

Journal of Hunan University Natural Sciences

# 湖南大学学报

ISSN 1674-2974

---



[Home](#) > [Editorial Team](#)

## Editorial Team

Editor-in-Chief:

Prof. Yi Weijian

Advisors:

Deng Wei, Party secretary of the CPC Hunan University Committee; professor.

Duan Xianzhong, member of the CPC Hunan University Committee and its standing committee, president of Hunan University; professor and doctoral supervisor.

Yu Xiangcheng, vice secretary of the CPC Hunan University Committee.

Xie Chi, HNU Vice President, member of the Academic Research and Academic Degrees Committee and director of the Academic Committee of Department of Management of the HNU.

Wang Weibin, Vice president of Hunan University.

[Editorial Team](#)

[Editorial Policies](#)

[Focus & Scope](#)

[Author Guidelines](#)

[Abstracting and Indexing](#)

[Publication Ethics](#)

[Paper Submission](#)

### INDEXED BY SCOPUS



0.26

powered by scimagojr.com



**TEMPLATE**



**USER**

Username

Password

Remember me

**Login**

**NOTIFICATIONS**

› [View](#)

› [Subscribe](#)

**JOURNAL CONTENT**

Search

Search Scope

All ▼

**Search**

Browse

- ▶ [By Issue](#)
- ▶ [By Author](#)
- ▶ [By Title](#)

**INFORMATION**

- ▶ [For Readers](#)
- ▶ [For Authors](#)
- ▶ [For Librarians](#)

---

**Journal of Hunan University Natural Sciences**

Copyright 2012-2022  
(e-ISSN: 1674-2974 )

[Home](#)

[Search](#)

[Archives](#)

[Contact](#)

[About](#)

[Current](#)

[Sitemap](#)

[Paper](#)

[Submission](#)

**+86-731-88823137**  
editorial-office@jonuns.com



Journal of Hunan University Natural Sciences

# 湖南大学学报

ISSN 1674-2974

---



Home › Archives › Vol 48, No 12 (2021)

## Vol 48, No 12 (2021)

### Table of Contents

#### Articles

- Living Lab” for Sustainability: Embedding the Spirit of Ownership and Proactivity with Disaster Resilient Supply Chain for Water-Waste-Energy Interrelatedness PDF  
*Salil K. Sen, Tartat Mokkhamakkul*
- A Deep Convolution Neural Network-Based SE-ResNext Model for Bangla Handwritten Basic to Compound Character Recognition PDF  
*Mohammad Meraj Khan, Mohammad Shorif Uddin, Mohammad Zavid Parvez, Lutfur Nahar, Jia Uddin*
- An Analysis of High Frequency and Resistance Pattern in Pseudomonas Aeruginosa Isolated from Clinical Specimens Obtained from Tertiary Care Hospital PDF  
*Maria Muddassir, Sadaf Munir, Faiza Sadia, Almas Raza, Syed Shoaib Ahmed, Syed Zeeshan Haider Naqvi*
- Characteristics of Working Fluid Flow in Convergent-Divergent Injectors in Vapor Compression – Steam Jet Refrigeration PDF  
*Firman Firman, Muhammad Anshar, Amrullah Amrullah*
- Cyber-Physical System (CPS) Based Heart Disease's Prediction Model for Community Clinic Using Machine Learning Classifiers PDF  
*Fahmida Akter, Mohammad Abul Kashem, Md. Monirul Islam, Mohammad Asaduzzaman Chowdhury, Md. Rokunojjaman, Jia Uddin*
- Determinants of Market Choice and Strategies Adopted by Small-Scale Pig Producers in Redline Areas of Mpumalanga Province, South Africa: A Fractional Outcome-Tobit Model Approach PDF  
*Priscilla Munzhelele, Oluwaseun Samuel Oduniyi, Marco Leon Scheltens, Michael Antwi, Mbajiorgu Christian, Folorunso Oludayo Fasina*
- Evaluation of Pseudomonas aeruginosa Antibiofilm Activity of Chlorogenic Acid-Protamine Sulfate Combination Using Ex Vivo Porcine Skin Model PDF  
*Nisreen Ahmad Dahshan, Suha Mujahed Abudoleh, Ahmad Talhouni, Zahira Alkhani*
- Factors Affecting Financial Effectiveness: A Case Study of Accounting Service Enterprises in Vietnam PDF  
*Mai Thanh Loan*
- Floristic Diversity of Karak Province and a New Record of Consolida Hispanica to Jordan Flora PDF  
*Feryal Jamal Kherissat*
- Frequency of COVID-19 Complications and Their Outcomes in Patients Admitted to a Tertiary Care Hospital in Karachi PDF  
*Mariyam Gohar Ali, Fatima Iqbal Hussain, Ashok Kumar, Dilanthi Priyadarshani, Santosh Kumar Sidhwani, Kanooz Zohra*

