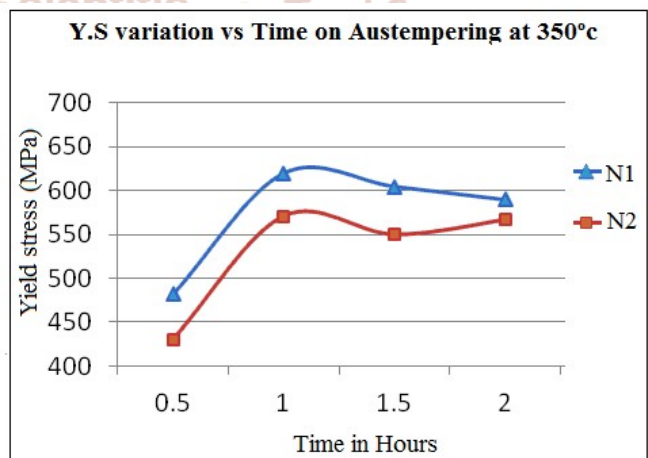
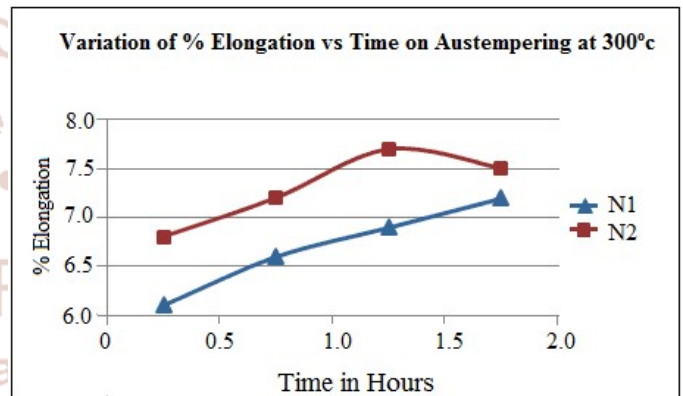
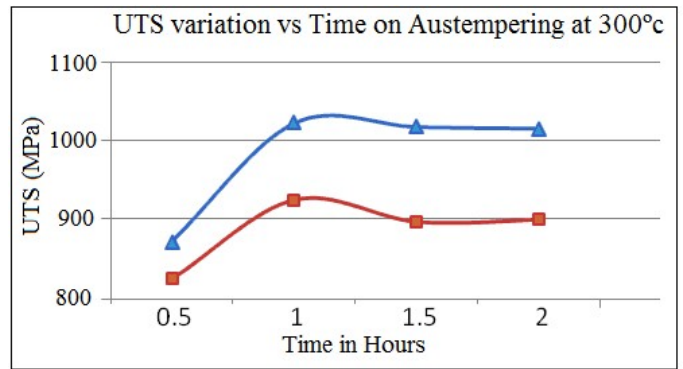
From correlation of elasticity of two distinct evaluations of tests with various medicines, it is watched that, there is a little change in their properties. The U.T.S of tempered examples was more than the standardized examples tempered examples. The malleable properties change with the network write, i.e martensitic (if there should arise an occurrence of extinguishing and treating) pearlitic (if there should be an occurrence of standardized examples), and bainite (in austempered tests) framework. In this manner prolongation increments , U.T.S and yield worry for tempered treatment (from 300 C° to 600 C°) diminishes relying upon pearlite substance of the framework. Tempered examples have higher ductile properties than the standardized examples, yet as the hardening temperature is expanded there was an abatement in U.T.S and yield worry, as appeared in fig B1 and C1. The extension of tempered examples is higher than standardized examples, due to the development of martensite and temper martensite and so on then again, the stretching increments with the hardening temperature as appeared in figure A. Looking at the two evaluations of tests N1 and N2 , demonstrated that example with copper (N1 review) has higher UTS and Yield pressure and lesser prolongation than review N2 for both Normalized and Tempering Treatment.

