Evaluation of Mechanical and Microstructural Properties of Cast Iron with Effect Of Pre Heat and Post Weld Heat Treatment

Rajneesh Kumar[1], Munish Kumar[2], Vaibhav Trivedi[3], Rahul Bhatnagar[4]
P.G. Student, Department of Mechanical Engineering, IFTM University, Moradabad, U.P, India[1]
Assistant Professor, Department of Mechanical Engineering, IFTM University, Moradabad, U.P, India[2]
Assistant Professor, Department of Mechanical Engineering, IFTM University, Moradabad, U.P, India[3]
Assistant Professor, Department of Mechanical Engineering, IFTM University, Moradabad, U.P, India[4]

Abstract

Most of the welding of cast iron is repair welding. Carbon pickup and resulting cracks are the main concerns when welding CI. The casting process is never perfect, especially when dealing with large components. Instead of scrapping defective castings, they can often be repaired by welding. Naturally, the very high carbon concentration of typical CIs causes difficulties by introducing brittle martensite in the heat-affected zone of weld. It is therefore necessary to preheat to a temperature of 650 °C, followed by slow cooling after welding, to avoid cracking. The welding was carried out with manual shielded metal arc welding using ENiFe–CI filler metal. Shielded metal arc welding process using a nickel electrode was used to join a grey cast iron. The effect of pre heating on the microstructure, hardness, tensile and toughness was studied than the effect of post weld heat treatment (PWHT) on the microstructure, hardness, tensile and toughness was studied after that the same was tested on the preheated and post weld heat treated specimens. After that we concluded that which heat treatment process is suitable for cast iron weld.

I. INTRODUCTION

Weldability of cast iron has been found to be very poor due to the heterogenity of matrix phase and non-Weldability of the graphite phase. These phases undergo a series of microstructural changes in the HAZ during weld repairing by fusion welding the project discusses the nature of these

changes occurring in the vicinity of the weld zone as well as method of controlling these to get satisfactory weldment.Weldability of ductile cast iron depends on its original matrix, chemical composition mechanical properties and structure of welding process and working condition .The preheating temperature range depends on the hardenability of the iron chemical composition or carbon equivalent, the size and complexity of the weld and the type of filler materials. Preheating must be sustained for a time sufficient to avoid martensite formation and to prevent secondary graphite from developing in the matrix upon annealing or multipass welding. The effect of preheat is to reduce residual stresses, distortion, prevent cold cracking and reduce the hardness in the HAZ In this study, the HAZ structures and mechanical properties of grey cast iron welds have been examined in the as-cast and fully ferritizing annealing conditions under preheat temperatures.

The selection of the joining process for a particular job depends upon many factors. There is no one specific rule governing the type of welding process to be selected for a certain job. A few of the factors that must be considered when choosing a welding process are:

- Availability of equipment
- Repetitiveness of the operation
- Location of work
- Materials to be joined
- Appearance of the finished product
- Size of the parts to be joined
- Time available for work
- Cost of materials
- Code or specification requirements
- Quality requirements (base metal penetration, consistency, etc.)

II. LITRATURE REVIEW

Bhatnagar et al [1] studied the problematic welding characteristics of the cast iron originate majorly from the high carbon content of the material. Researcher work on the two methods of welding cold welding and hot welding. Then he work on the preheating of metal and find the best suited method of welding. Alie — This paper investigates welding cast iron is used in ships, bridges, pressure vessels, industrial machinery, automobile, rolling stock and many other fields. Problems associated with welding are common issues in these fields. A Study was conducted to investigate Weldability of grey cast iron, as grey cast iron contains graphite in flake form, carbon can readily be introduced into the weld pool, causing weld metal embrittlement and Grey cast iron welds are subject to the formation of porosity and the cold cracking susceptibility of welds. I.C. MON et al [4], This paper presents the Austempered Ductile Iron (ADI) is a new engineering material with an exceptional combination of mechanical properties and important applications in different fields. This revolutionary material with a unique combination of strength, abrasion resistance, hardness, the noise and vibration capability, along with good machinability of the material has opened up new applications in various sectors of industry as a replacement of conventional materials such as steel. Jorg C. Sturm et al [8], The researcher investigate the cast iron high strength compacted graphite iron (CGI) or alloyed cast iron components are substituting previously used non-ferrous castings in automotive power train applications. The mechanical engineering industry has recognized the value in substituting forged or welded structures with stiff and light-weight cast iron castings. New products such as wind turbines have opened new markets for an entire suite of highly reliable ductile iron cast components.

