



제 9회 단조심포지엄

항공기용 열간단조품 개발

*김성태, *최영순, **권용남, **이정환

* (주)현대기공

** 한국기계연구원 공정연구부

HD HYUNDAE MACHINERY
FORGING IND CO., LTD.

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(주) 현대기공 소개

Dec.	1983	Established Hyundai Machinery Forging Co., Ltd
Feb.	1984	Opened Seoul office
Mar. 19th	1985	Approved by L.R(Lloyd's Register of Shipping)
Dec. 30th	1985	Approved by K.R(Korea Register of Shipping)
Dec.	1988	Initial shipment to Japan
May	1989	Relocated to Changwon industrial complex 2nd area (land : 8,264.2 m2)
Nov.	1989	Initial shipment to U.S.A
Jan.	1990	Installed 2 induction heater (500 KW)
Feb.	1991	Installed 2 induction heater (500, 800 KW)
Apr.	1991	Capital increased up to 1,200,000 dollars
Dec.	1991	Extended new forging plant
Apr.	1993	Installed 1350 ton Forging Press
Sep.	1993	Introduced CAD/CAM system
Jun.	1994	Installed heat treatment furnace 2 set (Car-type)
Oct.	1995	Introduced Metal Forming Simulation system
Nov.	1997	Certificated ISO 9002 (LRQA)
Apr.	1998	Entered [Consortium for Advanced Forging Technology]
Dec.	1999	Certificated QS 9000 (LRQA)

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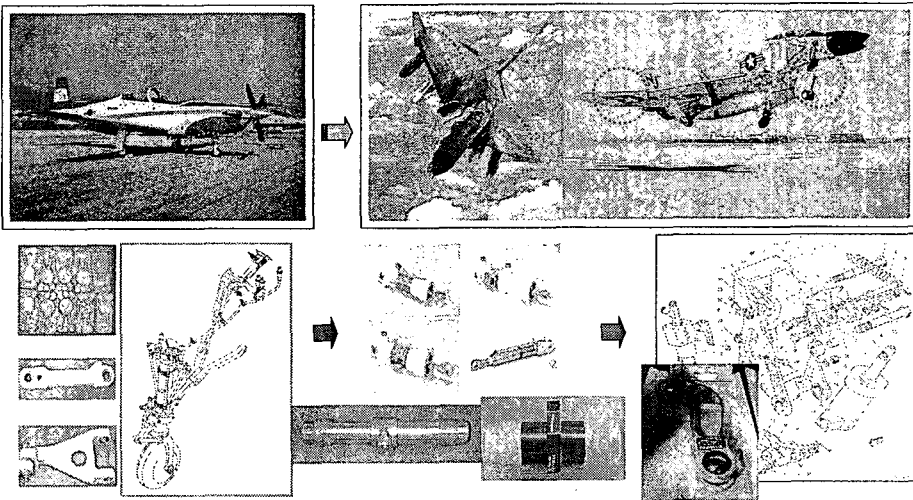
Main Customer & Products

NO.	CUSTOMER	OEM	TURN OVER (DOLLARS)	ITEM	REMARKS
1	CTR	HMC KMC EXPORT	3,327,280	-Suspension parts	-Car -Van/Jeep
2	KDTS	HMC	2,314,078	-T/M parts -Axle parts	-Commercial Truck -All kind of Bus -Van/Jeep(Gallopser)
3	JHMC	HMC DMC EXPORT	1,621,296	-T//M parts -Axle parts	-Commercial Truck -All kind of Bus -Van/Jeep(Gallopser)
4	DYGEAR	EXPORT	1,457,817	-T/M parts	-All kind of Truck
5	VCE Korea	VC&C	334,086	-T/M parts -Cylinder parts	-All kind of Heavy Equipment
6	KASCO	HMC KMC	130,480	-Propeller Shaft parts	-Commercial Truck -Passenger Car -Van/Wagon
7	EXPORT	U.S.A	1,097,056	-Chassis part -Air Tool parts	
		JAPAN	199,507	-Hook, Pin -Clamp	
SUB TOTAL			10,481,380		
8	OTHERS		2,178,100	-Automobile parts	
			820,000	-Industrial Machi-	
			1,022,520	-Others	
		SUB TOTAL	4,018,620		
TOTAL			14,500,000		

