INTESIFICATION OF PROPERTIES AFTER HEAT TREATMENT AND ALLOYING OF SPHERULITIC GRAPHITE CAST IRON.

YAWER HAMID

M.TECH (Industrial and Production Engineering)
Galaxy global group of institutions Dinarpur Ambala.
Affliated to University of Kurukshetra

ABSTRACT

Spherulitic cast iron is characterized as a high carbon containing, iron based amalgam in which the graphite is available in minimal, circular shapes as opposed to in the state of pieces. Spherulitic cast iron or spheroidal graphite cast iron is in some cases alluded to as flexible iron, as it has graphite as spheroids (ferritic or pearlitic) implanted in the steel framework. These knobs of graphite are framed straightforwardly from the fluid amid the procedure of hardening. The knobs are more standard, sharp, little and constitute just little regions of shortcoming in a steel-like grid. In light of this the mechanical properties of ductile irons are connected straightforwardly to the quality and flexibility of the network present just like the instance 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 heatth 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, greyinishes commotion and vibration in the segments or parts.

Keeping in view these components, 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 Spheriodial graphite (S.G) iron was licensed in 1948. With a lofty ascent being developed work in 1950 inside 10 years ductile iron was widely utilized as a part of Industries as a prevalent designing material. Its utilization in business application is as yet important in today situation.

Graphite is available as chips in grey iron while it is available as spheroids in the ducile iron which throws it strange mix of properties. By including a little, yet particular measure of Mg and Ce or both to liquid iron of appropriate structure this method of hardening is acquired. Like moldable iron, Ductile Iron shows a direct ironure strain proportion; a significant rang of yield qualities and as its name suggests flexibility. An extensive variety of sizes with areas which are thin or thick in the castings are made by ductile iron.

By controlling the network structure around the graphite as they are thrown or by ensuing heatth treatment the diverse evaluations are created. Controlling of the framework structure as-cast to give reaction to heat treatment is finished by combination expansion.

In introduce explore work, are to decide the mechanical properties and microstructure of heatth treated flexible iron with two distinct evaluations, and to contrast these properties and diverse treatment conditions.

Pliable Iron or nodular iron is an iron-carbon amalgam having structure of knobs of graphite implanted in steel lattice. The graphite spheroids assume a basic part in heat treatment, since they act both as source and sink for carbon. Carbon promptly diffuses from the spheroids to immerse the austenite network when it is heated into the austenite temperature range.Carbon comes back to the graphite "sinks" on moderate cooling, by prudence of which carbon substance of the austenite gets decreased. To heat treat and to build the scope of properties in pliable iron accessibility of overabundance carbon and the capacity to exchange it between the grid and the knobs makes it less demanding.

Objective of work:

- The target of this work is to decide the mechanical properties and microstructure of heat treated treated flexible iron with two unique evaluations. One is with Cu and other is without Cu.
- To study and contrast these properties and distinctive treatment conditions, the treatment conditions are for the most part hardening at various temperature and austempering at steady temperature and variety of time.
- Mechanical properties are:
  1. Elasticity (U.T.S., 0.2% lengthening),
  2. % Elongation,

  Then these mechanical properties are connected with microstructure and break surfaces of the distinctive examples after treatment.

EXPERIMENTAL PROCEDURE

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

i) Specimen preparation

ii) Tensile test

iii) Heat treatment

iv) Hardness test

v) Mechanical property study

vi) Microstructure study

For our work the as a matter of first importance work is the example arrangement. The example size ought to be good to the machine determinations so flexible iron were obtained from a business foundry. Two evaluations of malleable iron N1 and N2 were utilized one containing copper, while other was without copper whose Chemical creations are summerised in table 1 and table 2 individually