III.SPECIMEN PREPARATION

A. Foundry Work

- Making a pattern of wood in carpentry shop exact to the replica of plate to be cast i.e. Dimension- 320 mm length, 30 mm width, 6 mm thickness.
- With the help of pattern, making the sand mould by proper mixing of sand, clay and moisture.
- After removing the pattern, the mould cavity was formed.
- Melting of cast iron on pit furnace
- Pouring safely the molten metal in the mould cavity, after cooling the cast plate of Dimension was produced. The no of plates are 12.
- After casting plates are cleaned with brush and little hammering.

B. Machining Work

- All the plate are cut in two halves with the help of band saw in lab, after cutting the plate dimension become 60mm length, 50mm width and 6mm thickness.
- For making groove for welding plate, one of the edges of plate is cut at 22.5 degree so that both plates matched; angle of 45 degree was made. Edge cutting on all plate was made on when shaper machine in machining shop, the angle was given to the tool of shaper by moving it to 22.5 degree.
- Single V weld specimen was made because the thickness of the plate was only 6mm and from economy point of view it consumes less electrode then U joints.
- After the cutting, grinding and cleaning of welding surface were done.

C. Tensile Test

The sample for tensile test was prepared on lathe machine by turning operation as ASTM E8 standards. The tensile testing of the composite was done on UTM. Standard specimens with 100mm gauge length were used to evaluate ultimate tensile strength. The comparison of the properties of the composite materials was made with the commercially pure aluminium.

D. Impact Test

1. IZOD Test: The specimens for the IZOD test were prepared on shaper machine. The IZOD test specimen was 75mm long with 10×10 mm2 cross section, having a standard 45o notch 2mm deep.

2. CHARPY Test: The specimens for the CHARPY test were prepared on shaper machine. The IZOD test specimen was 55mm long with 10×10 mm2 cross section, having a standard 45o notch 2mm deep.

3. Hardness Test: The samples for the bending test were prepared on lathe machine. The samples were prepared according to ASTM E10. The dimensions for samples were 10mm diameter and 15mm length. After this, with the help of microscope, indent caused by the ball indenter is measured, a inbuilt micrometer scale is present in the microscope, which is adjustable according to the position of indent we can adjust it to measure the diameter of indent.

E. Microstructure:

The microstructure was taken with and without etching at different resolutions. The Microstructure was done to find the properties of weld of cast iron as well as the HAZ of weld.

IV.RESULT & DISSCUSSION

A. Tensile Strength Measurement

Tensile test was performed on universal testing machine. The specimens were prepared according to ASTM E8 standard. The first specimen prepared by manual metal arc welding process. Second specimen was prepared by preheating before welding process. Third specimen was prepared by preheating before the welding then welding the post welding procedure is applied. Forth specimen was a post welding heat treating.

S. No .	Prepared Samples	Tensile Strength(Mpa)			
		Sample 1	Sample 2	Sample 3	Average of Sample 1, 2 and3
1	Manual Welding	59.75	60.25	58.5	59.5
2	Preheated Welding	144.25	144.75	143.5	144.2
3	Preheated and Post Welding	159.25	158.75	158.5	158.85
4	Post Weld Heat Treating	161.25	162.75	160.5	161.5

Table 1: Tensile Test Result

S. N o.	Prepared Samples	Impact Strength(Joules)			
		Sample 1	Sample 2	Sample 3	Average of Sample 1, 2 and3
1	Manual Welding	26	25	27	26
2	Preheated Welding	30	29	30	29.67
3	Preheated and Post Welding	28	29	28	28.33
4	Post Welding Heat Treating	29	30	28	29

Table 2: Impact Strength Result

V. IMPACT STRENGTH MEASUREMENT (CHARPY TEST)

Charpy test was performed on impact testing machine. The specimens were prepared according to ASTM E23 standard. The first specimen prepared by manual metal arc welding process. Second specimen was prepared by preheating before welding process. Third specimen was prepared by preheating before the welding then welding the post welding procedure is applied. Forth specimen was a post welding heat treating.