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개발 항공기용 단조품



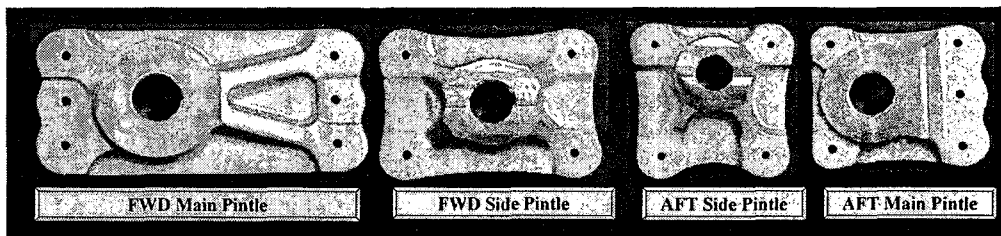
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Pintle Brackets

- 용도 : 기체 구조물 간 결합
 - Landing Gear와 동체를 연결하는데 사용되는 구조 부품
- 주요 요구 성능
 - 인장 강도 : 490MPa
 - 피로 수명 : 10,000시간



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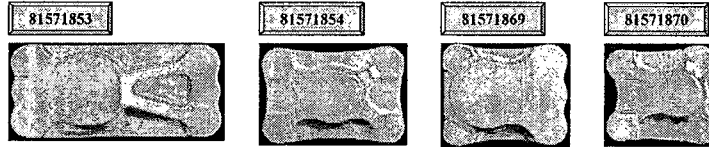
Pintle Brackets 단조품 제조 공정

- 원소재: AI 7050 (압출 봉재, AI7050-O)
- 단조 공정
 - 1차 단조(Blocker) → 1차 Trimming → 1차 세척 → 2차 단조(Finisher) → 2차 Trimming → 2차 세척
- 열처리
 1. 용체화처리: 475℃, 2hrs → W.Q(60~80℃)
 2. 잔류응력 제거: 두께대비3% 압축 가공/ 용체화처리후 2시간 이내
 3. 2단 시효: 120℃, 5hrs → 175℃, 7hrs → Air Cooling
- 후공정
 1. 액체 침투 탐상 검사
 2. 표면처리: 양극 산화 피막 처리, 화학피막처리
 3. 도장: 에폭시 프라이머 1회 실시
 4. 기계 가공
 5. 부품 번호 표기
- 부품 장착 시험: (주) WIA

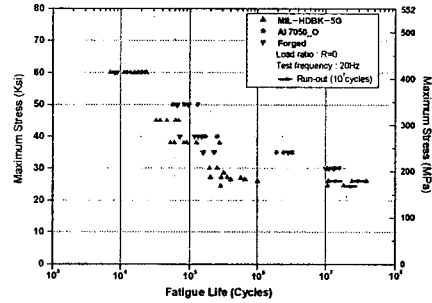
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Pintle Brackets 시험 결과



제품 종류	항복강도 (MPa)	인장강도 (MPa)	연신율 (%)
Spec.	434.4	496.4	9.0
81571853	437.8	508.8	10.9
81571854	435.1	521.9	11.0
81571869	435.7	506.8	10.7
81571870	436.4	509.5	12.2



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개발 효과

현재 생산 방법 : 후판 수입(Alcoa) → 기계가공(KAI) → 항공기 조립(KAI)



개발 후 생산 방법



재료 절감량(mm³) 70,000 mm³ 40,000 mm³ 57,000 mm³ 50,000 mm³

□ 기술적 성과

- > 기존 CNC 기계가공품을 단조품으로 대체 제작
 - 재료 이용율 : 10% 이상 향상
 - 연속된 Metal Flow를 얻을 수 있는 단조에 의한 제품 물성 향상

