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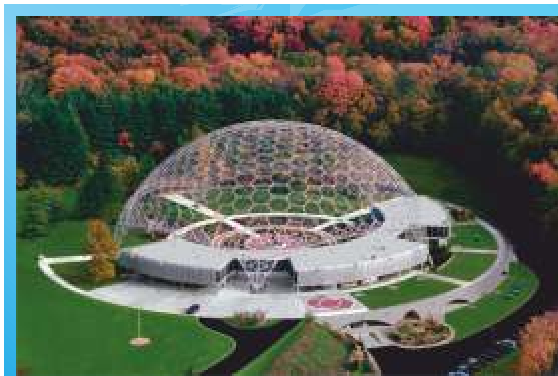
★★★★★ FIVE STAR CHAPTER



ASM International, Pune Chapter

Chapter News Letter

Issue No. : 15 | Editor - Louis F. Vaz | Chairman, News Letter Committee - Louis F. Vaz | August 2015

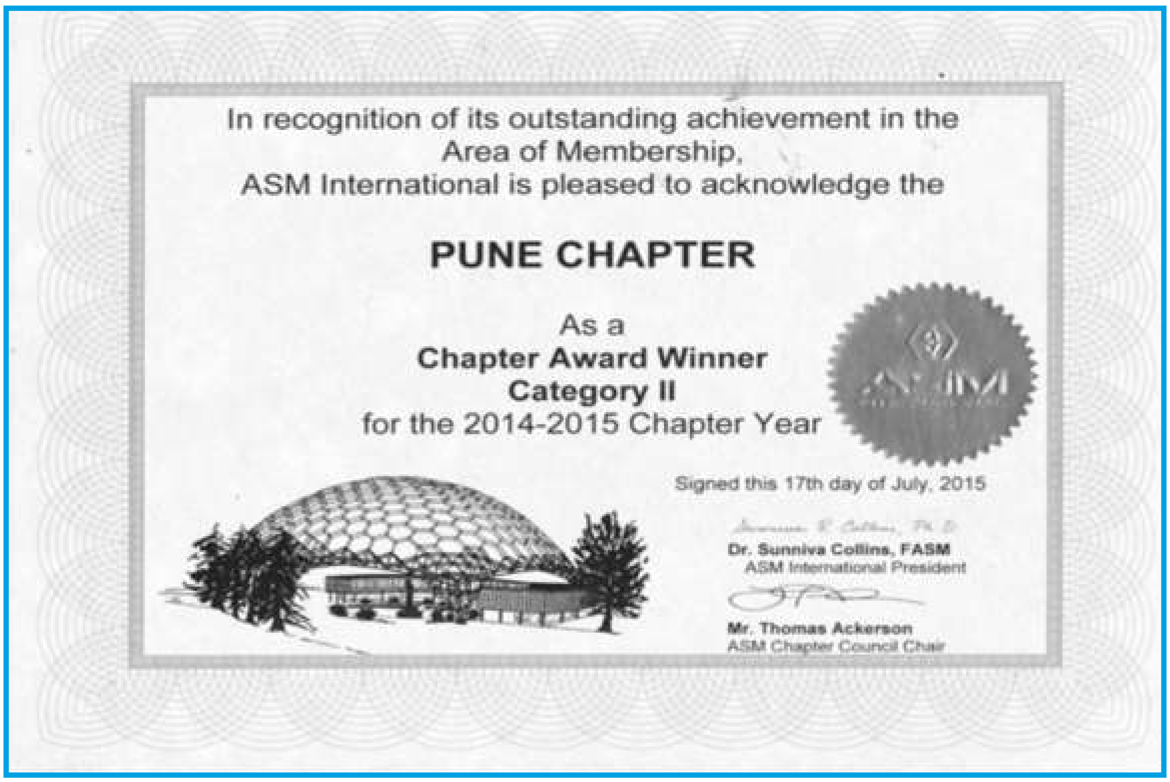
EDITORIAL...

ASM International, Pune Chapter

Welcomes you to the August 2015 issue of Newsletter. A Conference and Exhibition on Materials & Manufacturing Technology 2016 will be held in February 2016 in Pune. The 8th Annual Material Camp for students was successfully held. A technical session on Six Sigma was held. A technical article by Mr. Priyanshu Bajaj is featured in this issue. We welcome Mr.Pravin Mehta as Senior Executive at ASM, Pune Chapter.

Regards,

Louis Vaz
Editor



In recognition of its outstanding achievement in the Area of Membership, ASM International is pleased to acknowledge the

PUNE CHAPTER

As a
Chapter Award Winner
Category II
for the 2014-2015 Chapter Year

Signed this 17th day of July, 2015

Dr. Sunniva Collins, FASM
ASM International President

Mr. Thomas Ackerson
ASM Chapter Council Chair

We are glad to inform you that ASM Pune Chapter received the "Chapter Award Category II" from ASM International in recognition of its outstanding achievement in the Area of Membership for the year 2014-2015.

Materials & Manufacturing Technology 2016

On its Silver Jubilee Year ASM International Pune Chapter will be holding a Conference and Exhibition on Materials & Manufacturing Technology 2016. This will be held on the 24th and 25th February 2016 at Hotel Hyatt Regency, Nagar Road, Pune.