VI. HARDNESS MEASUREMENT

Hardness test was performed on Brinell hardness testing machine. The specimens were prepared as per the standard specified in machine manual. The first specimen prepared by manual metal arc welding process. Second specimen was prepared by preheating before welding process. Third specimen was prepared by preheating before the welding then welding the post welding procedure is applied. Forth specimen was a post welding heat treating.

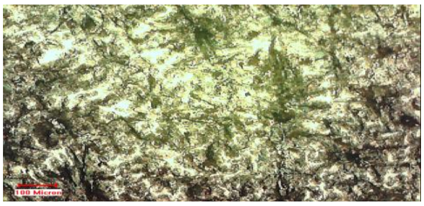
Table 3: Hardness Test Result

S N o	Prepared Sample				
		Sample 1	Sample 2	Sample 3	Average of Sample 1,2 and 3
1	Manual Welding	172	170	173	171.67
2	Preheating Welding	255	256	258	256.33
3	Perheating and Post Welding	212	211	212	211.67
4	Post Weld Heat Treatment	262	261	264	262.33

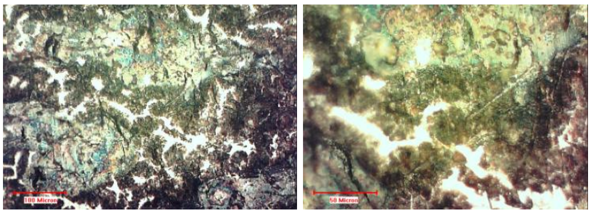
VII. ASSESSMENT AND EVALUATION BASED ON MICRO-STRUCTURE STUDY

A. *Normal Grey Cast Iron*

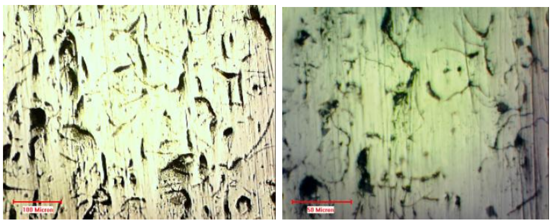
Microstructure of different region of welded specimen (base metal, welded zone, heat affected and partially melted zone) for different welded condition are given below:-



Microstructure1. Normal Grey Cast Iron base material after etching at 100X magnification



Microstructure2. Grey Cast Iron normal weld after etching 200 X and after etching 500X magnification



Microstructure3. Normal Welding without etching 200X and without etching 500X magnification

B. Microstructure of simple weld evaluation

Microstructure of welded grey cast iron at 200X and 500X magnification indicates that image is enlarged by 200 and 500 times of original image. The Micrograph is obtained after casting and the process applied of manual metal arc welding. The melt temperature for casting of grey cast iron is 1150 C. The micrograph shows that the intermolecular space is large.

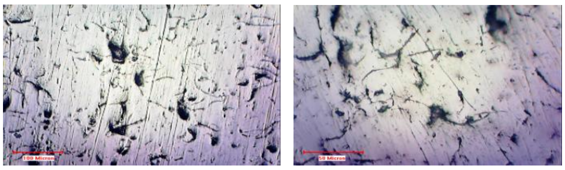
C. Base metal

Fig.1 shows microstructure of grey cast iron showing graphite in ferrite matrix and perlite matrix with hard and brittle phase of carbide.

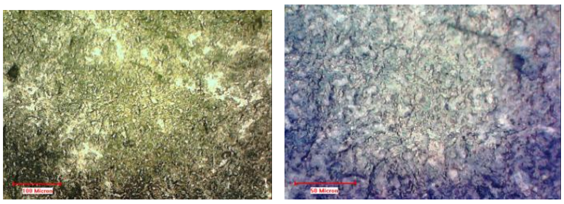
D. Fusion zone

Fig.2 & 3 shows the microstructure after and before etching at 200X and 500X magnification demonstrates that FZ microstructure consists of mainly an austenitic matrix plus small amount of dispersed graphite particles. Nickel filler metal is able to precipitate carbon, picked up from the BM, in its free form as graphite, nodular graphite structure is present.

