Austempered Ductile Iron (ADI) Alternative material for high performance applications

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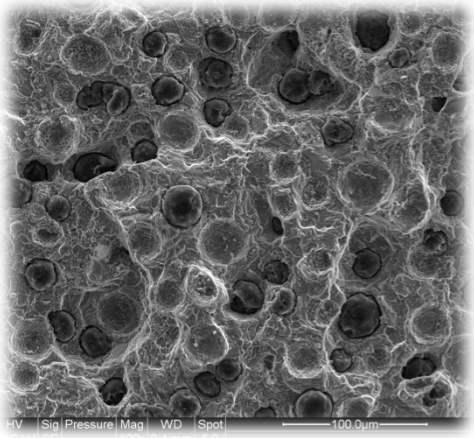
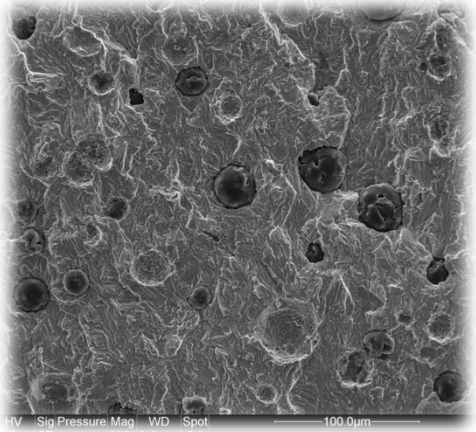
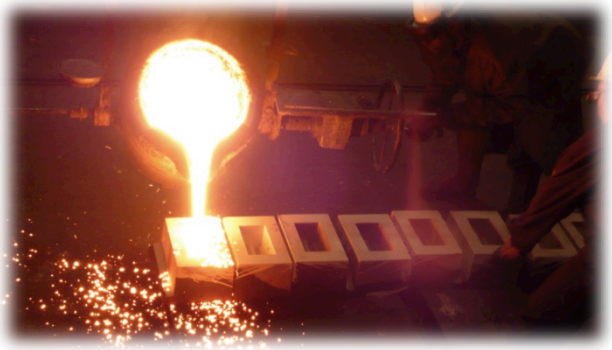
1. IK4-Azterlan
2. Adilan Group
3. ADI Treatments Ltd.
4. Tecnun (University of Navarra)

AGENDA

- Introduction
- Experimental procedure
  - Foundry practice
  - As cast material
  - Heat treatment
  - Fatigue and fracture







- Results and discussion
  - Relative toughness
  - Fatigue behavior
- Conclusions

INTRODUCTION

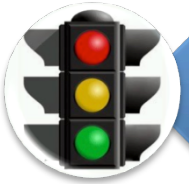
ADI Grades

		Rm [MPa]	Rp0.2 [MPa]	%A	Unnotched impact [J]	HBW 10/3000
ASTM A897M-15	Grade 1	900	650	9	100	269-341
	Grade 2	1050	750	7	80	302-375
	Grade 3	1200	850	4	60	341-444
	Grade 4	1400	1100	2	35	388-477
	Grade 5	1600	1300	1	20	402-512
EN 1564-2012	EN-GJS-800-10	800	500	10	110	250-310
	EN-GJS-900-8	900	600	8	100	280-340
	EN-GJS-1050-6	1050	700	6	80	320-380
	EN-GJS-1200-3	1200	850	3	60	340-420
	EN-GJS-1400-1	1400	1100	1	35	380-480
	EN-GJS-HB450	1600	1300	-	20	>450