About the Event –

Drive Line is heart of any vehicle and is primarily responsible for its performance. Stricter emission norms have led to lot of changes in Drive Lines, resulting in higher operating temperatures, pressures and speed. Weight reduction is another challenge. This puts a lot of demand on the Materials used. Hence, one is always on the lookout for better "Materials and Manufacturing Technology". M&MT 2016 will focus on latest Materials Technology as regards to Engines and Transmission.

Event Highlights –

- Light weight materials like aluminium alloys, magnesium alloys, micro alloyed steels, titanium alloys, sintered materials etc.
- Globally emerging processes like 3D printing, hollow forming, electro-chemical machining, metal injection moulding, near net shape forming, vacuum heat treatment, surface finishing, etc.
- Process equipment such as vacuum furnaces, continuous furnaces, furnace automation, furnace materials, furnace instrumentation, fixtures, high speed processing, distortion control, energy, environment, surface modification processes including shot peening.
- Synchronising materials
- Gears as per DIN7
- Impregnation technology
- Special interactive session on failure analysis.

We request your active participation in this event as Sponsor, Advertiser, Exhibitor, Speaker, and Delegate. to make this mega event a grand success.

Technical Presentation on Six Sigma ...A New Paradigm Shift

ASM Pune Chapter held a technical Presentation on Six Sigma ...A New Paradigm Shift, on 25th June 2015

Session was conducted by two renowned Six Sigma Black Belts, Mr. Pradeep Kulkarni Mr. Praveen Deshpande.

Mr. Pradeep Kulkarni gave an outline of Six Sigma, which was appreciated by all present.

Mr. Pradeep Kulkarni giving his presentation

Materials Camp 2015

ASM INTERNATIONAL PUNE- CHAPTER 2015

The 8th Annual Material Camp for students, was jointly organized by ASM International - Pune Chapter, COEP, ARAI & ASM Educational Foundation USA. It took place at Metallurgy and Materials Engineering department, College of Engineering, Pune. from May 26 to 30, 2015.

This event is specially designed for creating awareness and interest in students, on the importance of taking up Material Engineering and Metallurgy as a career.

The camp was inaugurated by Mr. V. K. Purohit, COO, Pefco Foundry Division, Kores India Ltd., on 26th May, 2015 . His talk inspired the students about research work not only in metallurgy but other related fields

Three days were used for hands on experience at COEP wherein participants did exercises in material testing, foundry, welding, heat treatment, corrosion, mechanical working etc. One full day was used for nondestructive testing wherein all basic methods like visual, magnetic particle, ultrasonic, radiography and electromagnetic were introduced.

One full day was spent for industrial visit to Tata Motors ,Emitec, and ARAI. Participants were thrilled to observe the vast applications of various principles they observed at laboratory scale in college, to the actual use in production and testing of vehicles and auto ancillaries

The Camp was a great success. Thanks to the efforts of Mr. Sudhir Phansalkar and his ASM members, Dr. Vagge and other staff members of COEP, Dr. Vora and other staff members of ARAI, Tata Motors and Emitec.

Mr. Hemant Zaveri seen explaining the principle and working of a thermocouple to students.

ASM Chapter Honor Roll

Mr. L. D. Deshpande

Mr. L. D. Deshpande has been an active executive committee member of Pune Chapter since 2005. He is chairperson for membership development and member of the India National Council. He was awarded the ASM Chapter Honor Roll for his excellent contribution in membership development.

JOHN DEERE FELLOW

Dr. Satyam S. Sahay, FASM is named among the first four John Deere Fellows for his exemplary knowledge leadership in materials engineering. The Fellow program has been created this year at John Deere for the highest recognition of functional expertise in the enterprise. Dr. Satyam Sahay co-leads the enterprise advanced materials engineering at John Deere and is based out of John Deere Technology Center India (Pune). He has received his PhD degree in metallurgical engineering from University of Utah (1995) and is an active member of ASM international since 1992.

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APPOINTMENT

Mr Pravin Mehta has been appointed as senior executive for our ASM, Pune Chapter office from 20th July 2015. His contact number is 9422034564.

Effect of Austenitising Temperature on Microstructure and Wear Properties of Low Carbon Equivalent Austempered Ductile Iron

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Effect of austenitising temperature on microstructure and wear properties of low carbon equivalent austempered ductile iron (ADI) has been studied. Three Samples were austenitised at 850°C, 900°C, and 950°C respectively for one hour; followed by austempering at 250°C for two hours. Hardness of all the samples was taken. Hardness values were compared with that of conventional ADI and as-cast sample. Microstructural study was done using 2% Nital, 2% Picral, Alkaline Sodium Picrate (ASP) and 10% Sodium Metabisulfite (SMB) as etchants. Coarser needles and blockier austenite was observed at higher austenitising temperature. Carbide contents decreased as the austenitising temperature increased and no carbides were observed in sample austenitised at 950°C. A mix of martensite, acicular ferrite and austenite was observed in the microstructure. The martensite was then tempered at two different temperatures. Pin-on-disc wear test (ASTM G 132-96) was carried out. Wear properties of low carbon equivalent ADI were found to be much better than conventional ADI; sample austenitised at 950°C gave significantly better wear resistance.