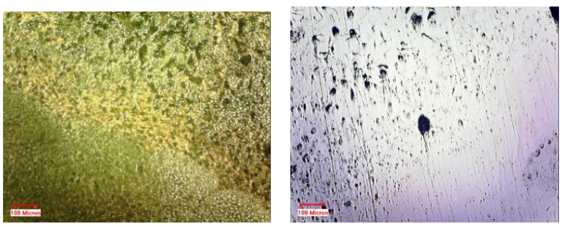
E. Preheated Welding



Microstructure4. Grey cast iron preheated welding base material before etching at 200X and 500X magnification



Microstructure 5. Grey cast iron preheated welding base material after etching at 200X and 500X magnification



Microstructure6. Preheated of grey cast iron the heat affected zone at etching 100X after and before of welding

Microstructure of preheat evaluation:-

F. Fusion Zone (FZ):

Fig. 4 this is the zone in which the base metal is melted and mixed with filler metal. Cooling rates are high in this zone producing very hard, brittle ledeburitic carbides in as welded Condition.

G. Heat Affected Zone (HAZ):

In this region, the peak temperature rises above the critical point. There is no melting but matrix transforms to austenite during heating. During cooling, a variety of transformation products are obtained.

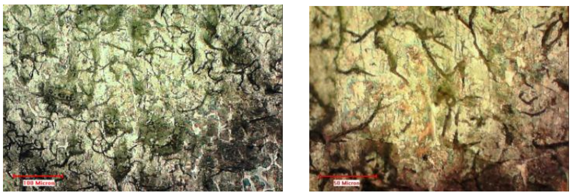
Fig.6 show some typical microstructures of HAZ for preheat. The HAZ contained approximately 80% pearlite and 20% martensite for the as-cast welding condition carried out at 650°C preheating. A thin film of pearlite may be observed around the spheroid formed due to diffusion of carbon back into the graphite spheroid resulting in a thin shell of austenite.

The mixed ferrite plus pearlite region is also observed; martensite in the as-welded HAZ contributes to inferior properties in the weldment after subcritical annealing. This is because the martensite decomposes to ferrite plus a fine distribution of secondary graphite

Decomposition of bainite or pearlite in the HAZ results in secondary graphite free ferrite with the carbon from bainite or pearlite matrix growing on the existing primary graphite in ductile cast iron.

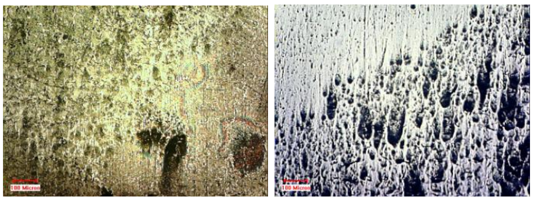
Martensite formation in the HAZ is associated not only with inadequate preheat temperatures but by neglecting to maintain the temperature for a sufficient time after welding to ensure transformation to non martensitic structures.

C. Preheated and Post Weld Heat Treatment:-

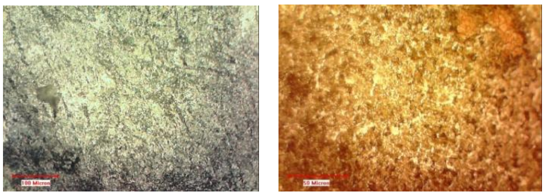


Microstructure7. Grey cast iron preheated and post weld heat treatment 200X and 500X magnification base metal with etching.

Microstructure8. Grey cast iron preheated and post weld heat treatment 200X and 500X magnification base metal without etching.



Microstructure9. Heat affected zone of preheated and post weld heated at with and without etching 100X magnification



Microstructure10. Grey cast iron preheated and post weld heat treatment 200X and 500X magnification welded metal with etching.

Microstructure Preheating and Post Weld Heat Treating Evaluation:-

H. Fusion zone

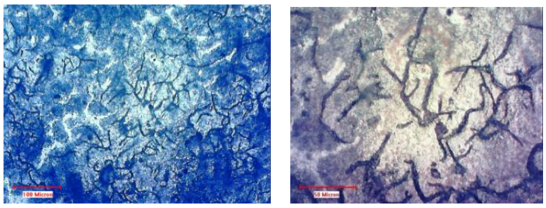
The Microstructure of base material fig. (7,8) of grey cast iron preheated and post weld heat treated at 200X and 500X magnification base material with or without etching the microstructure of grey cast iron showing grafhite in ferrite matrix. The microstructure of grey cast iron we can elaborate from this micrograph that the intermolecular space is reduced as compared to the Pure Grey cast iron sample and mechanical tests also prove it because the mechanical strength increases.

The Microstructure fig. (10) of base material of grey cast iron preheated and post weld heat treated at 200X and 500X magnification the microstructure of grey cast iron showing graphite in ferrite matrix.

