Application of ADI for Suspension Components in Off-Road Vehicles & other Application



World Conference on Austempered Ductile Iron, Oct. 27-28, 2016

'he Westin – Peachtree Plaza, Atlanta, GA

Project Goals: *Reduce weight by 150 KGS per vehicle*

- This presentation introduces the application of Austempered Ductile Iron (ADI) in the chassis suspension of an off-road vehicle.
- Computer-aided Engineering (CAE) tools were used to redesign the structure of components in order to maximize the performance of ADI.
- High quality ductile iron and attention to heat treatment process control produced Grade 1050 ADI that passed both benchmark and road testing prior to a successful application.
- Several ADI conversions of suspension components will be described to demonstrate that ADI should be a material of choice for automotive chassis components.
- The results met the project expectation.



ADI grade verification

Material	Rm(MPa) Min.	Rp0.2(MPa) Min.	Elongation (%)	Heat treatment	Specification
QT400-15	400	250	15	As cast or anneal	EQC1626-2013
QT420-12	420	275	12	As cast or anneal	EQC1626-2013
QT450-10	450	310	10	As cast or anneal	EQC1626-2013
AD900	900	650	9	Austempering	SAE J2477-2004
AD1050	1050	750	7	Austempering	SAE J2477-2004
ZG270- 500	500	270	18	Normalizing	EQY-108-2011
ZG310- 570	570	320	15	Normalizing	EQY-108-2011
ZG35Mn V	600	360	10	Normalizing	EQY-108-2011
ZG40Mn V	700	400	8	Normalizing	EQY-108-2011
ZG40Cr	690	480	16	Q&T	EQY-108-2011
40Cr	980	785	8	Q&T	GB/T 3077-1999

Table 1. Mechanical properties of materials for vehicle chassis applications are listed.

REDESIGN - ADI CONVERSIONS

Working Condition	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5	Condition 6
Original structure	49 MPa	294 MPa	119 MPa	470 MPa	86 MPa	56 MPa
ADI conversion	164 Mpa	678 Mpa	159 Mpa	739 Mpa	124 MPa	85 MPa



REDESIGN - ADI CONVERSIONS



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REDESIGN - ADI CONVERSIONS



MELTING & CASTING

Max. section	X/mm	С	Si	Mn	Р	S	Cu	Cr	Mg
Specification	15≤X≤20	3.5-3.7	2.3-2.7	0.25-0.35	≤0.04	≤0.02	0.45-0.55	≤010	
	20≤X≤30	3.5-3.7	2.3-2.7	0.25-0.35	≤0.04	≤0.02	0.70-0.80	≤0.10	
Actual	15≤X≤20	3.65	2.44	0.30	0.032	0.012	0.72	0.014	0.035
	20≤X≤30	3.61	2.55	0.29	0.033	0.011	0.71	0.013	0.033

1. High Quality Pig Iron was adopted

2. Casting Process was strictly controlled

MELTING & CASTING

The cored-wire nodularizing process was used to improve nodularity,

Stream inoculation was conducted to raise the nodule count to 150-200/mm²,

Pouring time was limited to 6 minutes,

Copper was added ensure hardenability for austempering,

Chills were used, when appropriate, to minimize the presence of porosity and shrinkage.

(This is representing the best casting technology in China today)

MELTING & CASTING



The location of chills in the mold for a front load bracket are shown.

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Heat Treatment at Austemper Suzhou



ADI COMPONENTS MECHANICAL PERFORMANCE

	Nodularity (%)	Nodule Count (#/mm ²)	Rm (MPa)	RP 0.2 offset (MPa)	Elongation (%)	E (GPa)
SAE J2477	≥85	≥100	≥1050	≥750	≥7	≥148
Actual	90	150	1200	980	7.0	190



APPLICATION

		Unit Weight
No.	Description	(kg)
1	Front link bracket (left/right)	33.60
2	Middle link bracket (left/right)	42.53
3	Rear link bracket (left/right)	42.36
4	Upper control arm (left/right)	20.80
5	Lower control arm (left/right)	44.39
6	Front stable bar bracket (left/right)	1.74
7	Rear stable bar bracket (left/right)	2.35
8	Front upper block bracket (left/right)	3.07
9	Rear upper block bracket (left/right)	3.17
10	Front lower block bracket (left/right)	4.52
11	Rear lower block bracket (left/right)	6.63
12	Front spring upper bracket	2.47
13	Upper control arm bracket	2.24
14	Clamp	0.78

APPLICATION



Figure 6. Front link bracket



Figure 7. Middle link bracket



Figure 8. Rear link bracket

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Figure 9. Upper Control Arm Figure 10 Lower Control Arm.