□ 사업화 성과

- > 공군 보수유지품으로 사업화

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Torque Link

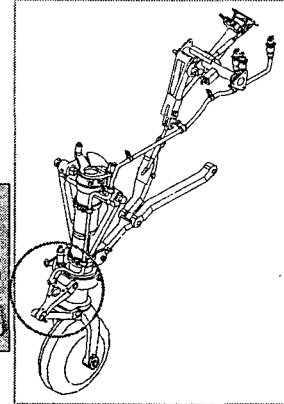
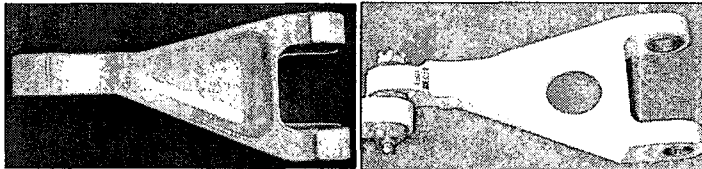
□용도 : 항공기 착륙 장치

휠포크 조립체와 조향잠금 토크칼라 사이에 연결되어 Alignment 역할을 수행함

□요구 성능

인장 강도 : 490 MPa

피로 수명 : 10,000 시간



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Torque Link 단조품 제조 공정

□ 원소재: AI 2014-O 압출봉

FEIS BS 2L 77 Class 1 B,C,A

항복강도 : 395 MPa / 인장강도 : 450 MPa

□ 단조 공정

□ 열처리

용체화 처리 : 500 °C / 2hrs → W.Q to 40 ~70 °C

인공시효 처리 : 185 °C / 6hrs

□ 주요 요구 특성(BS 3L 100)

시험편은 지정된 위치에서 채취 / 연속 생산 300개 마다 1개 시험

항복강도 : 339 MPa / 인장강도 : 416 MPa / 연신율 : 6%

침투 탐상 검사(FEIS 701B)

□ 주요 후처리

Vapour Blast(FEIS 704)

임시보호처리(FEIS 110)

FEIS ; 영국 Feary Hydraulic사의 규격

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Lower Drag Stay

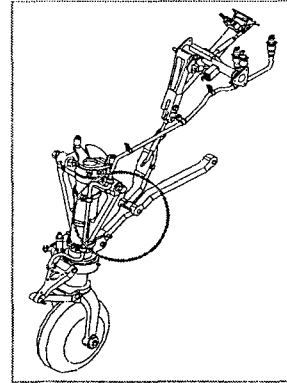
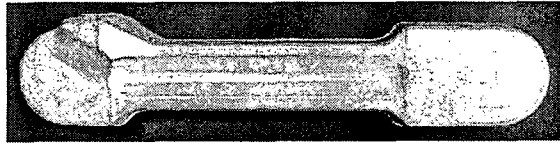
□ 용도 : 항공기 착륙 장치

항공기 조립시 Upper D/S와 올레오 조립체에 연결되어 전륜 착륙장치를 지지함

□ 주요 요구 성능

인장 강도 : 490 MPa

피로 수명 : 10,000 시간



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Lower Drag Stay 단조품 제조 공정

□ 원소재: AA 7075-O 압출봉

FEIS BS 2L 77 Class 1 B,C,A

항복강도: 360MPa(ST방향), 370MPa(LT방향), 385(L방향)

인장강도: 420MPa(ST방향), 440MPa(LT방향), 455(L방향)

연신율: 3%(ST방향), 4%(LT방향), 7%(L방향)

□ 단조 공정

DEF STAN 00-970 요구사항에 따른 Class 1 단조

□ 열처리 (T73)

용체화 처리 : 465°C / 2hrs → W.Q to 60~80°C

인공시효 처리 : 110°C / 24hrs → 177°C / 9hrs

□ 주요 요구 특성(BS 3L 100)

시험편은 지정된 위치에서 채취 / 연속 생산 Batch 마다 기계적성질 측정

침투 탐상 검사(FEIS 701B)

전기전도도 시험(BS L161)

응력부식시험 (BS L161)

□ 주요 후처리

Vapour Blast(FEIS 704)