Health Risks and Community Perceptions due to the Impact of Fine Particles from Coal-Fired Power Plants <i>Slamet Isworo, Poerna Sri Oetari</i>	PDF
Impacting COVID-19 Pandemic on the Profitability: A Case Study of Commercial Banks in Vietnam <i>Nga Phan Thi Hang</i>	PDF
Internalization of Ocean Literacy Value through Language Learning <i>Cintya Nurika Irma, Febi Junaidi, Kundharu Saddhono, Ramadhan Kusuma Yuda, Valentina Edellwiz Edwar</i>	PDF
Morphological Variations in Endemic Fish Sailfin Silversides ( <i>Telmatherina Prognatha</i> ) in Matano Lake, South Sulawesi, Indonesia <i>Andi Chadijah, Sulistiono, Gadis Sri Haryani, Ridwan Affandi, Ali Mashar</i>	PDF
Role of Presepsin and Comparison with Conventional Markers for Early Diagnosis and Differentiation of Sepsis <i>Faraz Hassan Mirza, Faraz Ahmed Baig, Serajuddaula Syed, Ashok Kumar, Moazzam Ali Shahid</i>	PDF
Self-Care Practice among Iraqi Patients with Inherited Bleeding Disorders: A Cross-Sectional Study <i>Nidal Karim Al-Rahal, Fatma Abd Al Hamza, Maha A. Alnuaimi</i>	PDF
Self-Medication Use and Associated Factors among University Students <i>A. Alkhawaldeh, M. Al Bashtawy, O. Al Omari, K. Mohammad, A. Al-Natour, N. Al Ali, N. Abu Baker, S. Al Bashtawy, Z. Al Bashtawy, A. Musa1, M. Alshloul</i>	PDF
Tender Coconut Water Can Inhibit Inflammation Caused by Cigarette Smoke <i>Siti Thomas Zulaikhah, Sampurna, Joko Wahyu Wibowo, Helmia Fitri Nurul Aini, Arrizki Azka Pratama</i>	PDF
The Impact of E-Government Success Factors on Citizen Satisfaction: The Context of UAE <i>Hisham O. Mbaidin</i>	PDF
The Use of Honey as Anti-Oxidative Agent: Hatching Rate Embryo of Tor Soro after 48h Post-Cold Storage <i>Suci Lestari, Abinawanto, Anom Bowolaksono, Retno Lestari, Astari Dwiranti, Rudhy Gustiano, Anang Hari Kristanto</i>	PDF
Comparative Analysis of Fingerprint Features Extraction Methods <i>Mua'ad M. Abu-Faraj, Ziad A. Alqadi, Khaled Aldebei</i>	PDF
Expression of LncRNA-MALAT1 in Type 2 Diabetic Patients with or without Coronary Artery Disease <i>Sadia Arif, Fouzia Shaikh, Shumaila Usman, Najia Tabassum, Faisal Memon, Aliya Irshad Sani</i>	PDF
Medical Image Concept Detection Using Full Scale VGG-like Shallow and Transfer Learning Networks <i>Farhat Ullah Khan, Izzatdin Aziz, Nordin Zakaria</i>	PDF
The Effect of Digital Technology on Educational Outcomes through Student Engagement in Distance Education <i>Hani Jarrah, Hanene Lahiani</i>	PDF
The Perception of Individuals' Privacy Concerning the Adoption of Smart City Healthcare Services: A Generic Model Development <i>Abdullah Aslam Alzawamri, Hairoladenan Kasim, Moamin Mahmoud</i>	PDF
A Study on Impact Energy Absorption Performance of Reinforced Rubber Motorcycle Helmet Shells to	PDF

Dear Author,

We hope our e-mail finds you well. Welcome to the Journal of Hunan University Natural Sciences!