INTRODUCTION

- Implications of high strength materials

High performance applications require advanced design approaches



Some standard properties become “go-no go” gages

High strength introduces a Ductile vs. Brittle competition

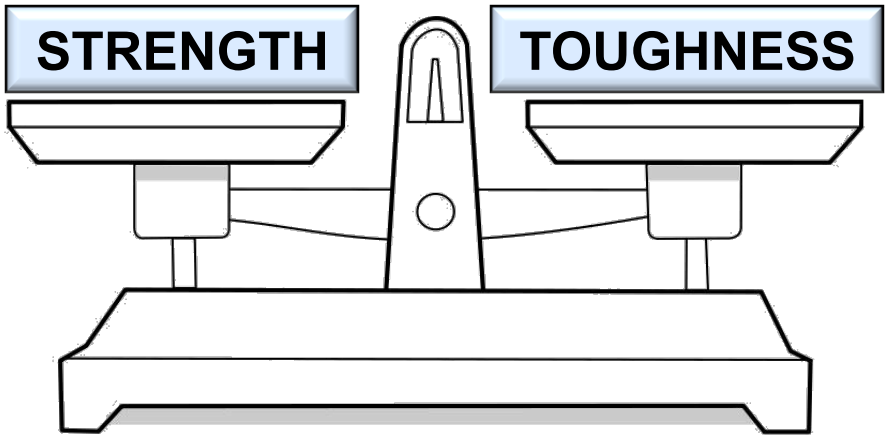
ADI is an example of how design paradigms can change

INTRODUCTION

- Comparison of two ADI Grades in he frame of the following key points affecting the performance of high strength materials.

  - Does higher strength of ADI mean lower toughness?
  - How fatigue and fracture behaviors change the design scenarios.

ADI 900



ADI 1200

EXPERIMENTAL PROCEDURE

▶ SAMPLE MANUFACTURE

Industrial foundry practice

ADILAN

Austempering Heat Treatment

ADI TREATMENTS

Toughness and fatigue study





IK4 AZTERLAN Research Alliance

Metallurgical control of the as cast condition

IK4 AZTERLAN Research Alliance

Metallurgical control of the heat treated condition

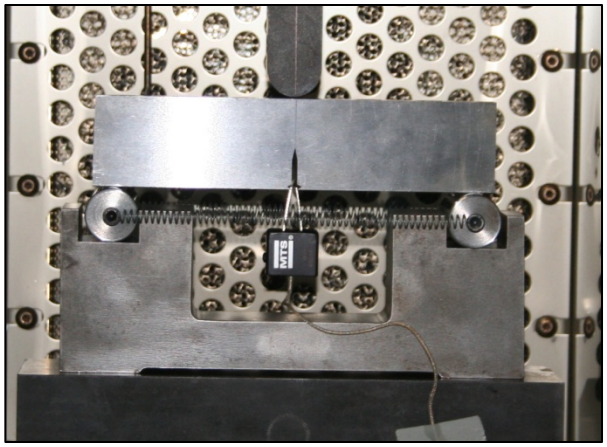
EXPERIMENTAL PROCEDURE

► REMARKS ON THE TESTED MATERIALS

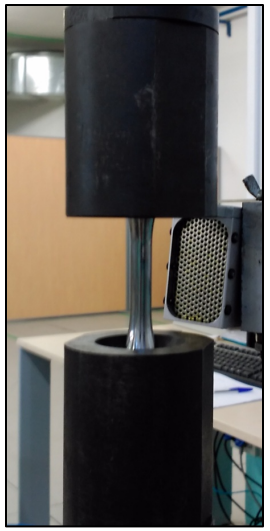
- The samples are not manufactured at laboratory scale but under regular industrial production conditions.
- From the material point of view, the only variable of the process is related to the ADI grade, and more specifically, to the isothermal quenching temperature.
- The ADI Grades that have been used are GJS-900-8 (Grade 1) and GJS-1200-3 (Grade 3).
- The conventional tests have been performed in “as cast” condition and “heat treated” condition to ensure that materials represent the target standard grades.

