Fatigue Phenomena in Meehanite Cast Irons with Nodular Graphite

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Meehanite irons of nodular type, " S " type of Meehanite irons, have been developed for service conditions calling for exceptional strength and toughness. They are particularly suited for applications, where resistance to shock is important. They offer the advantage of castings to replace forgings and weldments in a wide range. The heat treatment of those irons increases strength, hardness and toughness.

We investigated the fracture surfaces of tensile test specimens of Meehanite irons of nodular type, aimed for production of crank shafts and also the fractured surfaces of broken crank shafts after testing in diesel engine.

We investigated two types of the nodular irons. The SP type which possesses in the as cast condition combination of high strength and toughness. The SP type is a pearlitic nodular graphite iron, finding many applications where high stresses and shocks are encountered. Examples are cast - to - form pressing and stamping dies, heavily stressed machine parts, heavy duty gears. The SP type meets the requirements of British Standard Specification 2789,37/2.

Another type is the SH iron, which after heat treatment gives various combinations of strength and hardness values to suit particular service conditions. It provides high strength with moderate hardness for machinable wear or high stress applications. Where exceptional strength and toughness are required, with moderate machinability, a normalising treatment may be employed.

Cast irons containing graphite in the spheroidal form allows the mechanical properties of the matrix to be fully exploited and in pearlitic cast irons, fractured at room temperature considerable ductility is observed.

With SP types the following values of cast irons are obtained :

Tensile strength	min.	60 kp/mm^2
Yield strength	min.	42 kp/mm^2
Elongation on 2"(50 mm)	min.	2 %
Brinell Hardness		180 - 240 BHN

The normal types of test bars specified for irons with flake graphite are not suitable for irons with nodular graphite. This is because the normal cylindrical bars used for flake graphite give centre - line shrinkage when used for nodular irons. This is recognized by the fact that all national specifications stipulate that the test bars must be cast as " Y " blocks or " U " blocks. The dimensions of those blocks are prescribed by the British Standards BS 2789 : 1961 and the German Standards DIN 1693.

The German standard DIN 50146, for the tensile testing for steel, prescribes that the rate of loading must be such that the deformation must not be more than 0.4 % per second, after passing the yield point.

The chemical analyses for the Meehanite S Types can only indicate the required analyses for casting sections of progressive thicknesses as shown in Table I. The maximum phosphorus content of the S types of Meehanite should be 0.01 % P. It is proposed not to exceed a C_E value of 4.4 where $C_E = TC + 1/3\ Si$.

Meehanite spheroidal graphite irons are appreciably more sensitive to the presence of small amounts of elements, which in flake graphite irons are relatively unimportant so the procedures involved in the production process of the S types of Meehanite are more complex as those with flake graphite irons and it is easily understood that our Department was involved in many investigations product testing procedures of nodular Meehanite cast irons [1-4] which were produced in Torpedo foundry in Rijeka, with which we are in close cooperation.[++]

Table I. Recommended Target Analyses for the Meehanite S Types indicating the required analyses for casting sections of progressive thicknesses

Casting section in mm	SP and SH			SPF[+]		
	T.C.	Si	Mn	T.C.	Si.	Mn
15	3.5	2.6	0.60	3.5	2.6	0.30
15 - 25	3.5	2.5	0.70	3.5	2.5	0.30
25 - 40	3.5	2.4	0.90	3.5	2.4	0.30
40 - 60	3.4	2.3	0.90	3.4	2.3	0.40
60 - 100	3.4	2.0	1.00	3.4	2.0	0.50
100 - 150	3.3	1.8	1.00	3.3	1.8	0.60

[+] Meehanite iron with nodular graphite meets the requirements of British Standard Specification 2789, 32/7 having ferritic and pearlitic matrix.

Microstructures characterisation in the TEM and SEM

As already pointed out we investigated a series of fracture surfaces of the tensile test bars and of the fractured surfaces of crank shafts after running in diesel engine under service conditions.

For those investigations we used the TEM and SEM techniques. While the theory and instrumentation principles[5] and practical aplication[6] of the SEM and TEM are treated in detail elsewhere, the SEM and TEM possess similarities as a result of their common basis in electron optics we could obtain mostly comparable results of fractographic examina=

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tions of the fractured surfaces. The TEM like the SEM utilizes a magnetic lens system to focus the electron beam onto the sample.

To obtain fractographs of the broken surfaces the TEM of Carl Zeiss in Jena was used, operated at 65 Kilovolt accelerating potential. The direct carbon replicas were made by evaporating a thin film of carbon directly into the fracture surface in a vacuum evaporator.

To obtain scanning electron micrographs small specimens 1/2 in x 1/2 in x 1/8 in were cut from the fracture surface and mounted into a specimen stub of a Cambridge Stereoscan Mark II with Durifix and colloidal silver.

In general we obtained almost the same results of fractographic examinations of the fractured surfaces on behalf of TEM and SEM techniques.

On the broken surfaces the fatigue striations as intergranular fractures were observed. The river patterns could not exactly be observed on cleavage fractures, obtained with the TEM and SEM techniques.

Another important result represents the fracture pattern obtained with the SEM on the 4 - stroke diesel engine crank shaft, having the following mechanical characteristics:

Tensile strength	86,6	kp/mm^2
Yield strength	58,6	kp/mm^2
Elongation on 2"	3,0	%
Brinell Hardness	278	BHN
Toughness K_α	0,84	kpm/cm^2

which broke after the following running times :

at n = 2000 rev. .... 14,5 hours
at n = 2300 rev. .... 42,5 hours

On the fractured surface of the investigated crank shaft we observed that the spheroidal graphite particles did not interact with the matrix during this practical fatigue testing so the overall resemblance to the dimple rupture was partially observed.

The similar results were obtained after cyclic testing of the samples in fatigue.

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