Keywords: Austempered Ductile Iron (ADI), Carbon Equivalent (CE), Wear, Austenitising, Microstructure.

INTRODUCTION

Austempered Ductile Iron (ADI) is a very unique material which possesses a combination of strength and toughness; also it offers a very good wear resistance. It is lighter than steel and its strength-toweight ratio is higher than aluminium. The material is also cheap, easy to form (thorough casting) and has good machinability. A wide range of mechanical properties can be obtained by varying the heat treatment parameters. Although, a lot of work has been done on this material to study the effect of various processing parameters such as austenitising time and temperature[1-5] and austempering time and temperature[1, 4-11] on the microstructure and properties, very little information is available about the austempering of high modulus cast iron, i.e. the low carbon equivalent ductile iron. The work presented below is an attempt to throw light on that aspect.

BACKGROUND

Austenitising is done to produce an austenitic matrix with desired carbon content. The austenitising temperature depends on the desired carbon content in the austenite and the alloy composition[1]. Gong Wenbang developed a formula for calculating carbon content of austenite for a given alloy at a specified austenitising temperature[12].

$$C_a = C_S + (T_a - T_{S1})/\eta$$

Where, C_a is carbon content of austenite, T_a is austenitising temperature, C_S is carbon content of austenite at upper eutectoid, T_{S1} is upper eutectoid temperature, η is influencing coefficient of the carbon on the temperature for x% Si[12].

$$C_S = 0.68 - 0.015\,x\,(\%)$$

$$T_{S1} = 738 + 40\,x\,(°C)$$

$$\eta = (416\text{-}37.5\,x) / (1.4\text{-}0.202\,x)\ (°C/\%)$$

The formula clearly indicates that C_a increases as S_i content decreases or as the austenitising temperature is increased. As the austenitising time is increased, carbon content increases linearly with it until it becomes constant[5]. On increasing the austenitising temperature, the carbon concentration of the austenite phase increases as per the ironcarbon-silicon phase diagram[1]. This increase in carbon content leads to a depression of $M_{s\ t}$ temperature[4]. Researchers have also found that with decrease in austenitising temperature rate of ausferrite reaction increases[2], ferrite needles become finer and more uniformly distributed[3, 5] and volume fraction of retained austenite phase decreases[5]. On decreasing the austenitising temperature, the austenite grain size decreases and thus the grain boundary area increases; now as ferrite nucleates heterogeneously at austenite grain boundaries[4], an increase in grain boundary area promotes nucleation of ferrite needles resulting in finer needles and higher rates of ausferrite reaction.

Austempering is done to get a microstructure of austenite and ferrite which can give optimum strength and ductility[1]. This microstructure is known as ausferrite[13]. As austempering time is increased, amount of martensite and hardness of ADI decreases[9]. As the austempering temperature is increased, fracture toughness increases[10], metastable carbon content in the matrix austenite decreases[6], yield strength and tensile strength decreases while percentage elongation and ductility increases[1, 8]. W. Dubensky conducted a massive electron microscope study of ADI; he observed iron carbides in the ausferrite product in samples austempered at low temperatures (< 371°C)[7]. Lower austempering temperature (about 260°C) produces a structure suitable for wear resistant applications[1].

Work on wear properties of ADI have shown that wear resistance of ADI is equivalent to that of AISI 4340 steel and that the wear properties of quenched ductile iron were comparable with ADI; better in case of dry sliding wear[14]. The transformation of carbon stabilised austenite to martensite has been attributed as the reason for these superior wear properties[14]. This transformation is more favoured when microstructure contains more of blocky austenite[15].

Low carbon equivalent (CE) ductile iron is a high modulus cast iron, having modulus of elasticity comparable with that of steel. In spite of the extensive information available for ADI, very less work has been reported in the field of low CE ADI. Researchers have shown that it exhibits higher hardness than conventional ADI after austempering[9].

Although, so much work has been done on ADIs, no one has studied the wear properties of low CE ADI. In this work, we have studied the effect of austenitising temperature on microstructure (using different etching reagents, under optical microscope) and wear properties (Pinon-disk test) of low CE ADI. This work will also help in better understanding of effect of austenitising process and austempered microstructure.

EXPERIMENTAL PROCEDURES

Samples with composition given in Table-1 were prepared as cylindrical castings with diameter 2.5

Table-1: Chemical Compositions of the Alloys Used for the Study									
	% C	% Si	% Mn	% S	% P	% Cr	% Cu	% N	CE
Alloy 1	2.16	1.42	0.83	0.013	0.027	–	0.6	0.57	2.64
Alloy 2	2.86	2.5	0.88	0.01	0.02	–	0.59	0.55	3.69

Alloy 1 is low CE ADI, Alloy 2 is conventional ADI.

cm and length 30 cm in a commercial foundry using a 150 kg induction furnace. Steel scrap was used as raw material. Ferrosilicon with 70% Si was used to get the desired composition. Casting was done in CO_2 moulds.