Thank you for contacting our Editorial Board Members.

We have received the reports from expert reviewers on your manuscript.

Your paper has been reviewed and was accepted for publication in the Journal of Hunan University Natural Sciences, Volume 48 (12), 2021, with the below list of minor necessary corrections.

If you want to publish in Journal of Hunan University Natural Sciences, Volume 48, Issue 12, December 2021, you need to send the following to the editorial office via [editorial-office@jonuns.com](mailto:editorial-office@jonuns.com) (all in one archive):

1. The article, strictly formatted according to the template recommendations for authors and correct the article on the reviewers' recommendations, see <http://jonuns.com/docs/template.doc> .
2. Payment foto.

Please highlight the corrections in the article in red. We hope you'll do great.

First, we would like to congratulate the authors for their work. The authors present an interesting topic.

Secondly, we would like to make some comments on the reviews of the paper:

1. Please add research goals (two sentence) and scientific novelty (two sentence) in the abstract.
2. Please retain only the most recent references, preferably those published in 2016-2021.
3. Please describe scientific novelty (200-250 words) in the conclusion.
4. Please describe the limitations of the study, and the research perspectives in the conclusion.
5. The article needs English editing.

Deadline for corrections and payment: December 3, 2021.

Please find attached the invoice.

\*Please include the invoice number in the payment note.

\*\*Please write in the e-mail subject: Revised article and payment proof.

All articles published in are published in full open access. In order to provide free access to readers, and to cover the costs of peer review, copyediting, typesetting, long-term archiving, and journal management, an article processing charge (APC) of EUR 430 applies to papers accepted after peer review.

We recommend that the authors use the academic text editing service for the scientific articles, not just proofreading. Please use the American English option. We recommend the use of large, trusted companies with



editors having a Ph.D. degree. You should also attach an editing certificate or use the editorial office services. Articles that native English speakers do not edit are not allowed for publication. The editorial team provides English academic proofreading services for the authors at an additional cost. The fee - EUR 70.00 was already included in the invoice because the certificate of English proofreading is not attached to the article.

The total fee is EUR 500.00, including English editing.

Payment in EURO must be made by wire transfer to the bank account. Banks fees must be paid by the customer for both payer and payee so that we can receive the full invoiced amount.

Volume 48 (12), 2021 will be published online in the end of December.

Thank you very much for your support of open access publishing.

If you have any questions, please do not hesitate to contact us via [editorial-office@jonuns.com](mailto:editorial-office@jonuns.com).

Have a nice day.

Take care of yourself!

Yours sincerely,

Editor-in-Chief

魏建义 Prof. Yi Weijian

Journal of Hunan University Natural Science

<http://jonuns.com/index.php/journal>

----- Original Message -----

Subject: Paper Submission

Date: 2021-11-08 12:50

From: Journal of Hunan University Natural Sciences <[office@jonuns.com](mailto:office@jonuns.com)>

To: [editorial-office@jonuns.com](mailto:editorial-office@jonuns.com)

Title of your paper: Characteristics of Working Fluid Flow in Convergent-Divergent Injectors in Vapour Compression “ Steam Jet Refrigeration

Corresponding Author's Email Address: [firman@poliupg.ac.id](mailto:firman@poliupg.ac.id)

Author(s): Firman Firman, Muhammad Anshar, Amrullah Amrullah

Keywords: refrigeration, vapour compression, steam jet, working fluid, injector

Abstract: One of the technological innovations that has been widely applied is the vapour compression refrigeration-steam jet refrigeration system (VCR-SJR). Vapour compression refrigeration (VCR) and steam jet refrigeration (SJR) are connected by an intercooler. The VCR unit uses a refrigerant working fluid of Hydrocarbon MC 22. The vacuum process in the SJR unit uses a convergent-divergent type injector. The performance of the VCR-SJR refrigeration engine is influenced by the characteristics

of the working fluid flow in the injector. This study aims to determine the characteristics of the working fluid flow in the injector on the VCR-SJR refrigeration machine. Visual analysis of fluid flow in convergent-divergent injectors is carried out by simulation using ANSYS 16.0 which has a FLUENT system analysis feature. Validation is carried out by testing an injector that has dimensions: suction chamber diameter 28 mm, nozzle inlet diameter 14 mm, suction chamber length 58 mm, secondary fluid inlet diameter (10, 15, and 20 mm), nozzle outlet diameter 5 mm, mixing chamber length 130 mm, throat length 95 mm, diffuser length 130 mm, and injector outlet side diameter 40 mm. It is concluded that the diameter of the suction side affects the flow profile of the working fluid in the injector