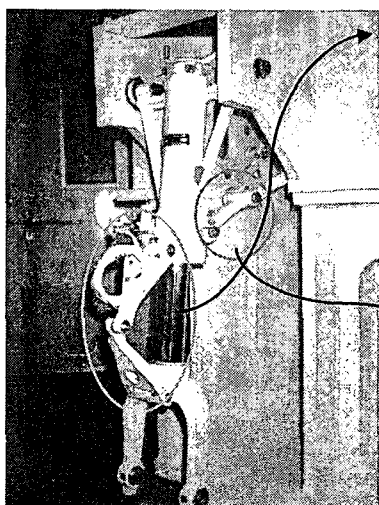
임시보호처리(FEIS 110)

FEIS ; 영국 Feary Hydraulic사의 규격

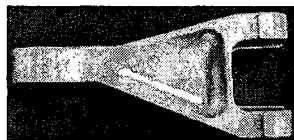
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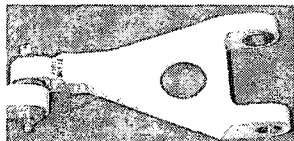
Landing Gear 조립 성능 평가



Torque Link



가공/조립성
우수함



Lower Drag Stay

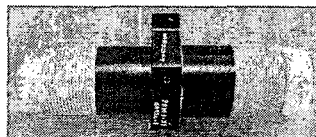
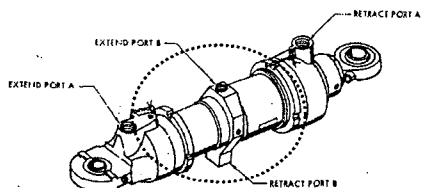


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Tandem Spoiler

□ F4 Phantom용 Tandem Spoiler Outboard Body



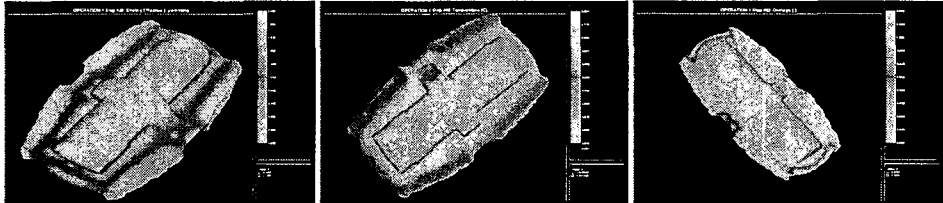
장착위치

- 항공기 날개 Spoiler 작동시 필요한 유압 System
- 용도 : 이착륙 및 방향 조정용 Actuator
- 주요 요구 성능
 - 내압
 - . Operating Pressure : 3,000 psi
 - . Proof Pressure : 4,500 psi
 - . Maximum Pressure : 7,500 psi
 - 피로수명 : 10,000 비행시간
 - 인장강도 : 448 MPa

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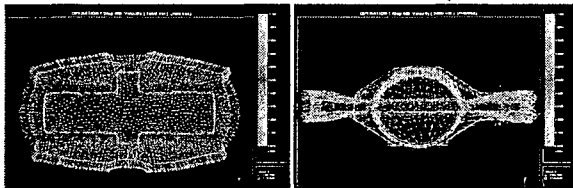
유한요소해석 공정설계