The heat treatment was carried out in a specially designed twinchamber austempering furnace. Samples from Alloy-1 were austenitised at three different temperatures 850°C, 900°C and 950°C for 1 hour. Alloy-2 sample was austenitised at 900°C for 1 hour. After austenitising, samples were quickly lowered into a salt bath furnace maintained at 250°C for 2 hours for austempering. Samples were then cooled to room temperature in air. Low austempering temperature was chosen to get a fine microstructure.

All the samples were tested for hardness using a diamond indenter and 150 kgf load (C-Scale) in a Rockwell hardness tester.

Microstructural study was carried out by optical microscopy using 2% Nital, 2% Picral, Alkaline Sodium Picrate (ASP) and 10% Sodium Metabisulfite (SMB) as etchants to clearly identify the various phases present in the microstructure. Samples were prepared using standard metallographic preparation techniques. Microstructures were captured using Carl Zeus POB 4041, D 37030 microscope and Axio-Vision Rel. 4.6 software at 500 X.

Martensite was observed in the microstructure and hence it was decided to carry out tempering. Differential Scanning Calorimetry (DSC) was done to identify the suitable tempering temperature. Accordingly, samples were tempered at 215°C and 336°C in a salt bath furnace for 1 hour.

Wear properties were studied by performing pin abrasion test (ASTM G 132-96) of all the samples[16]. The test was done at an RPM of 400, path diameter 40 mm, using a 2 kg load for 100 min. Emery paper 150 No. was used as the abrasive surface.

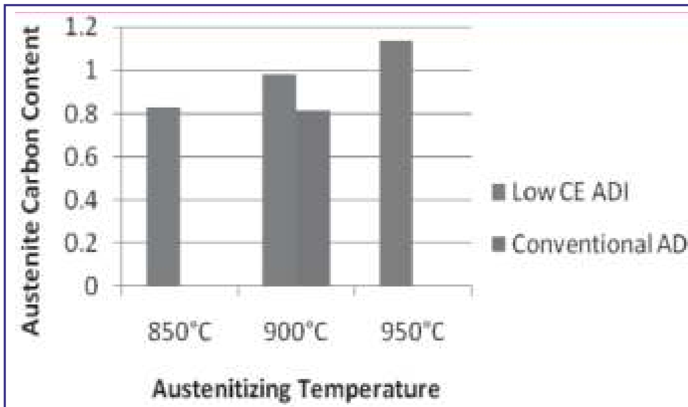
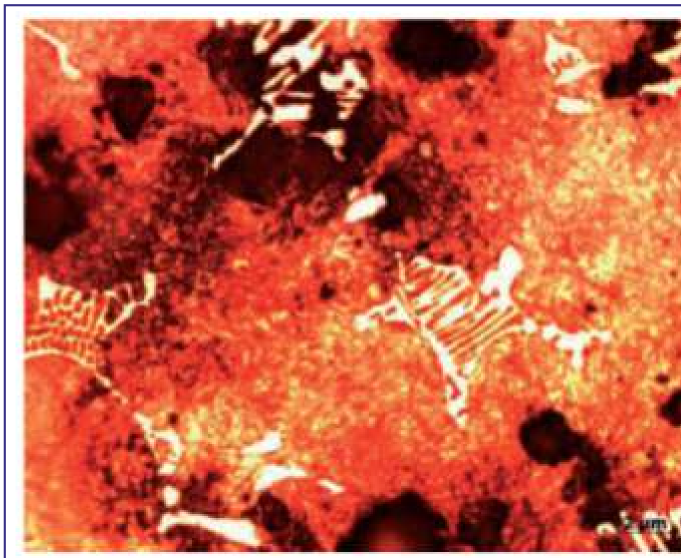


Fig. 1: Carbon content at austenite as calculated by formula developed by Gong Wenbang[12]



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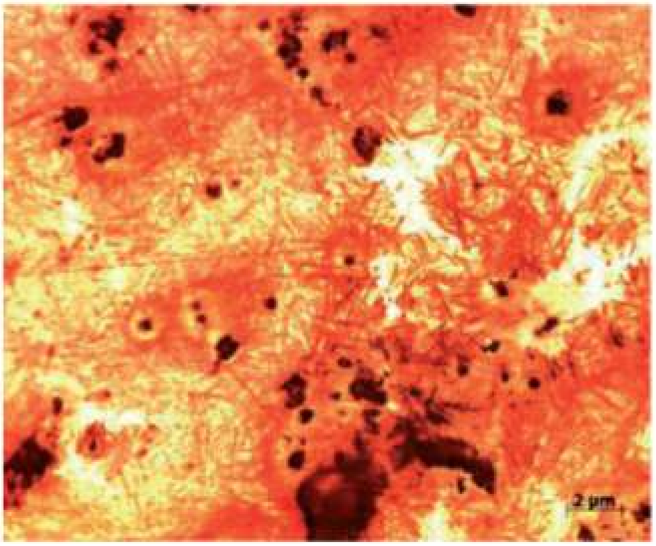