Dear,

Prof. Yi Weijian

Editir-in-Chief

Journal of Hunan University Natural Science

I herewith send the revised paper and confirm that I'm ready to follow all procedures

Best Regards,

Firman, Firman

- Analysis of the Level of Competition in Commercial Banks in Indonesia PDF  
*Nugroho Agung Wijoyo, Agit Kriswantriyono, Andriyono Kilat Adhi, Amzul Rifin*
- Comparison between Fuzzy-logic MPPT and the Exciting Incremental Conductance Method under Fast Varying of Irradiance PDF  
*Mohammed. S. Al-Mohamade, Hussein D. Al-Majali*
- Business Environment and Competitive Strategy in Improving Sharia Bank Performance in Indonesia PDF  
*Febri Rusnal, Dian Masyita, Erie Febrian, Sulaeman Rahman Nidar, Erika Nurmartiani, Miftachul Huda*
- Challenges of Acquisition Bathymetry Information on PlanetScope Data and Nautical Chart: Experiment Based on IHO S-44 Total Vertical Uncertainty in Multi-Method Satellite-Derived Bathymetry PDF  
*Agung Kurniawan, Widodo Setiyo Pranowo, Yosef Prihanto, Avando Bastari, Johar Setiyadi*
- Collaborative Play Needs Analysis: Introducing Mathematics to Early Childhood PDF  
*Feri Faila Sufa, Gunarhadi, Muhammad Akhyar, Munawir Yusuf*
- Comparison between Fuzzy-logic MPPT and the Exciting Incremental Conductance Method under Fast Varying of Irradiance PDF  
*Mohammed. S. Al-Mohamade, Hussein D. Al-Majali*
- Factors for Safety Sustainability in Workplace: A Case Study in Anglers PDF  
*Shamsul Effendy Abdul Hamid, Mazdi Marzuki, Nik Harnida Suhainai, Miftachul Huda*
- Reconstruction of Educational Institutions in Business Development of Indonesian Human Resources through Cooperation among ASEAN Countries PDF  
*Muhammad Ihsan Dacholfany, Miftachul Huda*
- Reduction of Organic Pollutants Present in Wastewater from the Tanneries of La María in the Department of Quindío Using Photo-Fenton PDF  
*Irma María García Giraldo, Henry Reyes Pineda, Luis Alfonso Salazar*
- Studying the Preparation and Characterization of Composite Polyester Using Different Additives PDF  
*Omar K. Sayed, S. A. Hassan, M. A. Sadek, M. A. Radwan, Hany A. Elazab*
- The Effect of Trust Commitments on Organization: Empirical Insights into Managerial Performance PDF  
*Suharto, Marhaban, Prima Angkupi, Ihsan Dacholfany, Susminingsih, Miftachul Huda*
- The Inhibitory Activity of *Medinilla* Syrup Butanolic Extract against *Candida Albicans* ATCC 10231 PDF  
*Marcel Kurniadi, Agus Limanto, Kris Herawan Timotius*
- Quran Virtual Reality Brainstorming Quran Technology-Based Educational Game: "Beautiful Brainwave Mindset" Therapy PDF  
*Nurul Hidayah, Yuna Annisa Salsabila, Nidya Husna Kholidah*
- The Use of Research Method in Top Health Sciences Research Article: A Systematic Review PDF  
*Imane Ghazlane, Khalid Marnoufi, Bouzekri Touri, Mohamed Bergadi*
- Theoretical Investigation of the Flexural Behavior of Concrete Beam Containing Internal Steel Plates PDF  
*Douaa Najah, Majid D. Mutasher*