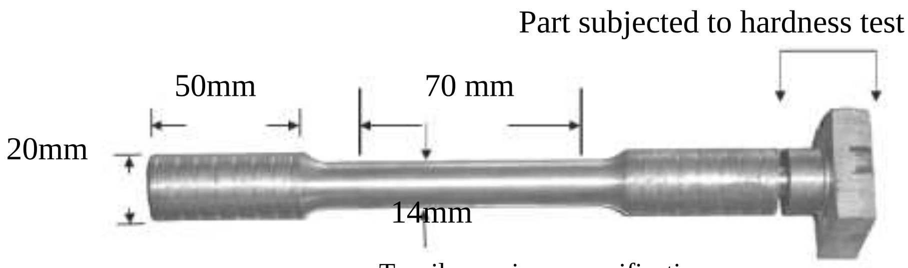
Specimen	C %	Si %	Cu %	Mn %	P %	Mg %	Cr %	Ni %	S %
With Cu (N1)	3.52	2.12	0.47	0.21	0.029	0.038	0.018	0.17	0.013

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 (milling. grinding and turning) to obtain the required greyension (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 specimen specifications

Heat Treatment:

For lattice microstructures creation 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 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.

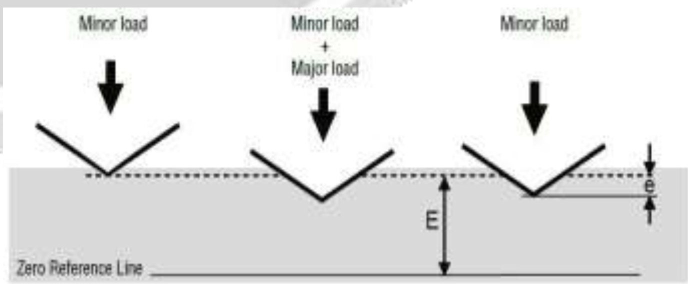
Twenty-six samples from each grade were taken in a group to homogenize the samples kept them in a muffle furnace for one hour at 900Cº (austenization), after that, two samples from each grade were normalized by rapid cooling in still air for 30 minutes, and 2 samples from each grade quenched in oil for 20 minutes. For Tempering treatment**:** After austenization, 6 samples from each grade were tempered at 300^0C, 450^0C and 600^0C for 1 hr, and for austempering, 16 of the samples from each grade were heated at 900^0C for I hr for anstenization and then 8 of this sample transferred quickly to a salt bath (salt combination was 50 wt % NaNO3 and 50 wt % KNO3) maintained at 300^0C, and the other samples to a bath of 350^0C . 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 intender. 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.

Value derivation: Hardness value was derived from the difference in the baseline and final depth measurements by converting distance into hardness number.

A = Indenter depth reached after application of minor load
B = Position of indenter during total load.
C = Final position
D = Distance b/w preload and major load position.
Rockwell-cycle
Rockwell HR = E – e



Tensile Testing Measurement-

The machine used was Instron Universal Testing Machine according to ASTM (A 370- 2002)
Process followed:
Thickness/gauge length/total length were measured accurately with the help of electronic slide calliper.
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 Stength were recorded (noted) and following formulae were used for calculations:

Calculations:

UTS = Max. load

% elongation = change in guage length x 100

Y.S = load at 0.2 % of initial x-sectional area

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.

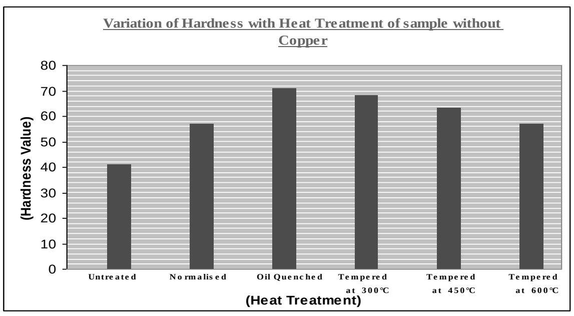
Table 3 Tensile strength, yield stress, elongation and hardness of Tempered ductile iron with and without Copper

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

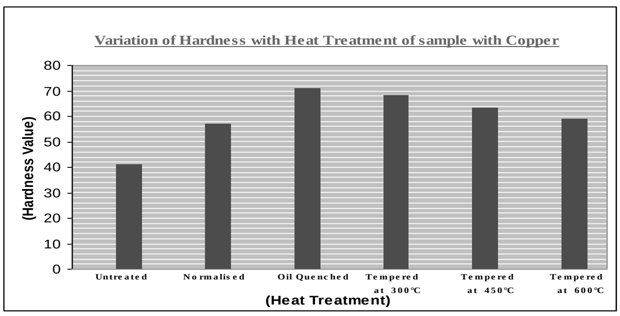
Table.3 Tensile strength, yield stress, elongation and hardness of austempered ductile iron with Cu.