EXPERIMENTAL PROCEDURE

▶ FRACTURE AND FATIGUE TESTING



- Toughness test after BS7448-1
  - B(E) specimens dimensioned W=25 mm / B=12,5 mm



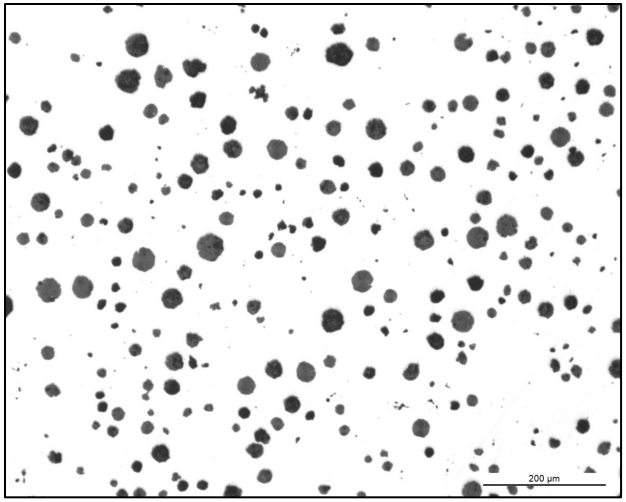
- Uniaxial fatigue testing after ASTM E466
  - Calibrated gage diameter Ø10 mm
  - Surface polished down to <0,2 μm Ra
  - Fatigue stresses proportional to $R_{p0,2}$

RESULTS AND DISCUSSION

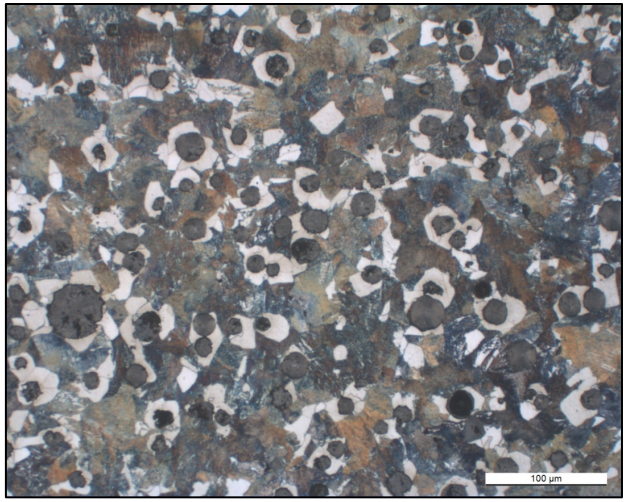
AS CAST CONDITION

		Results in %								
		C	Si	Mn	P	S	Mg	Ni	Mo	Cu
Target composition	*min.*	*3,65*	*2,10*	*<0,25*	*<0,040*	*<0,010*	*0,035*	*2,30*	*0,20*	*0,70*
	max.	*3,75*	*2,35*				*0,042*	*2,50*	*0,25*	*0,90*
Obtained composition		**3,69**	**2,28**	**0,19**	**0,025**	**0,008**	**0,037**	**2,45**	**0,20**	**0,79**

Hardness (HB10/3000W)	273						
Tensile testing	**$R_{p0.2}$ (MPa)**		**R_m (MPa)**		**A (%)**		
	625		852		4.7		
Impact testing	**KV (J)**			**Unnotched (J)**			
	5	5	5	39	34	37	