Effective Strain

Temperature

Damage



Metal Flow

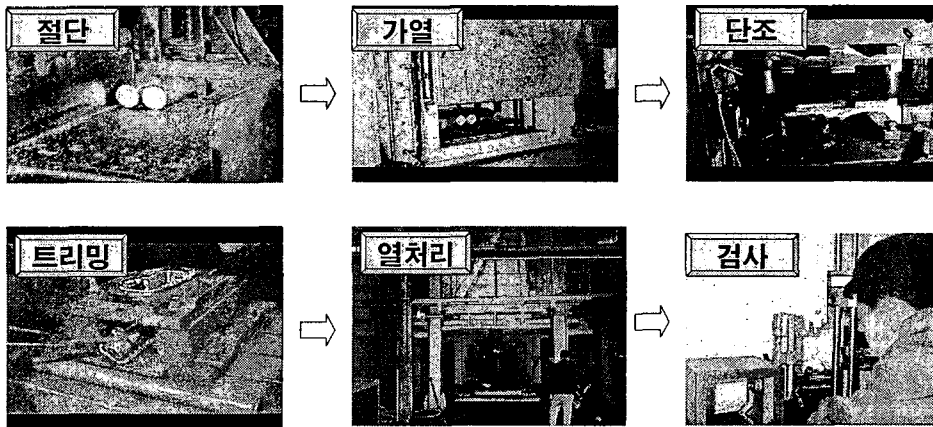
결함 없는 안정적인
공정이 예측됨

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단조품 제조과정



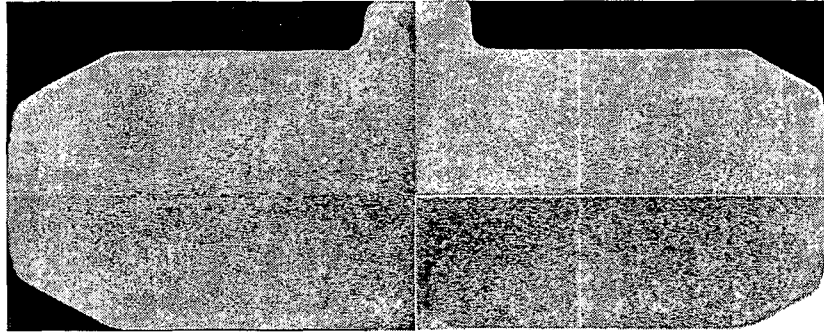
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단조품 Metal Flow

□ Parting Line 면

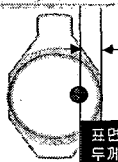


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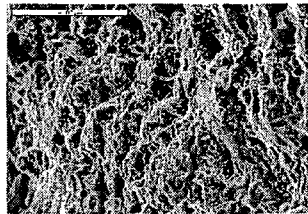


단조품 인장시험



표면에서
두께의 1/4 위치

시제 1차	YS(MPa)	TS(MPa)	% Elong.		YS(MPa)	TS(MPa)	% Elong.	
수평 1	437.2	494.3	13.3	수직 1	394.2	462.5	7.8	
수평 2	435.7	492.1	12.2	수직 2	404.4	462.6	9.5	
수평 3	458.8	509.8	10.5					
수평 4	440.0	482.7	8.5					
시제 2차	YS(MPa)	TS(MPa)	% Elong.		YS(MPa)	TS(MPa)	% Elong.	
수평 1	429.7	503.5	12.6	수직 1	420.0	473.7	9.6	
수평 2	451.5	507.9	12.3	수직 2	419.3	476.5	8.7	
수평 3	446.9	501.0	11.2	수직 3	428.1	475.7	8.3	
수평 4	457.7	512.1	12.9	수직 4	420.6	475.7	8.4	
규격	수평	386.12	448.175	6	수직	379.225	441.28	2



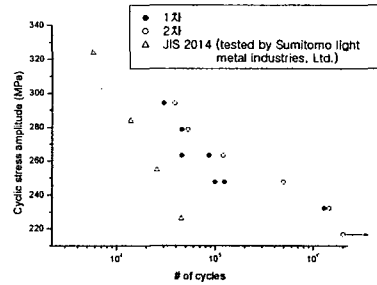
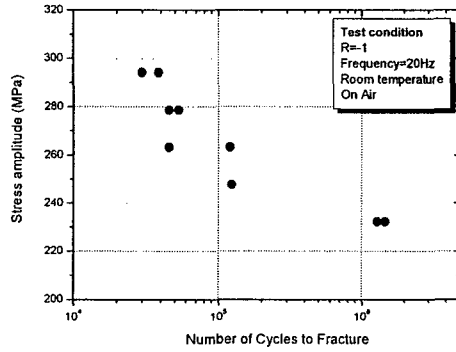
시편번호	충격흡수에너지 (J/cm ²)
#1	17.1
#2	17.1
#3	16.5
평균	16.9