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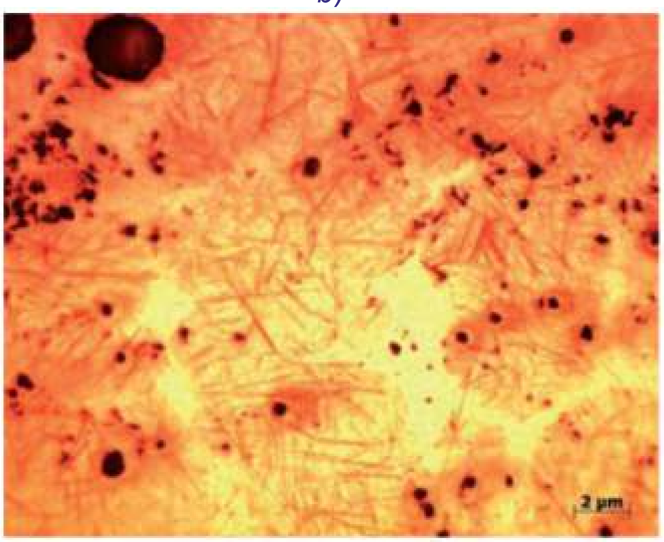
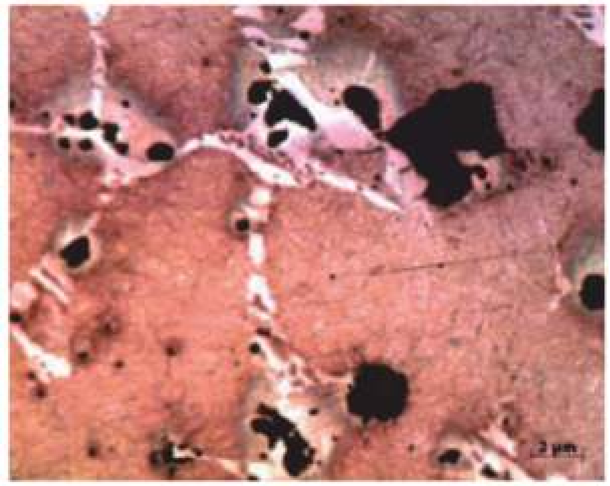


c)

Fig. 2: Microstructure of the Low CE ADI sample,
Etchant: 2% Nital
a) 850°C 1 hr, 250°C 2 hr.
b) 900°C 1 hr, 250°C 2 hr.
c) 950°C 1 hr, 250°C 2 hr.
Graphite nodules, needles of martensite and acicular ferrite, cementite and austenite are observed.



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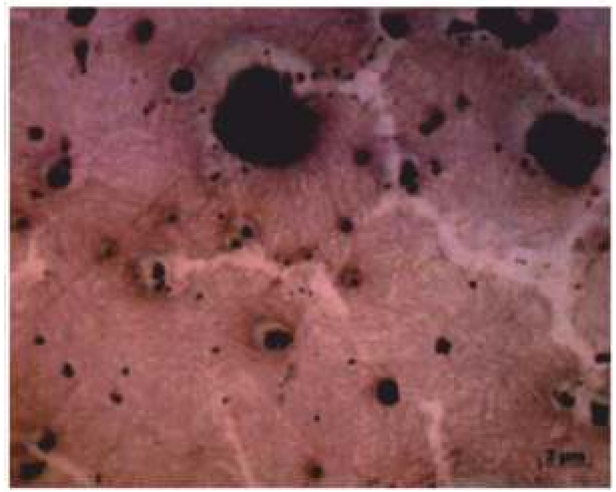

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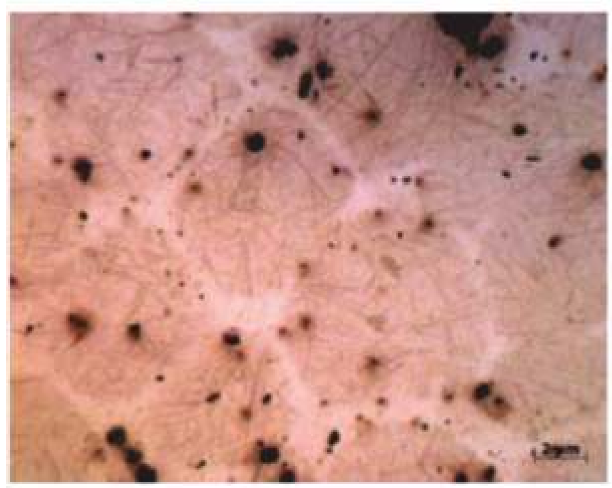
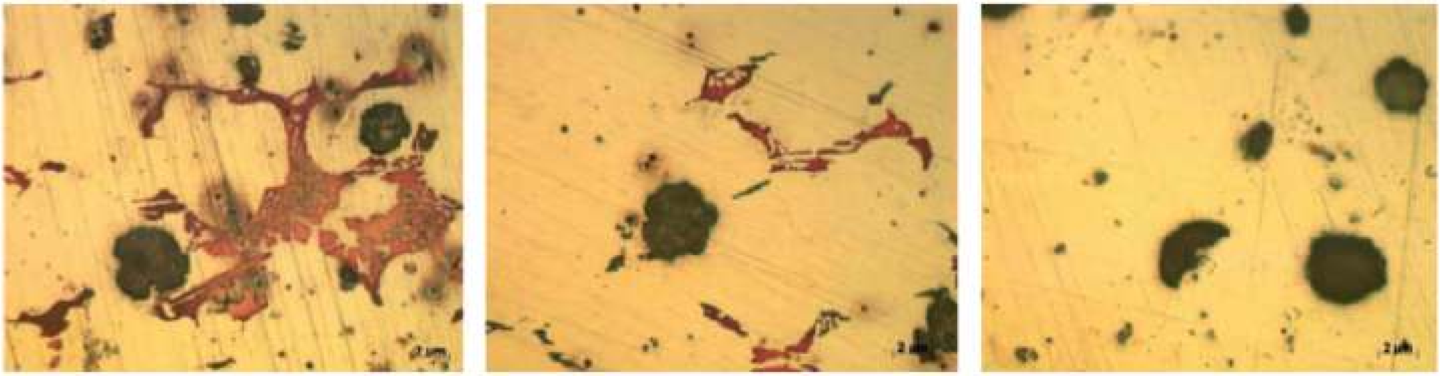


