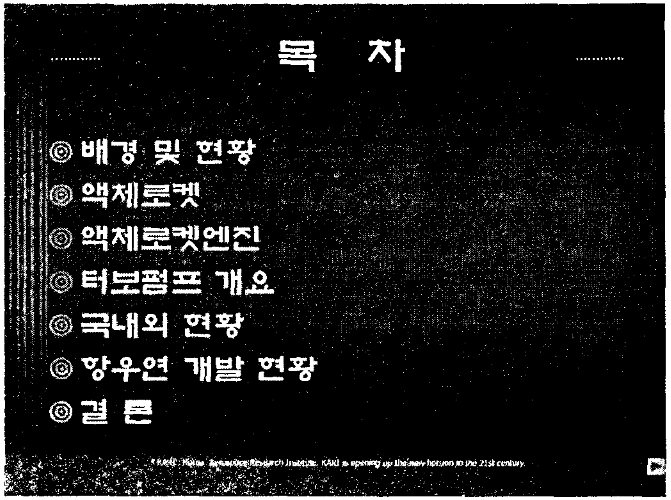
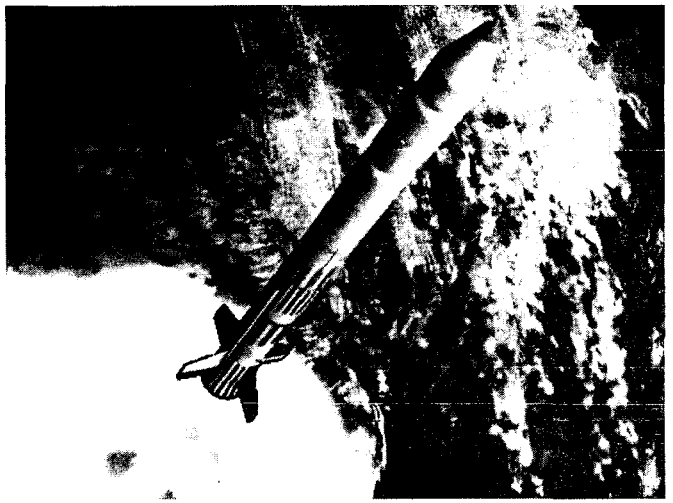
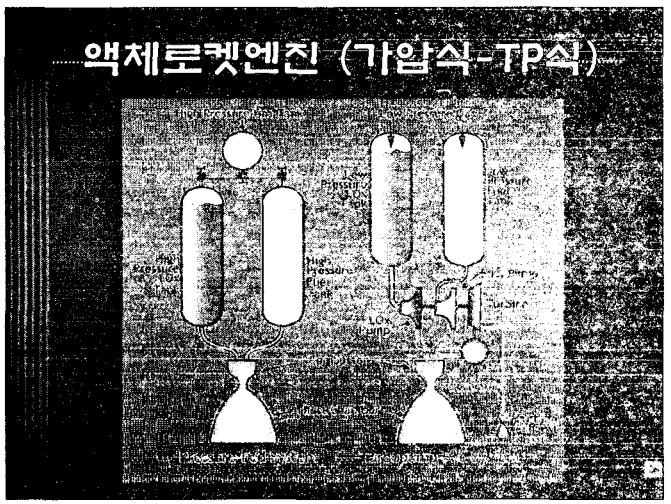
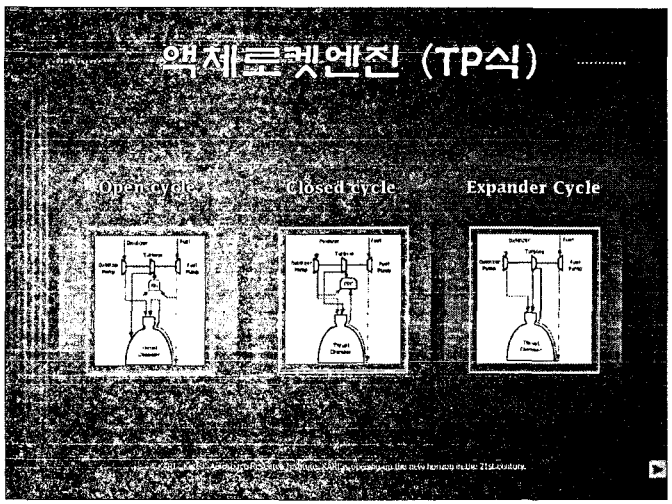
2005 유체기계 연구개발 발표회 논문집, pp. 43~52
창원대학교 국제교류센터 및 정보전산원 2005. 12. 1~2