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단조품 피로시험

□ Tension-Compression

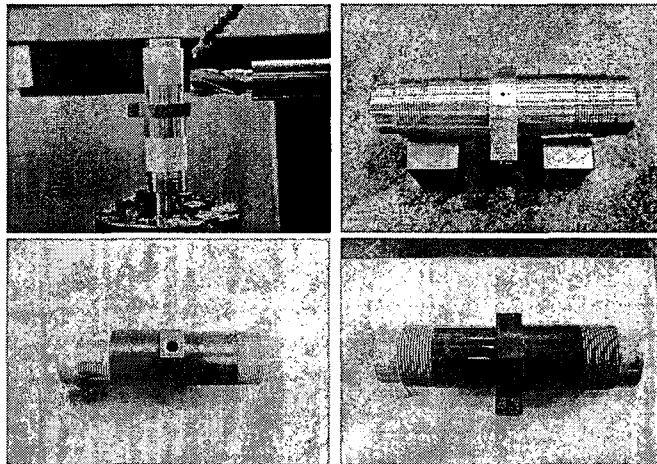


Reference Data

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단조품 기계가공성 평가



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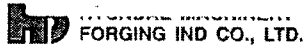
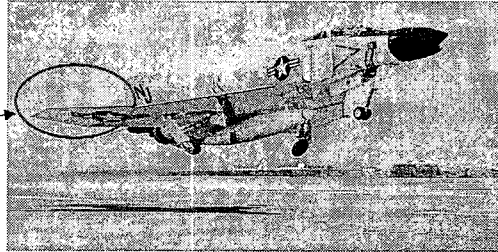
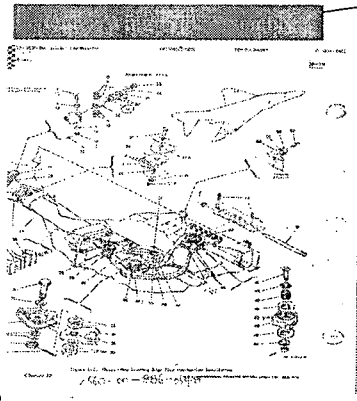
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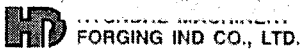
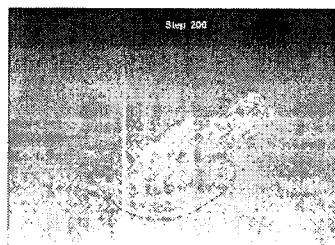
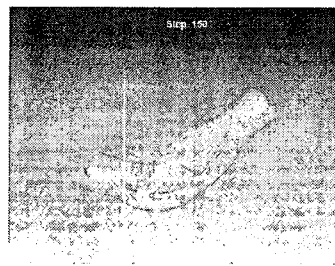
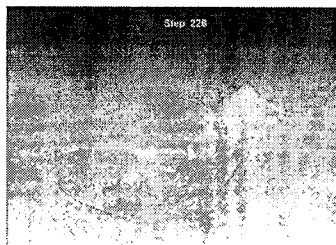
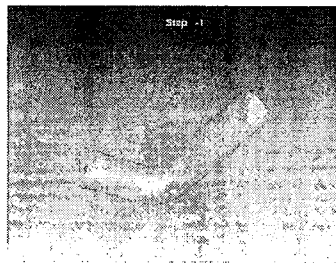
Link Assembly(F-4 Phantom용)

F-4 Phantom

- Link Assembly(4340 Steel)