Understanding of Batik for Character Education in State Elementary School <i>Ahmad Zainuri, Sukadari, Sunarti, Sisili Marsih, Eko Wahyunanto Prihono, Miftachul Huda</i>	PDF
A Simple, Efficient, Secure and Accurate Method of Speech Signal Cryptography <i>Rashad J. Rasras, Mutaz Rasmi Abu Sara, Ziad Alqadi</i>	PDF
Application of Technological Tool for the Development and Competitiveness of the Livestock Sector in Quindío, Colombia <i>Henry Reyes Pineda, Leidy Carolina Cardona Hernández, Marcelino Eduardo Galviz</i>	PDF
Preparation and Characterization of Polyurethane Foam Based on Different Fillers <i>Nirvana Elghannam, M. A. Sadek, M. A. Radwan, Hany A. Elazab</i>	PDF
Teaching Culture-based Character Education on Elementary School: Internalizing Local Culture during Covid-19 Crisis <i>Siti Supeni, Oktiana Handini, Luqman Al Hakim</i>	PDF
The Development of Pancasila and Civic Education Learning Integrated into Character Education in Junior High School Students in Sukoharjo Regency <i>Suyahman, M. Furqon Hidayatullah, Mulyoto, H. Asrowi</i>	PDF
Transnational Families in Letterkenny, Co Donegal, Ireland: Negotiating Religious Beliefs and Practices <i>Malika Shatnawi</i>	PDF
Critical Investigation of Al-Imām Hibatullāh Al-Bārīzī Al-Shāfi'ī's Contribution on the Science of Ḥadīth <i>Muhammad Zulfadhli Mohd Razi, Muhamad Rozaimi Ramle, Miftachul Huda</i>	PDF
Land Identification for Establishing Conservation Areas in Sloping Land Contexts Using a Geographic Information System: A Case Study of Gunung Mas Regency, Central Kalimantan Province, Indonesia <i>Soaloon Sinaga, Vera Amelia, Andy Bhermana</i>	PDF
Work-Life Balance and Its Impact on Turnover Intention of Married Female Academics in Malaysia: The Mediating Role of Job Satisfaction <i>Sudhashini Nair, Neeta Jayabalan, Ilangovan Perumal, Muthaloo Subramaniam</i>	PDF

---

[Editorial Team](#)


---

[Editorial Policies](#)


---

[Focus & Scope](#)


---

[Author Guidelines](#)


---

[Abstracting and Indexing](#)


---

[Publication Ethics](#)


---

[Paper Submission](#)

Hunan Daxue  
Xuebao/Journal of Hunan...

Q2

Multidisciplinary

best quartile

SJR 2020

0.26

powered by scimagojr.com



**TEMPLATE**



Journal  
Template

**USER**

Username

Password

Remember me

**NOTIFICATIONS**

› [View](#)

› [Subscribe](#)

Search Scope

All ▼

**Search**

Browse

- ▶ [By Issue](#)
- ▶ [By Author](#)
- ▶ [By Title](#)

### INFORMATION

- ▶ [For Readers](#)
- ▶ [For Authors](#)
- ▶ [For Librarians](#)

**Journal of Hunan University Natural Sciences**

Copyright 2012-2022  
(e-ISSN: 1674-2974 )

- [Home](#)
- [Search](#)
- [Archives](#)
- [Contact](#)
- [About](#)
- [Current](#)
- [Sitemap](#)
- [Paper Submission](#)

**+86-731-88823137**  
editorial-office@jonuns.com



Open Access Article

## Characteristics of Working Fluid Flow in Convergent-Divergent Injectors in Vapor Compression – Steam Jet Refrigeration

Firman Firman, Muhammad Anshar, Amrullah Amrullah

Mechanical Engineering Department, Politeknik Negeri Ujung Pandang, Makassar, Indonesia

**Abstract:** The vapor compression refrigeration-steam jet refrigeration system (VCR-SJR) is one of the technological innovations that have been widely applied. Vapor compression refrigeration (VCR) and steam jet refrigeration (SJR) are connected by an intercooler. The VCR unit uses the Hydrocarbon MC 22 refrigerant working fluid. The vacuum process in the SJR unit is provided by a convergent-divergent type injector. The performance of the VCR-SJR refrigeration engine is influenced by the characteristics of the working fluid flow in the injector. The technological innovation of this research is the combined VCR-SJR refrigeration machine using a convergent-divergent type injector in the SJR unit and the VCR unit using MC 22 refrigerant. This study aims to determine the characteristics of the working fluid flow in the injector of the VCR-SJR refrigeration machine. The characteristics are the working fluid flow and pressure profiles in the convergent-divergent injector with variations in the suction injector diameter. Visual fluid flow analysis in convergent-divergent injectors is performed by simulation using ANSYS 16.0 with a FLUENT system analysis feature. Validation is carried out by testing an injector that has the following dimensions: suction chamber diameter 28 mm, nozzle inlet diameter 14 mm, suction chamber length 58 mm, secondary fluid inlet diameter (10, 15, and 20 mm), nozzle outlet diameter 5 mm, mixing chamber length 130 mm, throat length 95 mm, diffuser length 130 mm, and injector outlet side diameter 40 mm. It is concluded that the suction side diameter affects the working fluid flow profile in the injector.