액체로켓엔진

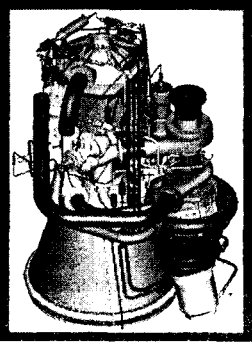

액체로켓엔진 (가압식-TP식)


액체로켓엔진 (TP식)
Open cycle
Closed cycle
Expander Cycle

액체로켓엔진

◎ KSR-III : 가압식

◎ KSLV : TP 식 →



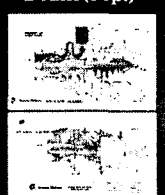
터보펌프 개요

* KARI : Korea Aerospace Research Institute. KARI is opening up the new horizon in the 21st century.

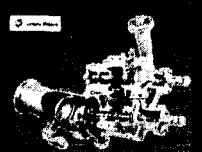
터 보 펌 프

1 Axis

2 Axis(sep.)



2Axis(G/B)



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항우연 개발 현황

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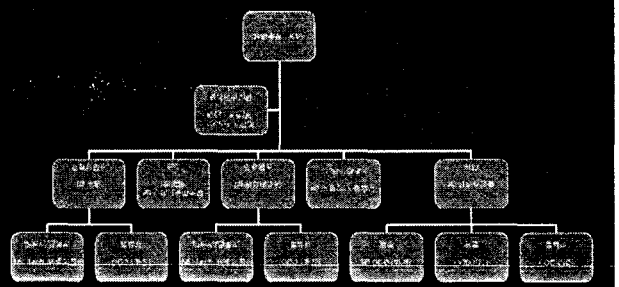
터보펌프 개발체계



터보펌프 개발체계

◎ 항우연
- ⊙ 설계 : 개념설계, 기본설계, 상세설계 (3D 모델 및 설계주요공차기입한 2차원 제작용 도면)
- ⊙ 시험 : 고압, 고회전수, 상온/저온 성능시험

◎ 산업계
- ⊙ 제작 : 제작상세설계, 제작
- ⊙ 시험 : 내압/기밀시험, 발란싱

◎ 학계
- ⊙ 해석 : 유동해석, 구조해석 (항우연 설계 검토용)
- ⊙ 시험 : 모델성능시험 (터빈 노즐/캐스케이드)

터보펌프 개발체계

◎ 학계: 모델성능시험, 유동해석
- ⊙ 과기원 : 터빈 열구조해석 (이인교수)
- ⊙ 부산대 : 터빈 노즐 및 캐스케이드 시험, 유동해석 (김귀순교수)
- ⊙ 서울대 : Cavitation 성능해석 (이수갑교수)

◎ 외부연구계 : 수류상사성능시험/해석
- ⊙ KIST : 설계데이터 베이스구축, 상사성능시험 (이용복박사)

터보펌프 개발체계

◎ 산업체
- ⊙ 삼성테크윈 : 연료펌프/터빈 제작상세설계,제작, 내압시험,발란싱
- ⊙ 로템/비츠로 : 산화제펌프/IPS 제작상세설계, 제작, 내압시험, 발란싱
- ⊙ 스페이스 솔루션 : Mech. Face Seal, IPS 제작상세설계, 제작

Hydraulic/Aerodynamic Design

Structural/Dynamic Design

Structural / Dynamic Design

- Most of rocket engine failures are turbopump failures
- Structural robustness and appropriate sealing should be maintained with minimal weights

Mechanical design

- Strength and weight test of casings
- Spin and vibration test of rotating parts
- Bearing / Seal tests

- Stress and deformation
- Cryogenic behaviors
- High temperature behaviors
- High pressure safety

- Structural vibrations
- Rotor dynamics

Structural / Dynamic Design

- Safety Margin

Rotordynamics & Structural Vibration

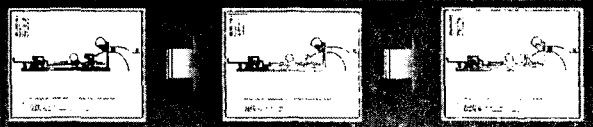
Item	Margin	Reference
TPU System Critical Speed	± 25 %	Operating RPM
Rotating Parts	± 20 %	Resonance Frequency
Bearing Load Capacity	+ 200 %	Axial & Radial Load
Bearing Life Time	+ 500 %	Operating Time
Seal Life Time	+ 500 %	Operating Time