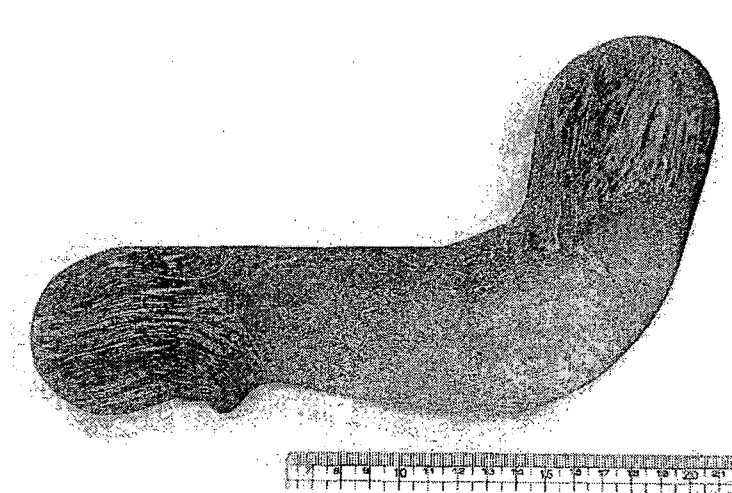


F-4 Link Assembly





Macrostructure/ Grain Flow

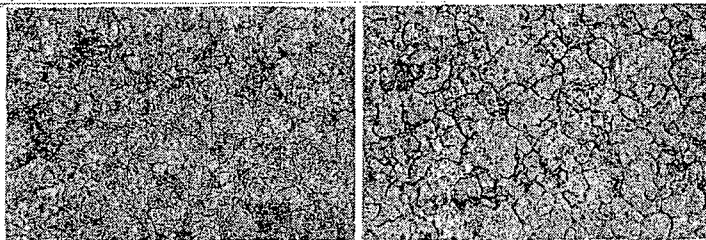


HD H⁺ FORGING IND CO., LTD.

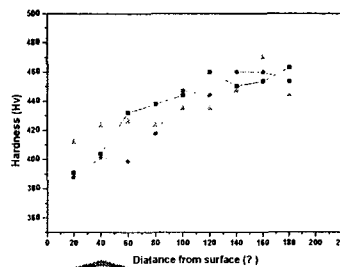
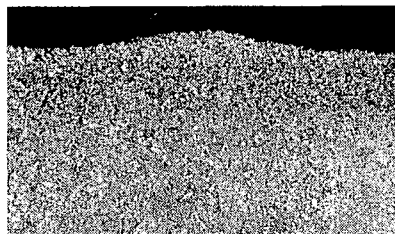
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Grain Size/탈탄



Grain Size :ASTM # 7



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인장/충격 시험

510°C Tempering

	YS(MPa)	TS(MPa)	%
1	1201	1286	15.9
2	1208	1301	15.9
3	1212	1290	14.9

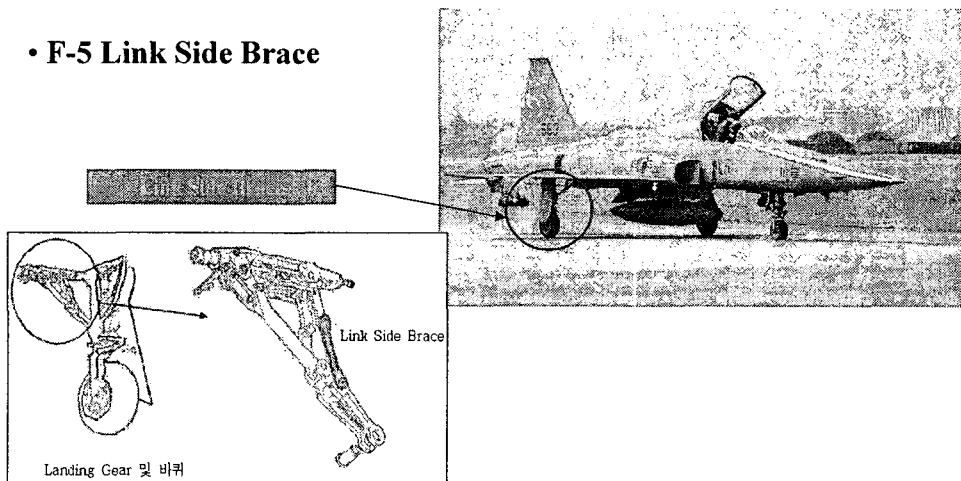
	시편 size	J
1	9.99×9.99	43.0
2	9.99×9.99	43.0
3	9.99×9.99	45.0

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Link Side Brace(F-5 Tiger용)