Nodularity %	Graphite density (nod./mm^2)	Ferrite/ pearlite ratio
>90	200	20/80

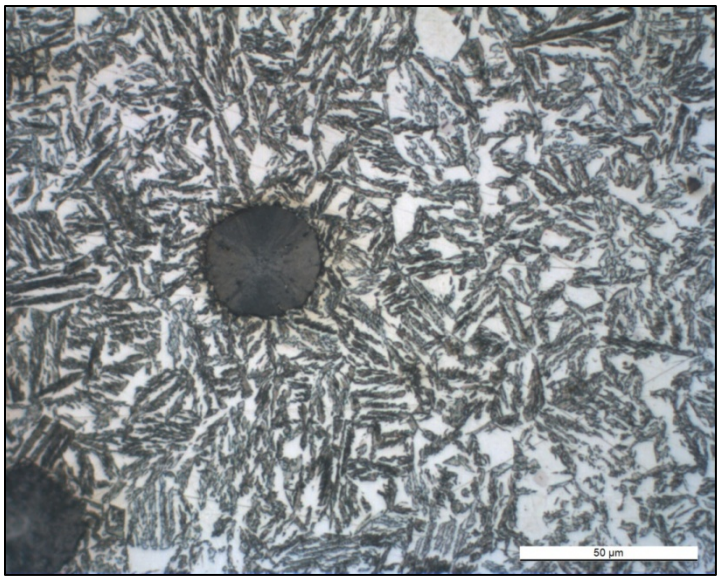


RESULTS AND DISCUSSION

AS HEAT TREATED

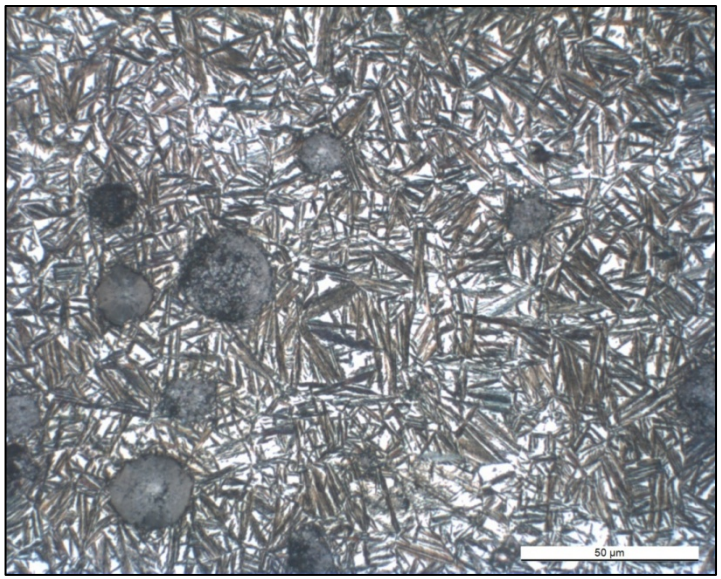
GJS- 900-8

Hardness (HB10/3000W)	314					
Tensile testing	$R_{p0.2}$ (MPa)			R_m (MPa)		A (%)
	622			963		10,4
Impact testing	KV (J)			Unnotched (J)		
	8	9	9	105	99	106



GJS-1200-3

Hardness (HB10/3000W)	397					
Tensile testing	$R_{p0.2}$ (MPa)			R_m (MPa)		A (%)
	1035			1260		9,8
Impact testing	KV (J)			Unnotched (J)		
	7	7	8	104	102	94