**Keywords:** refrigeration, vapor compression, steam jet, working fluid, injector.

## 蒸汽压缩-蒸汽喷射制冷中会聚-发散喷射器工作流体流动特性

**摘要:** 蒸汽压缩式制冷-蒸汽喷射式制冷系统 (录像机-SJR) 是已被广泛应用的技术创新之一。蒸汽压缩制冷 (录像机) 和蒸汽喷射制冷 (SJR) 通过中间冷却器连接。录像机装置使用碳氢化合物 MC 22 制冷剂工作流体。SJR 单元中的真空过程由收敛-发散型喷射器提供。录像机-SJR 制冷发动机的性能受喷射器中工作流体流动特性的影响。本研究的技术创新是在 SJR 机组和录像机机组采用 MC 22 制冷剂的集散型喷射器的录像机-SJR 组合制冷机。本研究旨在确定录像机-SJR 制冷机喷射器中工作流体的流动特性。特征是收敛-扩张喷射器中的工作流体流量和压力分布, 其中吸入喷射器直径发生变化。采用具有流利系统分析功能的 ANSYS 16.0 进行仿真, 对收敛-发散喷射器中的流体流动进行可视化分析。通过测试具有以下尺寸的喷射器进行验证: 吸入室直径 28 毫米, 喷嘴入口直径 14 毫米, 吸入室长度 58 毫米, 二次流体入口直径 (10、15 和 20 毫米), 喷嘴出口直径 5 毫米, 混合室长度 130 毫米, 喉部长度 95 毫米, 扩散器长度 130 毫米, 喷射器出口侧直径 40 毫米。得出结论, 吸入侧直径影响喷射器中的工作流体流动分布。

**关键词:** 制冷、蒸汽压缩、蒸汽喷射、工作流体、喷射器。



## 1. Introduction

Along with the rapid development of the industry, energy consumption is increasing as well. On the other hand, the world's energy reserves, especially fuel oil, are depleting and gradually run out. Therefore, strategic steps and innovation are needed to obtain energy-efficient technology. Applying a combined heat and power (CHP) system is very appropriate for industries that require a power plant and a cooling system. Steam jet refrigeration (SJR) is one of the technologies applied in the food industry sector. The SJR system utilizes residual steam from the boiler and then flows it through nozzles to a flash tank filled with water. The nozzle converts pressure energy into kinetic energy to evaporate water briefly and release it to the condenser. Chilled water produced from the condenser cools the product through the transfer process. According to [1], the SJR system can be operated at a boiler temperature of 120 to 140°C and an evaporator temperature of 5 to 15°C. In general, 1% water evaporation in the tank can reduce the water temperature by 6°C [2]. The evaporator temperature is saturation temperature which depends on the evaporator pressure. Low pressure or vacuum in the evaporator is very dependent on the design of the nozzle (injector). According to [3], the ejector area ratio has a maximum corresponding to an optimum inlet pressure value. The optimum value decreases with a backpressure increase. Therefore, it is necessary to design the right injector for application in the steam jet refrigeration engine. As reported in [4], the optimum design inclination angle of the steam injector is 20° for the convergent type and 30° for the divergent type with a 137 mm throat length. However, due to the geometry factor, the efficiency or performance (COP) of the steam jet refrigeration engine is still very low.

As stated in [5], VCR-SJR system COP using refrigerant R 134a increased compared to the single SJR system. The problem is that the refrigerant R 134a includes hydrofluorocarbon (HFC) refrigerant, affecting global warming. Therefore, developing environmentally friendly hydrocarbon refrigerant (HC) technology is necessary. Using a hydrocarbon refrigerant such as isobutane (R 1234yf) is a good option for the VCR-SJR combination refrigeration machine [6]. However, this option is difficult to implement widely because refrigerant R 600a is only produced for certain brands of refrigeration machines. Therefore, alternative refrigerants that are environmentally friendly and widely available in the market are needed.

