

2022년 가스/스팀터빈 분야 연구동향

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1. 서 론

한국유체기계학회 논문집과 한국유체기계학회 하계 및 동계 학술대회에 투고된 논문을 통해 2022년 국내 가스/스팀터빈분야의 연구 동향을 분석하였다. 전년과 마찬가지로 금년도에도 가스/스팀터빈분야로 투고된 논문들을 유동장^(1~22), 열전달 및 냉각^(23~48), 시험평가 및 성능해석^(49~72), 기술 및 현황 소개^(73~93) 등 총 4개 분야로 분류하였다. 압축기, 연소, 베어링, 회전체 동역학 등은 별도로 연구동향을 분석하므로 이 분석에서는 제외하였다.

표 1의 투고/발표 방법에 따른 논문 수를 보면, 가스/스팀터빈을 주제로 논문집에 총 9편의 논문이 심사를 통과하여 논문집 25권 1호~6호에 걸쳐 게재되었다. 2021년과 비교하여⁽⁹⁴⁾ 2022년도에 학술대회에 발표된 논문 수를 살펴보면, 예년에 비해 하계학술대회에서 발표된 논문 수는 상대적으로 적었으나, 코로나19 관련 방역규제가 대폭 완화된 동계학술대회에서는 연구자들의 대면 학술대회 발표 선호도가 높아져 하계학술대회의 2배에 가까운 수의 연구논문이 발표되었다. 가스/스팀터빈 분야 전체 논문 수는 표 2와 같이 최근 3년 동안 꾸준히 증가한 것을 확인할 수 있다.

표 1 2022년도 투고형태에 따른 논문 수

투고 방법	논문 수	
논문집	9	
하계학술대회	일반세션	16
	특별세션	9
	포스터	5
동계학술대회	일반세션	33
	특별세션	17
	포스터	4
합 계	93	

표 2에는 최근 3년간 가스/스팀터빈분야로 투고된 논문들을 주제별로 분류/정리하였다. 2022년에는 예년과 다르게 특정분야에 논문들이 편중되지 않고, 주제별 비슷한 수의 논

문이 투고되었다. 이는 항공용/발전용 가스터빈 국산화 모델 개발에 힘입어 관련 연구주제 다양화 및 제반기술 고도화에 의한 것으로 생각된다. 유동장 및 열전달 및 냉각 분야 논문 수는 예년과 비슷한 수준으로 논문이 투고되었으며 시험평가 및 성능해석, 기술 및 현황소개 분야에서 작년에 비해 많은 논문이 투고되어 전체 논문 수 증가를 견인하였다.

표 2 연도별 분류 기준에 따른 논문 수

분류 기준	논문 수 (편)		
	2020년	2021년	2022년
유동장	17	20	22
열전달 및 냉각	30	26	26
시험평가 및 성능해석	21	15	24
기술 및 현황 소개	8	18	21
합계	76	79	93

2. 유동장 관련 연구

가스터빈의 유동장과 관련되어 투고된 논문은 아래와 같이 3가지 세부주제로 총 23편의 논문이 투고되었다.

- 가스터빈 구성품 쉘 및 2차 유동
- 가스터빈 구성품 주유동 및 팁유동
- 가스터빈 연소기

최근 5년간 가스터빈 구성품의 기밀 및 누설 특성에 대한 연구발표 사례가 꾸준히 증가하였으며, 금년도 해당 분야에서는 총 8편의 논문이 투고되었다. 가스터빈 구성품 래버런스 쉘, 림셀 등 다양한 쉘 종류의 성능을 비교 분석한 논문, 또한 쉘의 개발 및 적용을 통한 터빈 단의 성능 평가에 대한 연구 등이 포함되어 있다. 가스터빈 구성품의 주유동 및 팁유동 분야에서는 총 11편의 논문이 투고되었다. 가스터빈 구성품의 설계 및 최적화, 익단 누설 유동 유동 및 내부 유동장 분석 및 이에 따른 구성품 성능평가 등의 내용이 주를 이루었다. 75톤급 한국형 발사체 터보펌프 터빈 성능평가 연구사

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례⁽¹⁷⁾ 및 항공기 가스터빈 엔진 개발 시 진행되는 트위킹 시험⁽¹⁸⁾ 등 흥미로운 주제의 논문도 발표되었으며, 항공용 가스터빈 엔진을 중심으로 4편의 가스터빈 연소기 관련 논문이 투고되었다.^{(19)~(22)}

3. 열전달 및 냉각 관련 연구

열전달 및 냉각 관련 연구논문들은 아래와 같이 크게 4개의 주제로 분류할 수 있으며, 2022년도에는 아래 주제로 총 26편의 논문이 투고, 발표되었다.