TREATMENT						
Tempered D.I without Cu (N2)	As Received	Normalized	Oil Quench	Tempered at 300°C	Tempered at 450°C	Tempered 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

Table .4 Tensile strength, yield stress, elongation and hardness of austempered ductile iron without Cu



Variation of Hardness with heat treatment of sample without Cu



Variation of Hardness with Heat treatment of sample with Cu

Austempered D.I with Cu	**TREATMENT**					
	As Recieved	Temperature (ºc)	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

Table 5 Austempring of ductile iron with copper

Austempered D.I without Cu.	**TREATMENT**					
	As Recieved	Temperature (ºc)	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

Table 6 Austempring of ductile iron without copper

Figure 1 shows the variation of hardness values in Rockwell Hardness "A" scale with the treatment conditions. It shows that hardness decreases as the tempering temperature increases in both cases (with Cu and without Cu additions). This is due to the transformation of martensite to tempered martensite. The hardness of martensite is due to the tetragonal structure of the martensite where caobon occupies tetrahedral voids. This structure results from the diffusion less transformation which occurs by shear mechanism. So when martensite is tempered, diffusion of C from the tetrahedral sites of the BCT structure takes place and thus the tetragonality of martensite gets reduced. Alternatively, the structure of martensite becomes less strained after holding it at a higher temperature but less than the lower critical temperature because of carbon diffusion. and, the hardness of tempered martensite is lesser than quenched martensite in both cases (with Cu and without Cu additions).

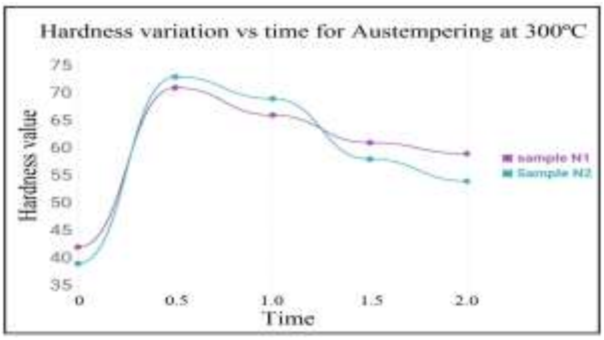


Fig 1

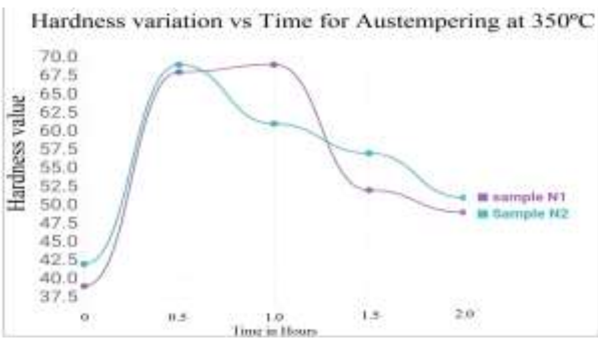


Fig 2

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.

Elongation, Tensile Strength and Yield stress Results:

In case of tempering elongation, ultimate tensile strength and yield stress variation with temperature, of two different grades are shown below in fig A1, fig B1 and fig C1 respectively.