Structural Strength

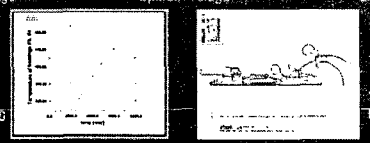
Item	Margin	Reference
Main Shaft & Spline Shaft	+ 30 %	Operating Power (Yield)
Rotating Parts (Pump)	+ 20 %	Operating Condition (Yield)
Rotating Parts (Turbine)	+ 10 %	Operating Condition (Yield)
Casing Parts	+ 10 %	Proof Pressure (Yield)

2D Transient Thermal Analysis

- Transient thermal analysis of the turbopump assembly considering chill-down operation and shut-down stage
- 2D axisymmetric analysis for simplification of the problem
- Prediction of thermal effect on each component



Chill-down stage | Operation stage | Shut-down stage



History of the bearing temperature

History of temperature contours

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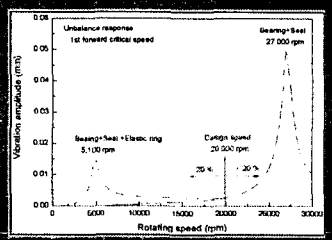
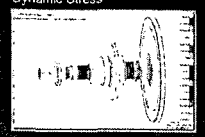
Mass Unbalance Response

- Imbalance ISO G2.5 with 0 phase at 3 points
- Synchronous response, small damping
- Acceptable dynamic stress, displacement



Dynamic Stress



Vibration Amplitude

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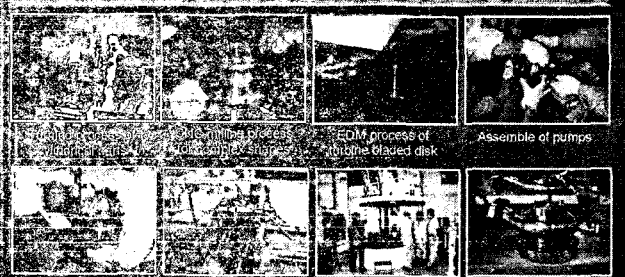
Manufacturing

* KARI : Korea Aerospace Research Institute. KARI is opening up the new horizon in the 21st century.

Manufacturing



Test

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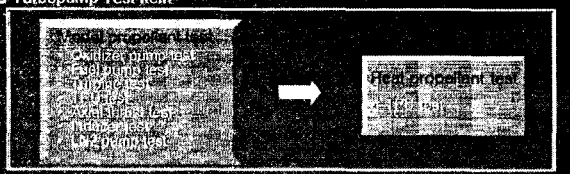
Turbopump Test

❑ Turbopump Test Item



❑ Model propellant test details

No	Test	Check point	Medium	Driving power
1	Oxidizer pump test	Hydraulic/cavitation performance	Water	Motor
2	Fuel pump test	Hydraulic/cavitation performance	Water	Motor
3	Turbine test	Aerodynamic performance	Air	Cold or hot air
4	TPU test	Power balance and vibration of TPU	Water/air	Cold or hot air
5	Axial thrust test	Axial thrust of pumps	Water	Motor
6	Inducer test	Hydraulic/cavitation of pump inducer	Water	Motor
7	LN2 pump test	Thermal effect in pump cavitation	LN2	Motor

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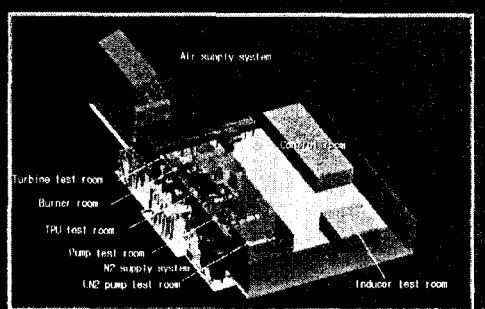
Layout of Turbopump Test Facility in KARI



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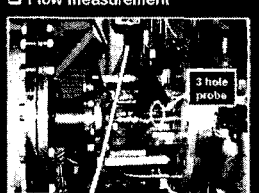
Inducer Test