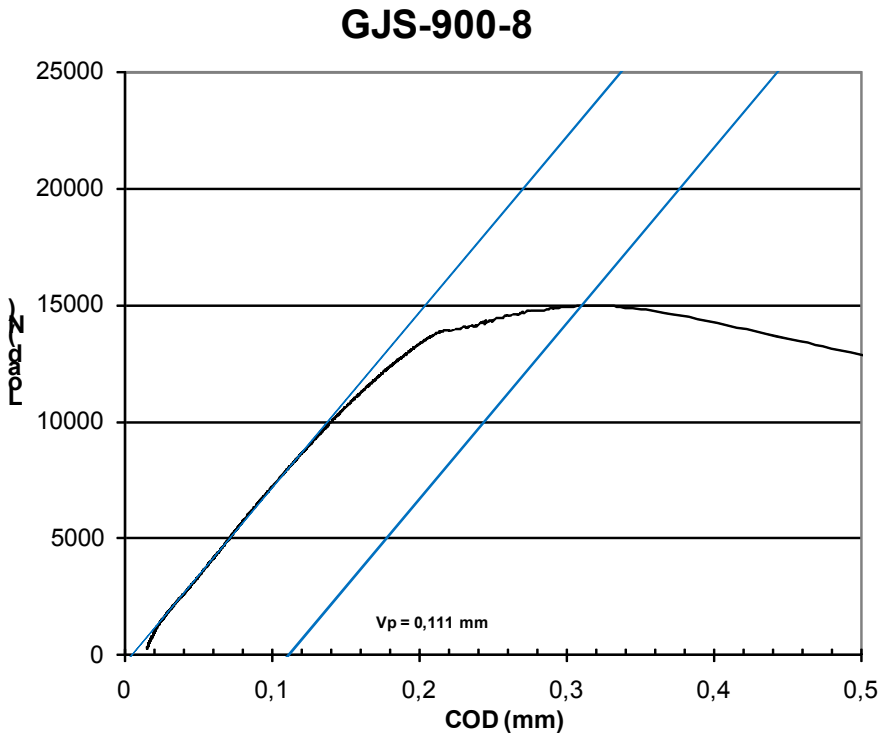


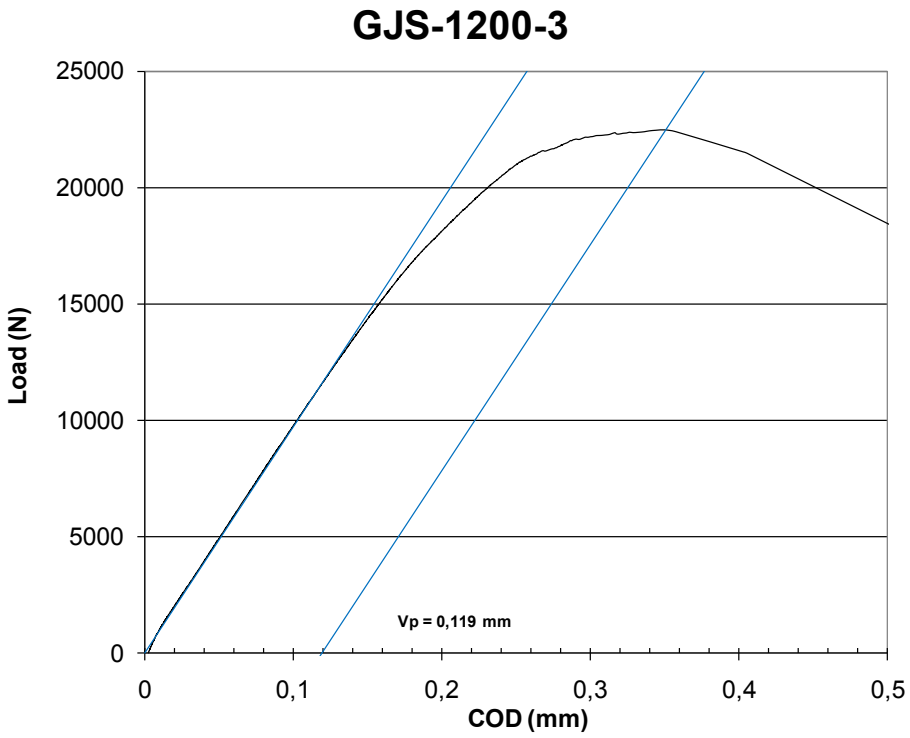
RESULTS AND DISCUSSION

FRACTURE MECHANICS

High strength grade is tougher!