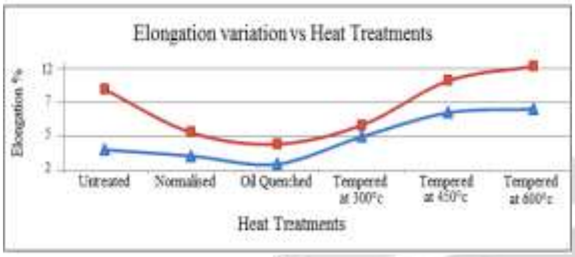


Fig A1 (Elongation with treatments)

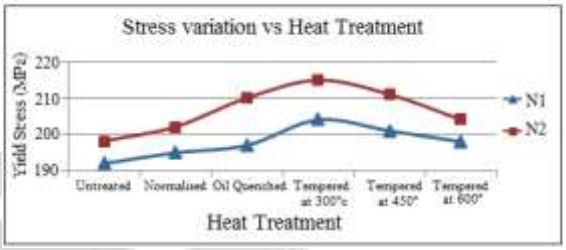


Fig B1 (Yield Stress vs Treatment)

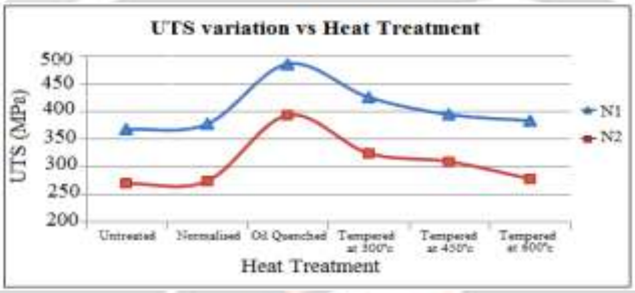


Fig C1 (Ultimate tensile strength with treatment)

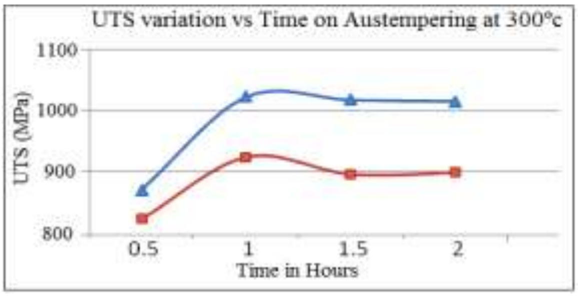
From comparison of tensile strength of two different grades of samples with different treatments, it is observed that, there is a little change in their properties. The U.T.S of tempered samples was more than the normalized samples tempered samples. The tensile properties vary with the matrix type, i.e martensitic (in case of quenching and tempering) pearlitic (in case of normalized samples), and bainite (in austempered samples) matrix. Thus elongation increases , U.T.S and yield stress for tempered treatment (from 300 Cº to 600 Cº) decreases depending on pearlite content of the matrix. Tempered samples have higher tensile properties than the normalized samples, but as the tempering temperature is increased there was a decrease in U.T.S and yield stress, as shown in fig B1 and C1. The elongation of tempered samples is higher than normalized samples, because of the formation of martensite and tempere martensite etc. on the other hand, the elongation increases with the tempering temperature as shown in figure A. Comparing the two grades of samples N1 and N2 , shown that sample with copper (N1 grade) has higher UTS and Yield stress and lesser elongation than grade N2 for both Normalized and Tempering Treatment.