Test objective
- Detailed cavitation measurement
- Detailed flow measurement

Test capacity
- Driving motor : 37 kW, 10,000 rpm

❑ Cavitation visualization

❑ Flow measurement



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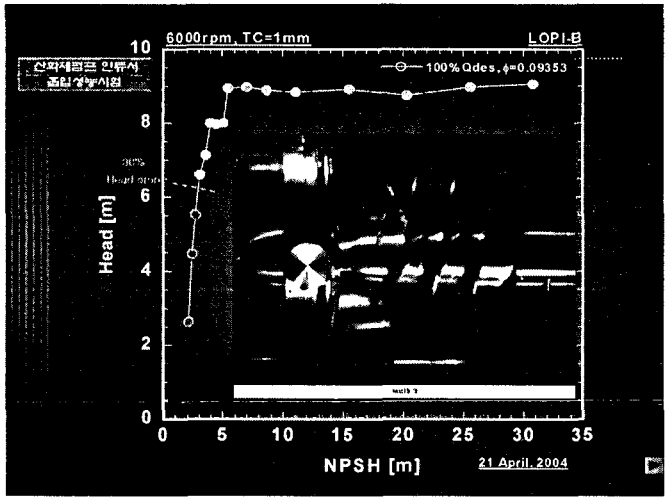
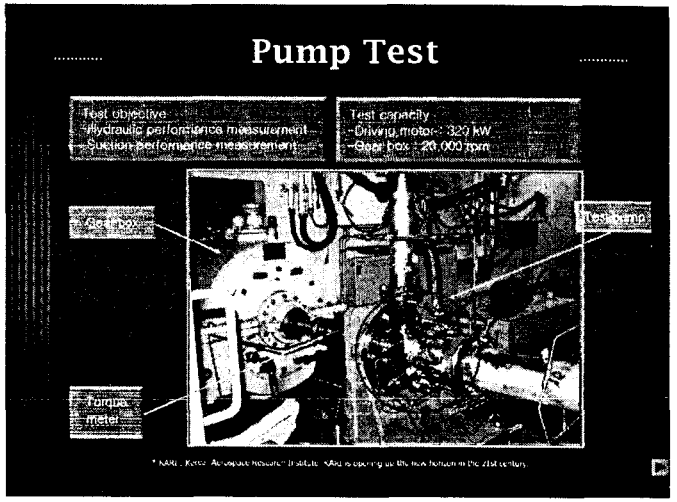
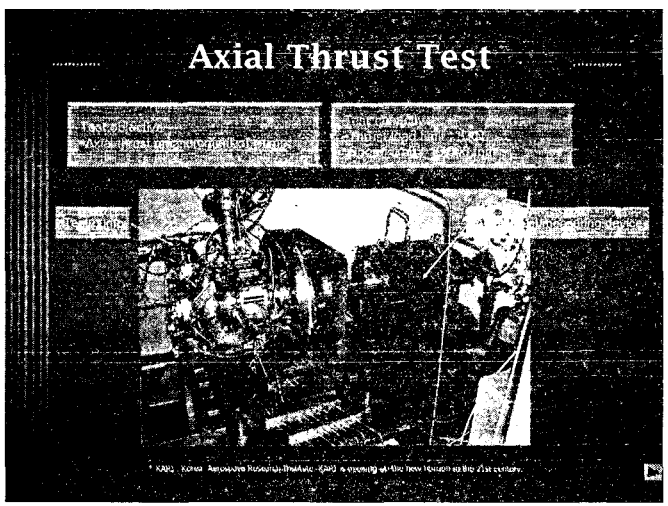
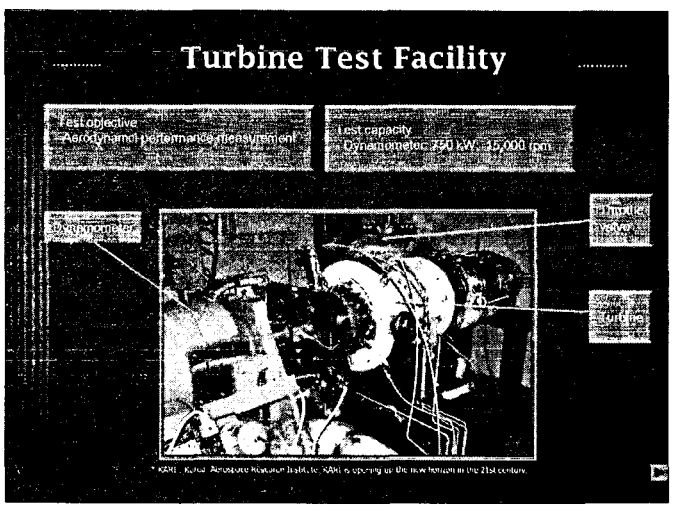