The technological innovation that will be applied in this research is the VCR-SJR combination refrigeration machine using a convergent-divergent type injector in the SJR unit and the VCR unit using MC 22 refrigerant. The performance of the SJR system highly depends on the efficiency of the nozzles, while the efficiency of the nozzle is influenced by the geometry

and fluid pressure in the injector [7], [8]. This study aims to determine the characteristics of the working fluid flow in a Convergent-Divergent Injector in a Steam-Jet Compression Refrigeration Machine.

## 2. Literature Review

The operating principle of the SJR refrigeration machine is that steam from the boiler flows into an evaporator or flash tank through a nozzle. The nozzle suction side is connected to the evaporator, while the outlet side is connected to the condenser. Nozzles convert pressure energy into kinetic energy to decrease the vapor pressure. This pressure drop causes the vapor in the evaporator to be sucked in and then flowed to the condenser. The very fast evaporation of 1 kg of water results in a temperature decrease of 5.7°C [2]. If this condition continues, the water temperature will be lower as well. This can be done until it reaches the desired water temperature. The disadvantage of the SJR system is that water will freeze at 0°C, so it cannot circulate in the system. Due to these shortcomings, the application of the SJR system at low temperatures is very limited.

The VCR system refrigeration machine consists of four main components: compressor, condenser, expansion device, and evaporator. The heat is absorbed from the refrigerant to the cooling load in the evaporator.

The use of alternative refrigerants that are environmentally friendly, such as hydrocarbon refrigerants, is growing and widely used. This is understandable because hydrocarbon refrigerants do not contain Chlor, so it does not damage the ozone layer or cause global warming. The selection of alternative refrigerants for the 21st century must consider ODS elimination programs, system efficiency, global warming, safety, and costs [9]. Therefore, in producing alternative refrigerants, manufacturers consider the things proposed by Carter. In connection with this proposal, the ozone layer damage caused by HC refrigerant emissions decreased compared to CFC refrigerants [10]. This shows that the use of HC refrigerants is much better than CFC refrigerants.

Hydrocarbon refrigerants are the best choice for domestic refrigeration machines because they are environmentally friendly and energy-efficient [11]. More efficient use of energy positively influences the use of HC refrigerants. The increase in efficiency is caused by the density of the refrigerant HC being smaller than the density of CFC, so the compressor work is also lighter [12]. The SJR system performance is highly dependent on the efficiency of the nozzles, while the efficiency of the nozzle is influenced by the geometry and fluid pressure in the injector.

The influencing factors in injector design are the geometry between the water surface and the injector suction side. The ratio between inlet pressure and critical pressure depends on the injector geometry and

the thermal properties of the working fluid [13]. Another important thing to consider is the mass flow rate of the primary flow [14]. The optimum geometry design of the steam injector is an inclination angle of  $2^\circ$  for convergent nozzles and  $3^\circ$  for divergent nozzles with a throat length of 137 mm [4]. On the output side, the parameter that affects the efficiency of the injector is the pressure drop [7]. Other factors to consider are critical pressure and shock waves at the injectors [15]. In addition, convection heat transfer below the boiling temperature is also important to consider [12].

### 3. Research Methodology

The secondary data visual fluid flow analysis in convergent-divergent injectors can be done by simulation using ANSYS 16.0, which has the FLUENT system analysis feature [16]. The first step of the simulation is to draw a convergent-divergent CAD injector using solid works. The second step implies import the convergent-divergent CAD injector into ANSYS using the geometry feature. At the third step, the convergent-divergent injector geometry is imported into the mesh. At the fourth step, the mesh is imported into setup, then set the solver based on pressure and steady-state problem in time type. At the fifth step, the energy equation is applied and the inlet and output pressures are set at the boundary conditions. Finally, the iterative solver and mixed initialization are selected, then the program is run.