c)

Fig. 3: Microstructure of the Low CE ADI sample,
Etchant: 2% Picral
a) 850°C 1 hr, 250°C 2 hr.
b) 900°C 1 hr, 250°C 2 hr.
c) 950°C 1 hr, 250°C 2 hr.
Graphite nodules, needles of martensite and acicular ferrite, cementite and austenite are observed.

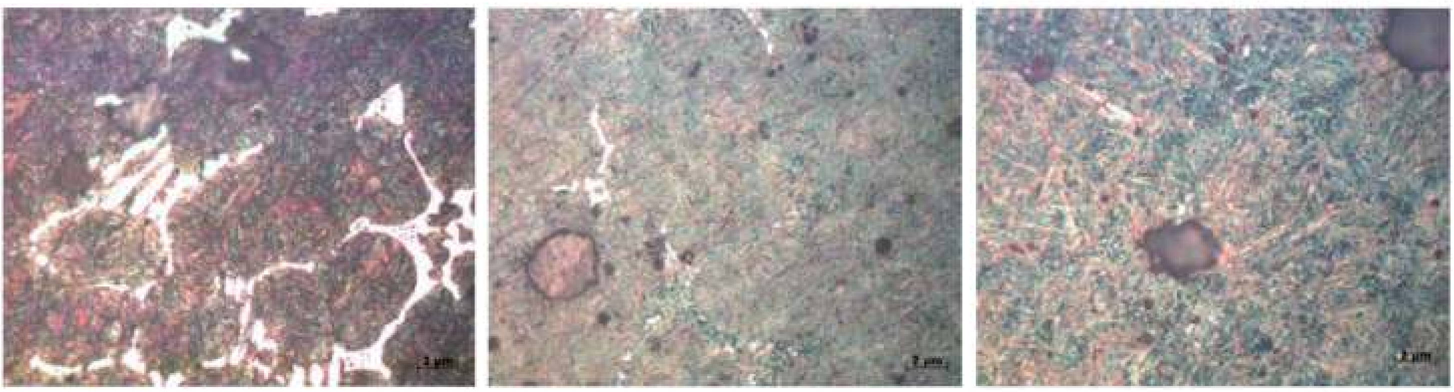
RESULTS AND DISCUSSION

The carbon content of austenite for all the samples calculated using the formula given above are shown in Fig. 1. The carbon content increases on increasing the austenitising temperature; also for a given austenitising temperature, carbon content of low CE ADI is higher than that of conventional ADI.



a) b) c)

Fig. 4: Microstructure of the Low CE ADI sample, Etchant: Alkaline Sodium Picrate
a) 850°C 1 hr, 250°C 2 hr. b) 900°C 1 hr, 250°C 2 hr. c) 950°C 1 hr, 250°C 2 hr.
Graphite nodules and cementite are observed in (a) and (b); only graphite nodules observed in (c)



a) b) c)

Fig. 5: Microstructure of the Low CE ADI sample, Etchant: 10% Sodium Metabisulphite
a) 850°C 1 hr, 250°C 2 hr. b) 900°C 1 hr, 250°C 2 hr. c) 950°C 1 hr, 250°C 2 hr.
Interwoven needles of martensite (in brown) and acicular ferrite (in blue-green) are observed.

Microstructural Study

Microstructures of Low CE ADI samples subjected to different heat treatments are shown in Figs. 2- 5. Different etching reagents were used to reveal various structural features. In Fig. 2 and Fig. 3, graphite nodules are observed in black colour, needles of martensite and acicular ferrite are also visible; carbides and austenite are in white. It is observed that coarser needles and more of blocky austenite are present in samples austenitised at higher temperature. The finer and more intermixed needles obtained in samples austenitised at low temperature offers a higher resistance to dislocation movement resulting in higher hardness.

Figure 4 shows microstructures of samples after etching with ASP, which colours the cementite into brown colour[17]. Amount of carbides decreases on increasing austenitising temperature and no carbide was observed in the sample austenitised at 950°C.

10% Sodium Metabisulphite (SMB) colours martensite into brown and acicular ferrite into blue-green[17], it was used to differentiate between the two phases. Figure 5 shows the microstructure of

samples etched with SMB. It is observed that intermixed needles of martensite and acicular ferrite are present in all the samples.