• F-5 Link Side Brace

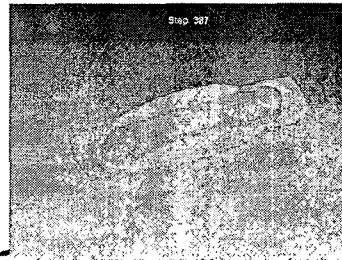
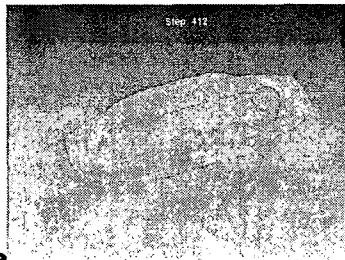
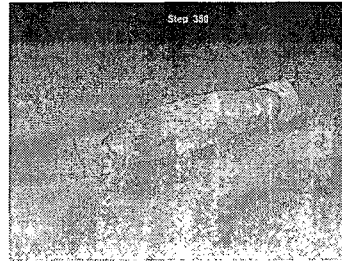
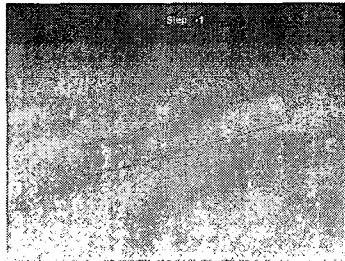


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F-5 Link Side

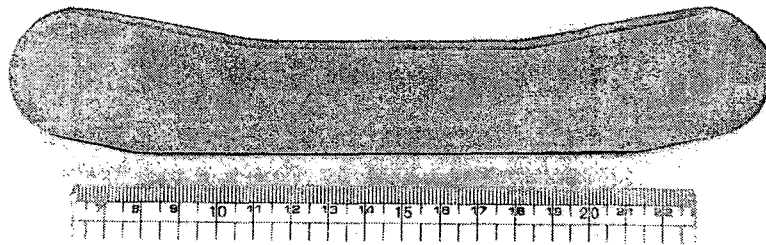


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Macrostructure/ Grain Flow

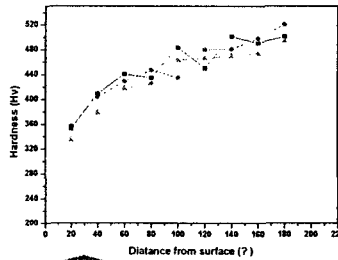
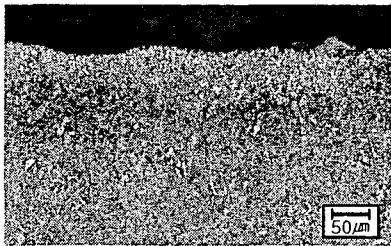
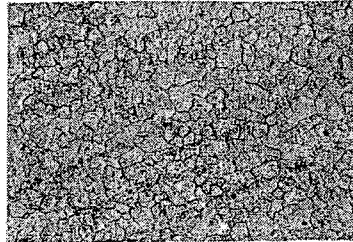
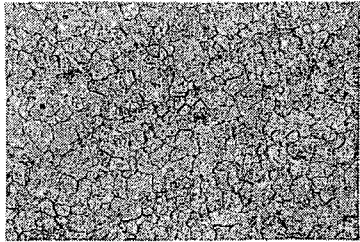


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Grain Size/탈탄



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인장/충격 시험

		YS(MPa)	TS(MPa)	%
254°C Tempering	1	1,553	1,881	8.8
	2	1,556	1,862	10.2
	3	1,521	1,852	11.7
530°C Tempering	1	1,221	1,314	12.8
	2	1,233	1,319	13.0
	3	1,201	1,323	14.3

	시편 size	J
1	7.99×9.99	31.0
2	7.99×9.99	30.0
3	7.99×9.99	30.0

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개발 성과

- 개발 항공기 및 한국공군 교체 부품 적기 개발 → “r & D” 구현
 - r: 연구 → 기초 DB 및 특성 평가
 - D: 개발 및 실용화 → 제작 및 실기 장착
- 기술적 성과
 - 외산품(영국 FHL사)에서 관찰되는 표면 조대결정립층의 제어 기술 개발
 - 피로강도를 포함한 대부분의 기계적 물성의 향상
- 사업화 성과
 - 공군 유지 부품으로 납품
 - 영국 FHL사 : 수출 가능