6000rpm, TC=1mm
LOPI-B
100% Qdes, ϕ=0.09353
Head [m]
NPSH [m]
21 April, 2004

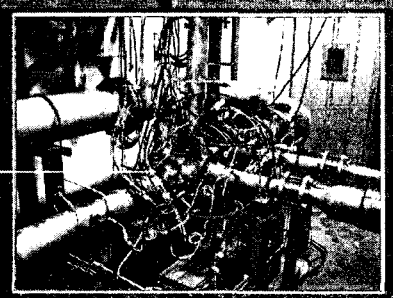

Pump Test
Test objective
Hydraulic performance measurement
Suction performance measurement
Test capacity
Driving motor: 329 kW
Gear box : 20,000 rpm
Test pump
Torque meter


Axial Thrust Test


Turbine Test Facility
Test objective
Aerodynamic performance measurement
Test capacity
Dynamometer: 750 kW, 35,000 rpm
Dynamometer

TPU Test Facility

- Test objective
  - Power balance check
  - Vibration measurement
- Test capacity
  - Turbine inlet temperature max : 400 ℃



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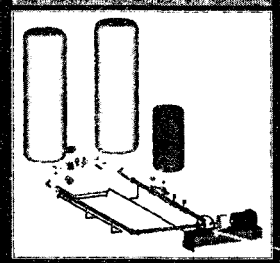
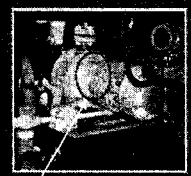
LN2 Pump Test Facility

- Test objective
  - Thermal effect on pump cavitation
  - Hydraulic performance of pump
- Test capacity
  - Driving motor : 320 kW
  - Gear box : 32,000 rpm





Test Inducer

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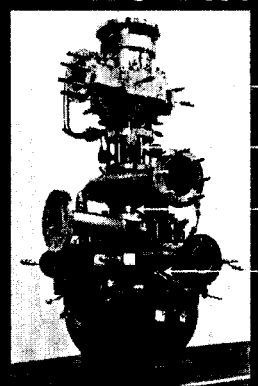
TPU Tested



Oxidizer Pump

IPS

Fuel Pump

Turbine

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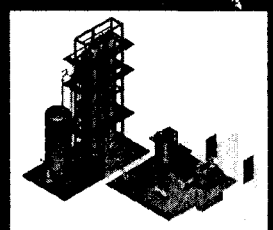
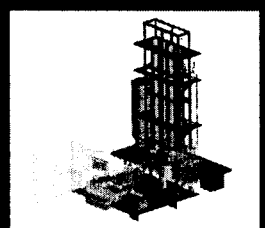
Cryogenic Bearing/Seal Test Facility

Objective : To perform cryogenic tests of bearings and seals.





Specifications of Test Facility

Working Fluid	LN2
Type	Blow Down
Max. Pressure	10 MPa
Max. Flow Rate	10 liters/sec

Capacity	3.0 m (LN2) 3.0 m (GN2)
Available Tests	Floating ring seal tests Bearing loading tests Mechanical face seal tests

결론 및 향후계획

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결 론

- 산학연 협력체계하에 터보펌프개발 진행
  - 산 : 삼성테크윈, 루텍, 스페이스솔루션
  - 학 : 서울대, 부산대, 과기원
  - 연 : KIST
- 2년간 산학연 협력의 결실로 선진국 수준(흡입성능, 펌프 효율, 터빈효율)의 터보펌프를 개념/기본/상세설계/제작상세설계/시험완료 및 Hotfiring 용 터보펌프 제작중
- 30톤급 액체로켓엔진용 터보펌프 향후 해결과제
  - 실매질 hotfiring을 통한 터보펌프의 작동안정성 검증
    - 터빈 : 간극, 얼구조 검증(특히 시동시)
    - 시스템 : 축추력검증, 임계위험속도 검증
    - Face seal : 실매질 검증
    - 베어링: 안정적 수급

향후계획

- 향후계획
  - 터보펌프 실매질 성능시험
  - Powerpack (터보펌프+가스발생기) 성능시험
  - 엔진장착 성능시험