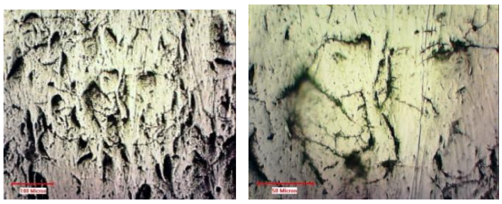
I. Heat Affected Zone

The microstructure fig.(9) of preheated and post weld heated of grey cast iron the heat affected zone at 100X magnification with or without etching showing heat affected zone consisting graphite flakes, martensite is in less quantities due to pre and post weld heating. Welded material of grey cast iron (preheated and post weld heated) at 200X and 500X magnification with etching the microstructure showing heat affected zone consisting graphite flakes, martensite is in less quantities due to pre and post weld heating. Partially melted zone cosist of carbon on nodular and flakes form.

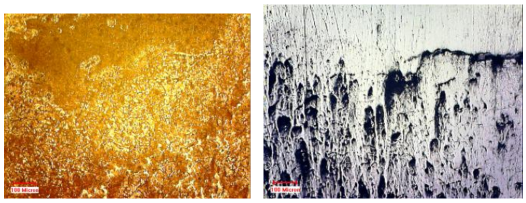
J. Post Weld Heat Treating:-



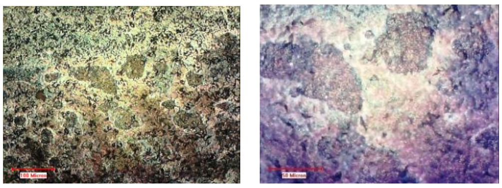
Microstructure11. Post weld treating the base material after etching at 200X and 500X magnification



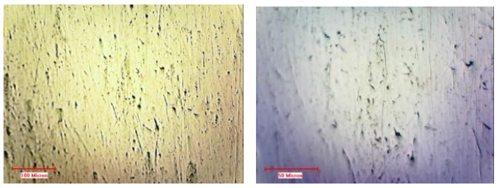
Microstructur12. Post weld heat treatment the base metal before etching at 200X and 500X magnification



Microstructure13. Post weld heat treating Heat Affected Zone after and before etching at 100X magnifications



Microstructure14. Post weld heat treating the weld metal after etching at 200X and 500X magnification



Microstructure15. Post weld the weld metal before etching 200X and 500X magnification

K. Microstructure after PWHT Evaluation:-

PWHT is necessary in most cases in order to eliminate the massive carbides and martensite in HAZ and PMZ and thus reduce hardness and brittleness. Two most common PWHTs for cast iron weldments are subcritical tempering and full (ferritizing) annealing. Low temperature tempering can reduce hardness of martensite; however, higher tempering temperature is required to graphitize the eutectic carbides. Secondary graphitization reduces the brittleness of PMZ and HAZ and improves impact properties. However, excessive graphitization can reduce ductility of weldment. PWHT rather than subcritical tempering gives better microstructure control and the excessive graphitization and formation of chain-like graphite is prevented.

Therefore, in this study a full annealing PWHT was chosen including heating up to 650°C, holding for 2 hours at 650°C and then furnace cooling. Fig. (11,12,14,15) shows various microstructural zones in the weldment after PWHT. As can be seen, the microstructure of FZ is remained unchanged after PWHT thermal cycle. However, HAZ microstructure significantly is affected by PWHT. As can be seen in fig.(13), HAZ consists of graphite matrix in a flakes in a ferrite matrix. Holding in 650^{o} C for two hours provide sufficient driving force to dissolve of eutectic carbide and the martensite phases formed during the welding. During the slow furnace cooling, graphite is formed in a ferrite matrix but not Fe-C. The applied PWHT can reduce formation of brittle phases in HAZ.

V. CONCLUSIONS

In this study it is observed that formation of martensite and carbide in fusion zone can be controlled via controlling of cooling rate and chemical composition of fusion zone. Result of the current study showed that by using nickel base filler material, the formation of brittle martensite and carbide in fusion zone is prevented. It was shown that HAZ microstructure of grey cast iron contains martensite. Also, PMZ microstructure contains hard eutectic carbide and martensite. To resist against this problem it is advisable to reducing cooling rate via preheating to prevent martensite and carbide formation or post heat treatment to decompose martensite and carbides to softer microconstituents.