Hardness Test

Table-2 shows the hardness values of various samples. Clearly, low CE ADI has superior hardness than conventional ADI. Also, as the Austenitising temperature increases, the hardness decreases. This may be explained by the microsturctural studies.

DSC Study

Results of DSC are shown in Fig. 6. Two peaks were obtained for each sample; hence two tempering temperatures were selected. The lowest peak temperature was selected for tempering of all the three samples.

Tempering temperatures were chosen at 215°C and 336°C; tempering time was 1 hour.

Wear Test

Wear rate (mass loss per unit area per unit time) as a function of austenitising temperature is shown in Fig. 7 for low CE samples in untempered condition, tempered at 215°C and tempered at 336°C; mass loss for conventional ADI austenitised at 900°C for 1 hr., austempered at 250°C for 2 hr. in untempered condition is also shown. Clearly, the mass loss of

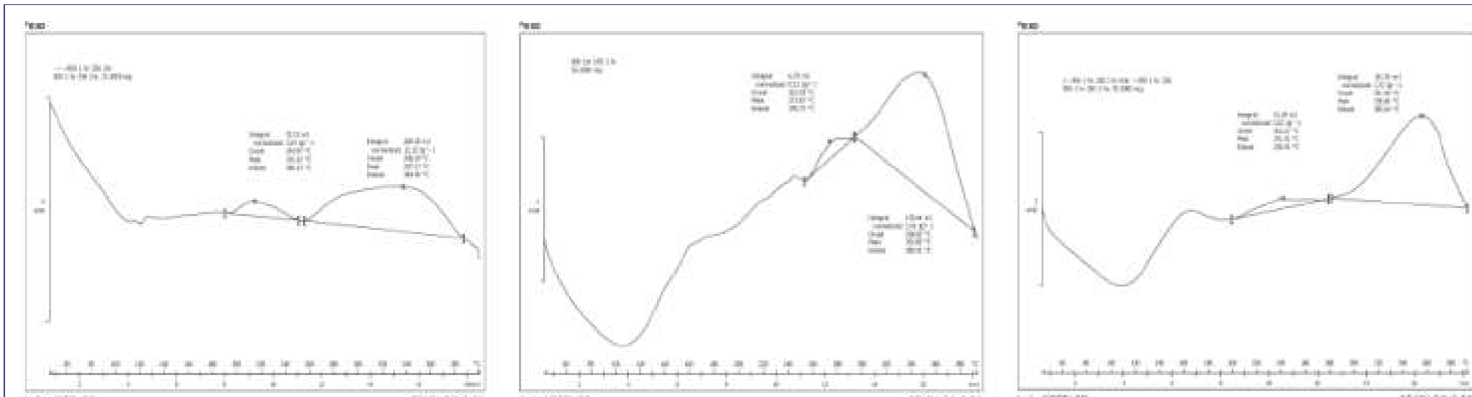
Table-2: Hardness Values of Samples Austenitised at Given Temperature for 1 Hour followed by Austempering at 250°C for 2 Hours

Austenitising Temperature	850°C	900°C	950°C
Low CE ADI	62-63 HRC	59-62 HRC	58-60 HRC
Conventional ADI	–	51-53 HRC	–
As-cast Hardness (for low CE Sample): 45 – 48 HRC.			

low CE ADI samples is much less than that of conventional ADI. Also, for low CE ADI, the mass loss decreases on increasing the austenitising temperature; in untempered condition, the decrease is almost linear. This may be because of the presence of higher amount of blocky austenite in samples austenitised at higher temperature (Fig. 2, Fig. 3) which transform to strain-induced martensite[15]. On tempering the hardness decreases, resulting in a higher mass loss. The increase in mass loss is lesser when tempering is done at 336°C, this may be because of the formation of carbide precipitates during tempering at higher temperatures[18].

SUMMARY OF OBSERVATIONS

- Hardness of Low CE ADI (58-63 HRC) is much higher than Conventional ADI (50-53 HRC).
- Hardness of Low CE ADI decreases as the



a) b) c)

Fig. 6: DSC curves

a) 850°C 1 hr, 250°C 2 hr. b) 900°C 1 hr, 250°C 2 hr. c) 950°C 1 hr, 250°C 2 hr.

austenitising temperature is increased.

- Needle size increases and austenite becomes blockier on increasing the austenitising temperature.
- In low CE ADI, carbide concentration decreases on increasing the austenitising temperature and all the carbides are dissolved in sample austenitised at 950°C for 1 hr.
- On austempering low CE ADI at 250°C for 2 hours, the microstructure consists of interwoven needles of martensite and acicular ferrite.
- Wear resistance of low CE ADI is much better than Conventional ADI.
- Wear resistance increases as the austenitising temperature is increased and decreases on tempering.

CONCLUSIONS

- Low CE ADI austenitised at high temperature (about 950°C) and austempered at low temperature (about 250°C) is suggested for wear resistant applications.
- To improve the toughness of the material tempering can be done at higher temperatures (>336°C) to get a tough wear-resistant material.

Acknowledgment

The authors express their sincere thanks to the Department of Science & Technology, Government of India for funding this project.