APPLICATION



Figure 11 Front Stable Bar Bracket

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Figure 13 Figure 14ल et Front Upper Block Bracket Rear Upper Block Bracket



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Project meets the goal-Reduce weight by 150 KGS

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Challenges of ADI in China

- **1.** Raw Material Quality is not consistent
- 2. Casting Quality is not consistent
- 3. Heat Treatment Equipment/Process Control is Poor

Challenge 1 ADI Development in China Raw Material Quality Need to be consistent



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Challenge 2 ADI Development in China Casting Quality Need to be consistent



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Challenge 3 ADI Development in China Heat Treatment Equipment & Process Control







ISO 17804 Issued 2005*	GB/T24733-2009 国标	ASTM A897/A897M Issued 2006
		750-500-11**
800-500-10**	QTD800-10	
900-600-08	QTD900-8	900-650-09
1050-700-06	QTD1050-6	1050-750-07
1200-850-03	QTD1200-3	1200-850-04
1400-1100-01	QTD1400-1	1400-1100-02
		1600-1300-01

*ISO designation for sections less than 30mm. **Produced by intercritically austenitizing.

The Austemper Heat Treat Process for Cast Iron 铸铁等温淬火工艺



Iron Types / Tensile Strength 铸铁类型/抗拉强度

Gray Iron 灰口铸铁 (140-275 MPa)

Compacted Graphite Iron 蠕墨铸铁 (275-400 MPa)

Malleable Iron 可锻铸铁 (400-725MPa)

Ductile Iron 球墨铸铁 (400-825 MPa) ADI 等温淬火球墨铸铁 (750-1600 MPa)



What is High Quality Ductile Iron? 何谓高品质的球墨铸铁?

Consistent Chemistry

稳定的化学成份

- 100 nodules/mm2 minimum
- 石墨球数大于100个/mm2
- 85%+ Nodularity

球化率大于85%

- 1.5% max. carbides, inclusions, porosity and micro-shrinkage combined.
- 碳化物、夹杂、缩孔和显微疏松等铸造缺陷总量应小于1.5%
- Consistent pearlite/ferrite ratio 稳定的珠光体/铁素体比例







First Commercial ADI Application ADI首例商业应用



Tecumseh Products, Wagner Casting Company, CAPCO-1972

ADI Crankshafts ADI曲轴





ADI Light Vehicle GM CV Joints for 4-wheel Drive 通用公司4轮驱动车ADI连轴器





Heavy Truck Air Suspension 重卡气体悬挂





Converted from a steel forging.

ADI悬梁代替 原来的锻钢件





 Cast structural beam — Redesigned beams utilize premium materials to improve durability more than 350 percent*

*Based on lab testing

Vehicle Suspension and Chassis 车用底盘和悬挂零件







GM Hypoid Ring and Pinion Gear Set-1977 通用公司从1977年开始生产ADI螺旋伞齿轮



ADI Timing Gears for Diesel Engines 柴油机ADI正时齿轮





ADI Mining Machinery component





ADI Transmission Components ADI传动零件



ADI Components for Large Gearboxes 大型齿轮箱ADI零件 (including wind turbines) 包括风力发电设备









ADI Railcar Suspension Components ADI 火车悬挂件



ADI Suspension Bracket Conversion 用ADI 替代的悬挂支架



Original Steel Design

原先钢件设计



ADI Sprocket Design - Case Study ADI 链轮设计-案例研究



Original Design - solid/thick 7003 ductile iron, induction hardened 最初设计-实心/厚的700-3级球墨铸铁, 感应淬火处理 Part Wt./零件重量 – 37.7 kg/公斤 (83 lbs/磅) Factor of Safety/安全系数 = 1.2 Re-design – hollowed/thin 7003 ductile iron (Austempered) 改进设计-空心/薄的700-3级球墨铸铁, 等温淬火处理 Part Wt./零件重量 – 22.6 kg/公斤 (50 lbs/磅) Factor of Safety /安全系数 = 2.3