**Austempering Treatment**

Austempering is a hardening process for metals which yields attractive mechanical properties including higher pliability, durability, quality for a castn hardness, protection from stun and lessened contortion, particularly with thin parts. Austempered pliable iron is created by warm treating thrown ductile iron to which little measures of nickel, molybdenum, or copper have been added to enhance hardenability. Particular properties are controlled by the watchful decision of heat treating parameters. Austempering includes the nucleation and development of acicular ferrite with in austenite, where carbon is rejected into the austenite.

Austempering is a heat treating process for medium-to-high carbon ferrous metals which creates a metallurgical structure called bainite. The properties condensed in Table 4 and Table 5, and figures demonstrates the variety of elasticity concerning the austempering time at temperature 300 degree celsius and 350 degree celsius separately for grades N1 and N2.

Table 4 and 5 Tensile Properties of Austempered ductile iron At 300 C° With and without Copper





The Tensile quality is incremented at first from 0.5 hr to 1 hr, at that point from 1 hr to 2 hr diminishes marginally for the two evaluations and with additionally increment in treatment time accomplishes a relentless state, as appeared in fig4 (a) and (b). The expansion in quality at first at low time interim is because of the high measure of martensite got from the unreacted austenite, however as the time increment over one hour the principal arrange response initiates in the intercellular locales for which quality abatements. With the further increment in time, the held austenite decreases, and malleability again increments w.r.t time. So flexibility expands further to a most extreme esteem which demonstrates the mediocre measure of martensite. The example alloyed with copper has expanded pliability and lesser quality than that example without copper content.

Extension for Austempered Ductile Iron (ADI) is expanding from 0.5 hr. to 1.0 hr. however, with slight diminished from 1.0 hr. to 2.0 hr. as appeared in figure 4.c and 5.c, which additionally demonstrates that (ADI) with copper is lower of that review without copper with little sum. Contrasting the rigidity and regard the austempering temperature for the two evaluations from table 3, it is discovered that elasticity is diminishing with expanding austempering temperature however stretching is increasing. Additionally the example with copper has higher malleability and lesser quality than that example without copper content.

#### Uses Of spherulitic graphite cast Irons in different fields

The uses of the S.G. iron have expanded massively lately as can be seen from the beneath mentioned equipments:

Tie rods  
U-bolt stop plates  
Wheel spindle  
Connecting rods  
Timing gears  
Tripot housing  
I-beams  
Axle holder  
Spring holder  
Wheels  
Motor wrench shaft  
Brake caliper, circle – brake grapple, brake stay plate  
Machine – device bed  
Electric encasing post and top

Controlling knuckle  
Jackhammer  
Wedges Chain sprockets  
Chain sprockets  
Mining wear parts  
Moving plant rolls  
Trim boxes and shape box clasps  
Brake shoe for rock solid brakes  
Glass molds  
Spacer confine for moving bearing  
Cylinder rings  
Fertilizer knives Digger points  
Corn grinder plates  
Wear guides  
Plow & till points

#### CONCLUSION

The following observations were acquired tentatively amid Austempering heat treatment

I). Hardness normally decreases in the midst of the system of austempering. Also it was watched that the hardness regard reduces with the extension in time when the temperature was kept same (either 250°C or 450°C degree or 650°C), 2. The strength and hardness values for the sample with copper are more while ductility was found to be more for the sample without copper

II) Sturdiness increments with increment in time and austempering treatment temperature and was altogether higher if there should be an occurrence of ADI tests with copper than without copper.

III) The tensile strength initially increases and then decreases in both samples with increase in time during Austempering Process

IV) Ultimate tensile strength and yield strength decreases while as elongation (ductility) increases with increase in temperature.

V) Amid process stretching first declines and after that increments.

For best combination of properties like ductility, Yield Strength, Hardness and Ultimate tensile strength one should opt austempering of the Spherulitic Cast iron as it is the most favourable method.

**Future Scope:**

Building uses and engineering applications of ductile iron in as cast and diverse heat treated conditions are developing step by step. Austempered Ductile Iron's application has expanded colossally in numerous modern regions. Austempered Ductile Iron is progressively the material of selection of creators and specialists due to their savvy execution and it has started to replace steel in some structural and engineering applications. More work is needed to improve the properties like corrosion resistance, relative abrasive resistance and hardenability of ductile iron through studies on the effect of different alloying elements and heat treatment processes on the ductile iron

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