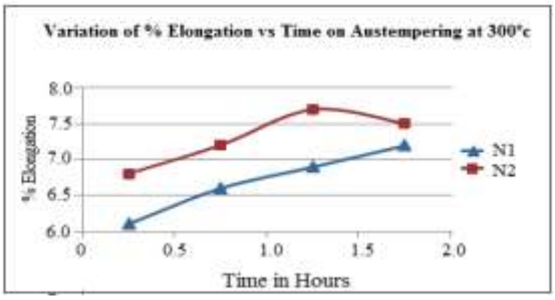
Austempering Treatment

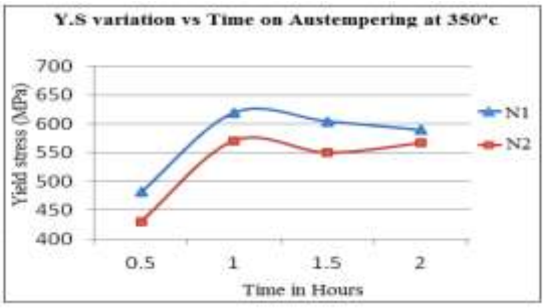
Austempering is a hardening process for metals which yields desirable mechanical properties including higher ductility, toughness, strength for a castn hardness, resistance to shock and reduced distortion, specifically with thin parts. Austempered ductile iron is produced by heat-treating cast ductile iron to which small amounts of nickel, molybdenum, or copper have been added to improve hardenability. Specific properties are determined by the careful choice of heat treating parameters. Austempering involves the nucleation and growth of acicular ferrite with in austenite, where carbon is rejected into the austenite.

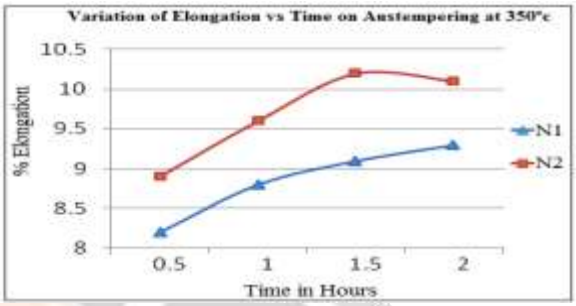
Austempering is a heat treating process for medium-to-high carbon ferrous metals which produces a metallurgical structure called bainite. The properties summarized in Table 4 and Table 5, and figures shows the variation of tensile strength with respect to the austempering time at temperature 300 degree celsius & 350 degree celsius respectively for grades N1 and N2.

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









The Tensile strength is increases initially from 0.5 hr to 1 hr, then from 1 hr to 2 hr decreases slightly for both grades and with further increase in treatment time attains a steady state, as shown in fig4 (a) and (b). The increase in strength initially at low time interval is due to the high amount of martensite derived from the unreacted austenite, but as the time increase above one hour the first stage reaction commences in the intercellular regions for which strength decreases. With the further increase in time, the retained austenite reduces, and ductility again increases w.r.t time. So ductility increases further to a maximum value which indicates the tolerable amount of martensite. The sample alloyed with copper(N1) has increased ductility and lesser strength than that sample without copper content(N2)

Elongation for Austempered Ductile Iron (ADI) is increasing from 0.5 hr. to 1.0 hr. but with slight decreased from 1.0 hr. to 2.0 hr. as shown in figure 4.c and 5.c, which also shows that (ADI) with copper (N1) is lower of that grade without copper (N2) with small amount. Comparing the tensile strength with respect the austempering temperature for both grades from table 3, it is found that tensile strength is decreasing with increasing austmpering temperature but elongation is Increasing . Also the sample with copper (N1) has higher ductility and lesser strength than that sample without copper content(N2).

Uses Of spherulitic graphite cast Irons:

The uses of the S.G. press have expanded massively lately as can be seen from the rundown beneath:
Motor wrench shaft
Brake caliper, circle – brake grapple, brake stay plate
Machine – device bed
Electric encasing post and top
Controlling knuckle
Rack and pinion of controlling get together
Cylinder for affect drills
Moving plant rolls
Trim boxes and shape box clasps
Brake shoe for rock solid brakes
Glass molds
Spacer confine for moving bearing
Cylinder rings

CONCLUSION

The following observations were acquired tentatively amid Austempering heat treatment cycle:

1. Hardness esteems ordinarily diminishes amid the procedure of austempering.Also it was watched that the hardness esteem diminishes with the expansion in time when the temperature was kept same (either 250°Cor 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

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

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

5. .Amid process stretching first declines and after that increments.

To obtain optimum combination of properties like ductility (elongation), Yield Strength, Sardness and Ultimate tensile strength one should go for austempering of the Spherulitic Cast iron.