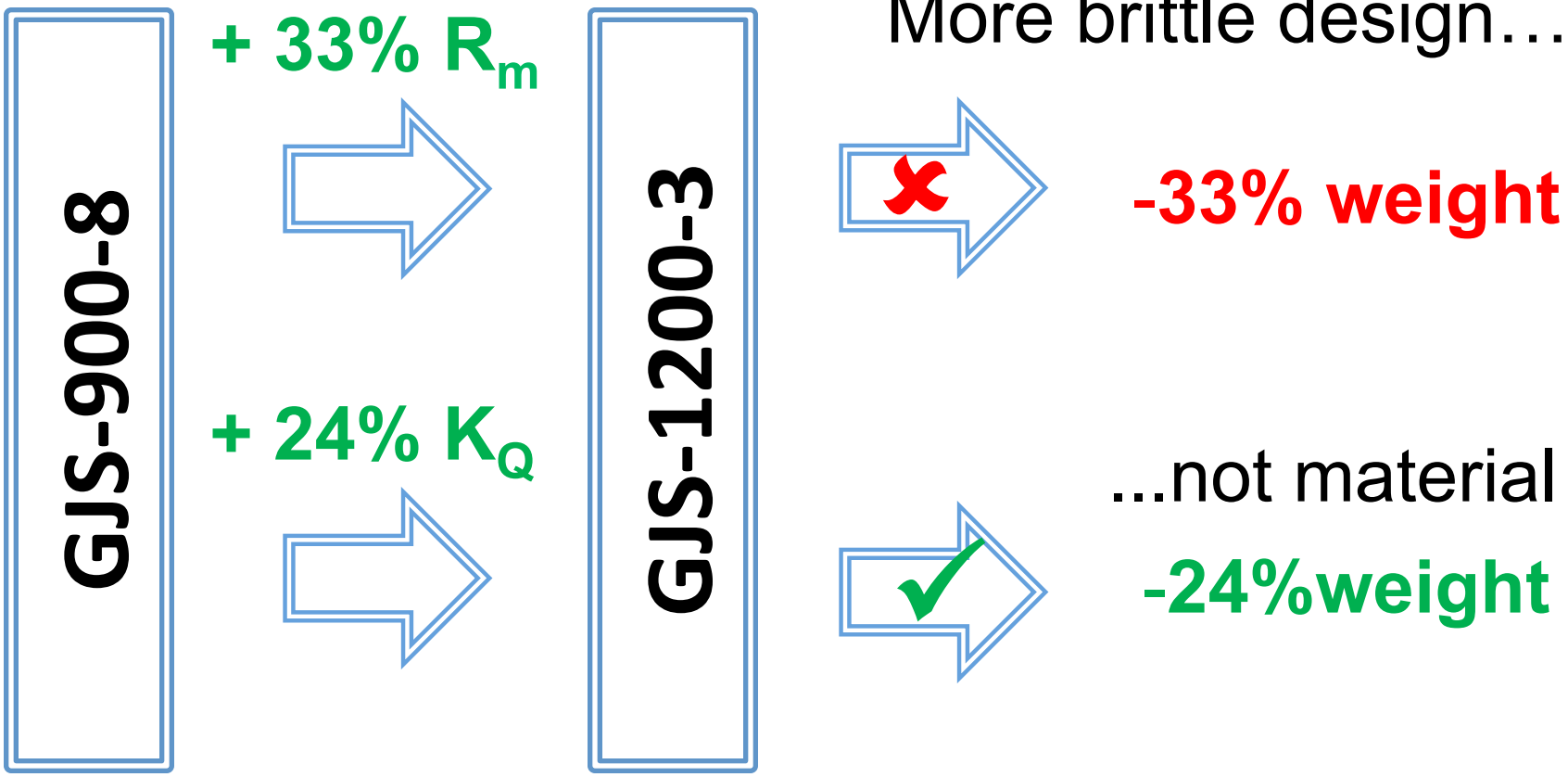
Grade	K_Q (MPa·m$^{1/2}$)	δ_c (mm)
GJS-900-8	50	0.05
GJS-1200-3	64	0.05