REFERENCES

1. Karl B. Rundman, Heat Treatment of Ductile Iron, ASM Handbook Volume 4, Heat Treating, ASM International (1990), p. 682-692.
2. D.J. Moore, B.S. Shugart, K.L. Hayrynen, and K.B. Rundman, Microstructural Determination of Isothermal Transformation Diagrams in a Low Alloy Ductile Iron, Trans. AFS. (1990).
3. T.N. Rouns and K.B. Rundman, Constitution of Austempered Ductile Iron and the Kinetics of Austempering, AFS Transactions Volume 95 (1987), p. 851–874.
4. Karl B. Rundman, It's About Austenite and Carbon, Mate - A Story of the Physical Metallurgy of ADI - Part II (2006).
5. Uma Batra, S. Ray, S.R. Prabhakar, Effect of Austenitization on Austempering of Copper Alloyed Ductile Iron, Journal of Materials Engineering and Performance, Volume 12, Issue 5 (October 2003), p. 597-601.
6. K. B. Rundman, D.J. Moore, K. L. Hayrynen, W.J. Dubensky, T.N. Rouns, The Microstructure and Properties of ADI, Journal of Heat Treating, Volume 5, No.2 (1988), p. 79–95.
7. W. Dubensky, K. B. Rundman, An Electron Microscope Study of Carbide Formation in Austempered Ductile Iron, AFS Transactions, Volume 93 (1985), p. 389–394.
8. U. Batra, S. Ray, S.R. Prabhakar, Tensile Properties of Copper Alloyed Austempered Ductile Iron: Effect of Austempering Parameters, Journal of Materials Engineering and Performance, Volume 13, Issue 5 (October 2004), p. 537-541.
9. S. S. Umale, P. P. Parhad, Ajay Likhite and S. U. Pathak, Austempering Heat Treatment of Low Carbon Equivalent Ductile Irons, Indian Foundry Journal, Volume 58, No. 5, (May 2012), p. 23-30.
10. Doong J. L., Ju F. C., Chen H. S. and Chen L. W., J. Mater. Sci. Letter, Volume. 5 (1986), p. 555.
11. Putatunda S. K. and Singh I., J. Test. Eval., Volume 23 (1995), p. 325.
12. Gong Wenbang, Chen Guodong and Xiang Gangyu, Calculation of Carbon Content of Austenite during Heat Treatment of Cast Irons, China Foundry, Volume 7 No.1 (Feb 2010), p.

30–32.

13. B.V. Kovacs, Austempered Ductile Iron: Fact and Fiction, Mod. Cast. (March 1990), p. 38–41.
14. Y.S. Lerner and G.R. Kingsbury, Wear Resistance Properties of Austempered Ductile Iron, Journal of Materials Engineering and Performance, Volume 7(1) (Feb 1998), p. 48–52.
15. Srinivasmurthy Daber, P. Prasad Rao, Formation of Strain Induced Martensite in Austempered Ductile Iron, Journal of Material Science, Volume 43, Issue 1 (Jan, 2008), p. 357-367.
16. Standard Test Method for Pin Abrasion Testing, Designation G132-96, ASTM International (Reapproved 2001), p. 563-567.
17. M. Radzikowska, Metallography and Microstructures of Cast Iron, ASM Handbook, Volume 9, ASM International (2004), p. 565–587.
18. Sidney H. Avner, Introduction to Physical Metallurgy, Second Edition (2009), p. 305-313.

Fig. 7: Wear rate in pin-on-disc wear test as a function of austenitising temperature for low CE ADI in untempered and tempered condition.

ABOUT THE AUTHOR

Mr. Priyanshu Bajaj is ASM Pune chapter Member and active member of Young Professional Committee. Their Paper titled "Effect of Austenitising Temperature on Microstructure and Wear Properties of Low Carbon Equivalent Austempered Ductile Iron" received the Best Technical Paper: Other than Non-Ferrous (Ferrous) Category Award by Institute of Indian Foundrymen (IIF). He is presently working at Kalyani Forge Limited, Pune as Value Stream Manager, KOSPO (Metallurgy and Materials). He may be contacted on Email – priyanshubajaj.8@gmail.com

Know Our Members

Praveen Deshpande is currently running his own consulting firm "JSK Consultants" consulting in the areas of Theory of Constraints, Lean –six sigma & Gear Design. His qualification is B.E. (Mech.) from B.L.D.E.A. Engg. College, Bijapur, Karnatak University, Dharwad.

Praveen Deshpande

He has over 22 years of experience in Manufacturing, Product Development, Quality Assurance, Vendor Management , Man Management & Product Engineering.

He has sound Technical Knowledge in Gear Engineering, Gear Manufacturing, Machining, Casting & Metallurgy.

He has also worked at RSB Transmissions Pune as Operations Head, American Axle & Manufacturing as Head Gear Engineering & Metallurgy, Carraro India Ltd. as Senior Manager Quality Assurance, Eicher Motors as Manager Quality & Manufacturing & Bharat Gears as Deputy Manager Manufacturing.

During his career he has undergone various training programs in the field of Gear Engineering, TOC & Lean Six sigma. He is holding Six Sigma Black Belt and completed more than 15 Black Belt projects successfully.

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