Future Scope:

Engineering applications of ductile iron in as cast and different heat treated conditions are growing day by day. Austempered Ductile Iron’s application has increased tremendously in many industrial areas. Austempered Ductile Iron is increasingly the material of choice of designers and engineers because of their cost effective performance. It has started to replace steel in some structural applications. It has also found it’s tremendous applications in automobile sector which includes crankshafts, disc-brake callipers, axle housings, etc. It is also used to manufacture spun pipes, pump bodies, rock drillers, etc. For all these applications, we need to take into consideration many other mechanical properties like, wear and erosion resistance, impact resistance, fracture toughness, creep resistance, noise reduction and energy saving properties, etc. So in future, we can measure the above mentioned mechanical properties to optimally select a material for its specific application.

REFERENCES

1. D’Amato C, Verdu C, Kleber X. et. al.; *Characterization of Austempered Ductile Iron through Barkhausen Noise Measurements; Journal of Nondestructive Evaluation,* Vol. 22, No. 4, December 2003.
2. Davis J.R., *ASM Specialty Handbook: Cast Irons, ASM International,* 1996, pages 437.
3. Eric O., Rajnovic Dragan, Zec S lavica et. al.; *Microstructure and fracture of alloyed austempered ductile iron; Materials Characterization,* Volume 57, January 2006, Pages 211-217.
4. Eric O., Sidjanin L., Miskovic Z. et. al.; *Microstructure and toughness of Cu-Ni-Mo austempered ductile iron; Materials Letters,* Volume 58, June 2004, Pages7–2711.
5. Eric O, Sidjanin L, Zec S, Jovanovic MT. Mater Letters,2004, Volume 58, Pages11–2707.
6. Fatahalla. N., Bahi. S.; *Metallurgical parameters, mechanical properties and machinability of ductile cast iron,* Journal of Materials Science 31 (1996) 5765- 5772.
7. G. Krauss, *Principles of Heat Treatment of Steel, ASM,* 1980.

8. Hafiz M. *Mechanical properties of SG-iron with different matrix structure; journal of Material Science,* Volume 36, 2001, Pages 1293-1300.

9. Hafiz M. *Tensile properties and fracture of ferritic SG-iron having different-shell structure.* Z Metallkd Volume 11, 2001, Volume 1258–61.

10. Haseeb A.S.M.A., Islam Aminul et.al.; *Tribological behaviour of quenched and tempered, and austempered ductile iron at the same hardness level; Journal of wear,* April 2000, Pages 15-19.

11. Heydarzadeh M., Ahmadabadi Nilli M.; *The role of austempering parameter on the structure and mechanical properties of heavy section ADI*, Journal of Material processing Technology, Volume 153-154, November 2004, Pages 203-208.

12. Hughes I.C.H., *Austempered ductile iron: their properties and significance,* Materials & Design Vol. 6, July 1985.

13. *Introduction to Physical Metallurgy;* Sidney H. Avenar.

14. Jaun Manuel Velez, Tanaka V.K; *Metallurgical & Material Transaction A,* Volume 29, December 1999, pages 2925-2934.

15. Karsay, *"S.I. ductile Iron I": Production (revised in 1976) the state of the art,* 1976, Sorel, Canda, Quebec Iron and Titanium, 1977.

16. Karsay, *"Production of S.G. Irons". A guide to mechanical properties of ductile iron, Mid – Atlantic Casting service.* Volume 9, chapter 6, Pages 70-90

17. Kiani-Rashid A.R., *Influence of austenitising conditions and aluminum content on microstructure and properties of ductile irons;* Journal of Alloys and Compounds, Volume xxx, February 2008.

18. Kim Yoon-Jun, Shin Hochoel; *Investigation into mechanical properties of austempered ductile cast iron(ADI) in accordance with austempering temperature*, materials Letters, Volume 62, May 2006, Pages 357-360.

19. Kocatepe. Kadir, Cerah Melika, Erdogan Mehmet; The tensile fracture behaviour of intercritically annealed and quenched + tempered ferritic ductile iron with dual matrix structure; Journal of Materials and Design, July 2005, Pages 172-181.