RESULTS AND DISCUSSION

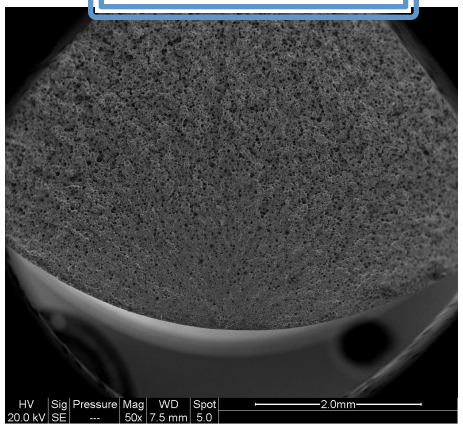
▶ FRACTURE MECHANICS

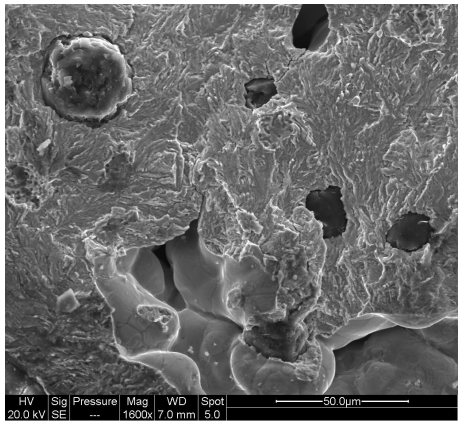


RESULTS AND DISCUSSION

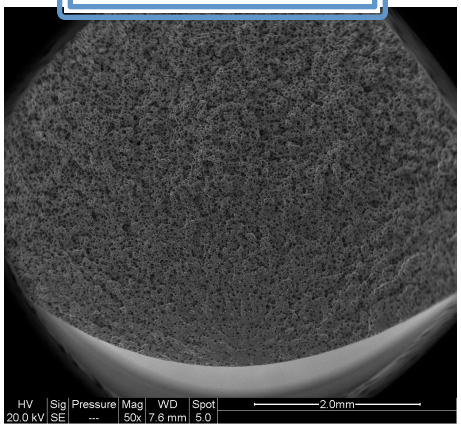
FATIGUE BEHAVIOR

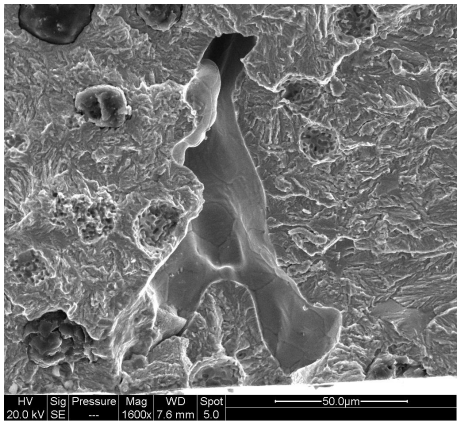
GJS- 900-8

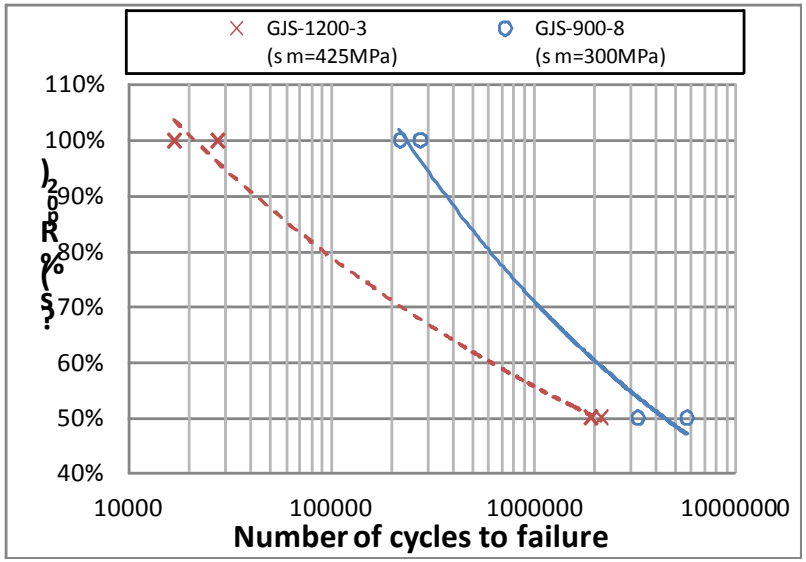




GJS-1200-3







The benefits of higher strength can not be directly implemented in weight reduction

CONCLUSIONS

- Micro-shrinkage sensitivity of the tested material conditions fatigue behavior. The extrapolation of the results is bound to reproducing the excellent foundry practice employed, that minimized shrinkage defects.

- GJS-900-8 y GJS-1200-3 Grades that have been manufactured for the study are able to develop plasticity on the crack tip and, thus, from a fracture mechanics point of view, they shouldn't be addressed as brittle.

- The ADI Grades are a solution for plenty of applications, provided fracture and fatigue are assessed during the design stage.

ACKNOLEDGEMENTS

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