- 냉각계통이 포함된 가스터빈 시스템 해석
- 단위요소(내부냉각 및 막냉각) 별 냉각 열전달 특성
- 터빈 날개 단위의 열전달 특성
- 적층제조를 활용한 냉각터빈 요소 제작

하계 학술대회에서는 가스터빈 열전달과 관련하여 ‘엔진 모사 환경에서의 가스터빈 열전달’⁽²³⁾ 및 ‘터빈 날개 전연에서의 냉각 기법’⁽²⁴⁾에 대한 2건의 특별강연이 진행되었다. 해당 특별강연을 포함하여 총 18편의 내부냉각 및 막냉각 등 냉각요소에 초점을 둔 연구개발 논문이 투고되었다. 고압터빈 실제 운용 조건에 가까운 고속 조건에서의 냉각요소 성능 평가에 대한 연구⁽³⁸⁾ 및 오픈소스 CFD 및 LES 코드를 활용한 막냉각 유동장 연구⁽²⁶⁾⁽²⁷⁾ 등과 같이 눈길을 끄는 연구내용도 있었다. 또한 항공기 엔진용 냉각터빈에 대한 복합 열전달 해석 및 상사시험을 통한 냉각성능 평가에 대한 연구도 다수 발표되고 있다.⁽²⁸⁾⁽⁴⁴⁾⁽⁴⁵⁾ 가스터빈 냉각요소 적층제조에 따른 냉각성능을 평가하는 연구⁽⁴⁶⁾⁽⁴⁸⁾도 관련 프로젝트 진행에 따라 꾸준히 발표되고 있다.

4. 시험평가 및 성능해석 관련 연구

2022년도에도 가스터빈의 시험평가 및 성능해석 관련 연구를 아래와 같이 3개의 주제로 분류하였고, 2022년도에는 아래 주제로 총 24편의 논문이 투고, 발표되었다.

- 가스터빈 시스템 성능해석
- 전산유체역학/구조해석
- 가스터빈 엔진/구성품 성능시험

국내 개발 발전용 가스터빈 엔진 사업의 진행에 따라 가스터빈 시스템의 시동, 성능평가, 진단 등을 평가하는 성능해석 분야 논문들이 발표되었다. 전산유체역학/구조해석 분야 논문에서는 하계학술대회에서는 ‘가스터빈 엔진 구성품 해석에 고정밀도 수치해석 필요성’을 설명하는 초청강연⁽⁴⁹⁾이 준비되었으며, 가스터빈 엔진 공력해석을 위한 CFD 기법 개

발, 주조공정 예측 및 열응력에 의한 피로평가 등과 해석연구 사례들이 발표되었다. 가스터빈 엔진/구성품 성능시험 분야에서는 ‘10MWe급 초임계 이산화탄소 발전시스템 압축기 성능시험’ 내용을 소개하는 초청강연⁽⁵⁰⁾과 함께 마이크로 가스터빈 엔진 제어, 파생모델 개발 연구 내용, 적층제조 공정에 따른 구조적 안정성 평가, 소재의 안정성 평가와 관련된 총 13편의 논문이 발표되었다.

5. 기술 및 현황소개 관련 논문

2022년에는 기술 및 현황소개 관련 발표가 21편으로 최근 3년 기준 가장 많은 수의 논문이 발표되었다. 특히 해당 논문들은 성격상 학술대회에서 발표된 논문들이 대부분이며, 기관별 기술개발 현황 및 과제진행 현황 등을 주로 특별세션을 구성하여 발표하였다. 탄소 중립 시대를 준비하기 위한 수소 가스터빈 관련 기술개발 현황 및 암모니아 혼소 및 분해를 통한 수소 공급기술 등을 소개하는 논문들^{(73)(76)~(81), (83)(84), (87)~(91)}이 하계/동계 학술대회에서 다수 발표되었고, 국산 발전용 가스터빈의 실증시험 및 구성품 개발, 계측 등의 관련기술을 소개한 논문⁽⁷⁴⁾⁽⁷⁵⁾⁽⁸⁵⁾⁽⁸⁶⁾이 발표되었다.

또한 항공기용 마이크로 가스터빈 엔진 기술⁽⁸²⁾, 무인기용 가스터빈 엔진 터빈 기술⁽⁹³⁾, 가스터빈 블레이드 리엔지니어링 기술, 항공기 가스터빈 엔진 고온부 성능평가 기술⁽²⁰⁾⁽⁴⁶⁾, 3D 프린팅을 이용한 냉각요소 및 세라믹 코어 제작기술⁽⁷⁴⁾⁽⁹²⁾ 그리고 등이 특별세션을 통해 해당 기술현황을 소개하고 연구개발 사례발표를 진행하였다.

6. 결 론

2022년 한국유체기계학회 논문집과 한국유체기계학회 하계 및 학술대회에서 발표된 논문을 바탕으로 2022년 가스/스팀 터빈 분야의 연구 동향을 살펴보았다. 2022년에는 2021년에 비해 양적으로도 발표된 논문 편수가 증가하였고, 주로 국산 가스터빈 연구개발 단계를 반영한 다양한 기관에서 특정 주제에 편중되지 않은 다양한 주제의 연구논문이 발표되었다. 2030 국가 온실가스 감축목표의 한 축을 담당하는 수소 가스터빈, 가스터빈 부품 제조 과정의 변화를 불러온 적층 제조 기술 관련 논문의 수가 꾸준히 증가하는 반면, 초임계 이산화탄소 사이클이나 유기랭킨 사이클과 같이 최근 논문 발표 건수가 축소된 사례도 찾을 수 있었다.

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