Preheating enables to avoid the formation of martensite, however high preheat temperature which is sufficient for prevention of martensite formation induces other problems distortion of the work pieces (in the case of local preheating). Only, very slow cooling rates can prevent the eutectic–carbide formation during solidification in PMZ, full annealing including heating up to 810°C, holding for 45 minute at 810°C and then furnace cooling was used. This PWHT was successful in the dissolution of martensite in HAZ and graphitization in this zone. Also, this heat treatment was successful in the reduction of PMZ hardness. Applied

PWHT was successful in producing a weld with nearly uniform hardness profile. Therefore, according to the results presented in this paper, it can be concluded that welding of grey cast iron with a nickel filler metal coupled with applying a proper full annealing (ferritizing) PWHT can serve as solution for grey cast iron welding problems.

ACKNOWLEDGMENT

This work is part of M.Tech Dissertation of first author, being submitted at IFTM University Moradabad, India. The author wish to record their sincere thanks to Mr. Munish Kumar and Mr. Rahul Bhatnagar for their guidance and the Management of the IFTM University for providing the necessary facilities and permission to carry out this work.

REFERENCES

[1] Ravi Kumar Bhatnagar1, Gourav Gupta2, "A REVIEW ON WELDABILITY OF CAST IRON" International Journal of Scientific & Engineering Research, Volume 7, Issue 5, May-2016.

[2] Alie Wube Dametew, "Experimental Investigation on Weld Ability of Cast Iron" Experimental Investigation on Weld Ability of Cast Iron. Science Discovery. Vol. 3, No. 6, 2015.

[3] Sachin B. Sutar1, Dr. K. H. Inamdar2, "Analysis of Mechanical Properties for Welded Cast Iron" Journal of Emerging Technologies and Innovative Research (JETIR), Volume 2, Issue 6, June 2015.

[4] I.C. MON1, M.H. ŢIEREAN2, "A REVIEW ON TESTS OF AUSTEMPERE DUCTILE IRON WELDING" Bulletin of the Transilvania University of Braşov • Vol. 8 (57) No. 1 – 2015.

[5] Saliu Ojo Seidu1, Bolarinwa Johnson Kutelu2, " Influence of Heat Treatment on the Microstructure and Hardness Property of Inoculated Grey Cast Iron" International Journal of Engineering and Technology Volume 3 No. 9, September, 2013.

[6] Johnson O. Agunsoye1, Talabi S. Isaac2, Olumuyiwa I. Awe3, "Effect of Silicon Additions on the Wear Properties of Grey Cast Iron" 1-61-67, Journal of Minerals and Materials Characterization and Engineering, 2013.

[7] E. Fraś1, M. Górny2, " Inoculation Effects of Cast Iron" ARCHI VES of FOUNDRY ENGINEERING, ISSN (1897-3310) Volume 12 Issue 4/2012.

[8] Jörg C. Sturm1, Guido Busch2, "Cast iron - a predictable material" MAGMA Gießereitechnologie GmbH, Aachen, Germany, February 2011.

[9] BIPIN KUMAR SRIVASTAVA1, DR. S.P. TEWARI2, JYOTI PRAKASH3, "A REVIEW ON EFFECT OF PREHEATING AND/OR POST WELD HEAT TREATMEMT (PWHT) ON MECHANICAL BEHAVIOUR OF FERROUS METALS" International Journal of Engineering Science and Technology Vol. 2(4), 2010.

[10] Hieu Nguyen, "Manufacturing Processes and Engineering Materials Used in Automotive Engine Blocks" School of Engineering Grand Valley State University, EGR250 – Materials Science and Engineering Section B, April 8, 2005.

[11] Jin-Shin Ho1, C. B. Lin2, C. H. Liu3, "The Effect of Heat Treatment on Interface Properties of S45C Steel/Copper Compound Casting "Tamkang Journal of Science and Engineering, Vol. 6, No. 1, pp. 49-56 (2003).

[12] K. Müller1, W. Baer2, P. Wossidlo3 and D. Klingbeil4, "Investigations on the Dynamic Fracture Toughness Behaviour of Nodular Cast Iron" Federal Institute for Materials Research and Testing (BAM), Under den Eichen 87, D-12205 Berlin, Germany.

[13] R. C. VOIGT1, C. R. LOPER2, "A Study of Heat-Affected Zone Structures in Ductile Cast Iron" 82-s | MARCH 1983.