Validation is done by testing an injector that has dimensions: suction chamber diameter 28 mm, nozzle inlet diameter 14 mm, suction chamber length 58 mm, secondary fluid inlet diameter (10, 15, and 20 mm), nozzle output diameter 5 mm, mixing length chamber 130 mm, throat length 95 mm, diffuser length 130 mm, and injector outlet diameter 40 mm. The injector is installed in a test circuit, as shown in Figure 1. The test is carried out by measuring several parameters, namely: injector steam inlet temperature,  $T_7$  ( $^\circ\text{C}$ ); the temperature of the steam and water mixture leaving the injector  $T_8$  ( $^\circ\text{C}$ ); injector steam pressure  $P_3$  (bar); the pressure of the steam and water mixture leaving the injector  $P_4$  (bar); flash tank inlet water temperature  $T_7$  ( $^\circ\text{C}$ );  $T_8$  flash tank inlet water temperature ( $^\circ\text{C}$ ); flash tank inlet water pressure  $P_5$  (bar); and  $P_6$  flash tank outlet water pressure (bar). The temperature measurement uses a data acquisition system instrument, while the pressure and flow rate measurement uses an analog system instrument both on the VCR and the SJR units.

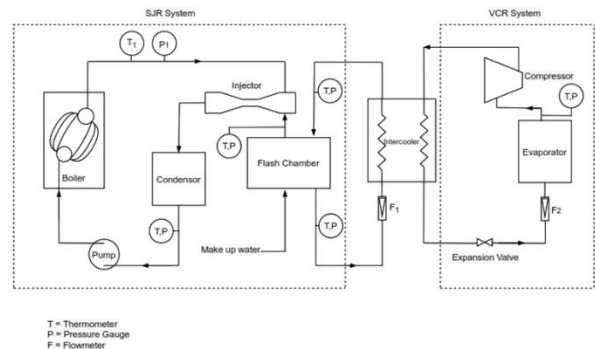


Fig. 1 Experimental setup

### 4. Results and Discussion

Figure 2 shows the static pressure variation inside the injector with a suction diameter of 10 mm. The high static pressure on the inlet side of the nozzle then drops after exiting the nozzle. Furthermore, the pressure drops drastically at a certain position and then tends to be constant until the injector exits. This is in line with the results of research conducted by [17].

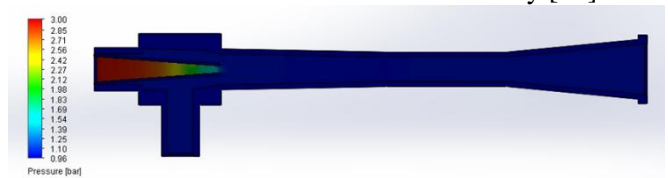


Fig. 2 Pressure contour with the suction diameter ( $d=10$  mm)

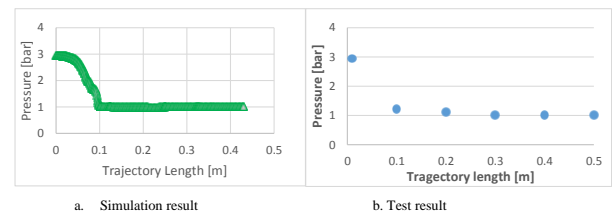


Fig. 3 Pressure vs. trajectory length with the suction diameter ( $d=10$  mm)



Fig. 4 Pressure contour with the suction diameter ( $d=15$  mm)

As in Figure 2 before, Figure 4 shows the static pressure variation inside the injector with a suction diameter of 10 mm. The high static pressure on the inlet side of the nozzle then drops after exiting from the nozzle. Furthermore, the pressure drops drastically at a certain position and then tends to be constant until the injector exits.

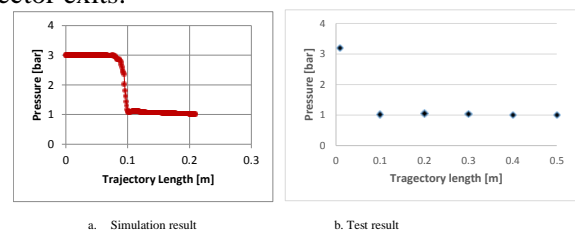


Fig. 5 Pressure vs. trajectory length with suction side diameter ( $d=15$  mm)

Same as is the case with Figure 3, Figure 5 (a) also shows the simulation results of the pressure profile along the injector path, and the pressure profile conforms to the test results (b).



Fig. 6 Pressure contour with the suction diameter ( $d=20$  mm)

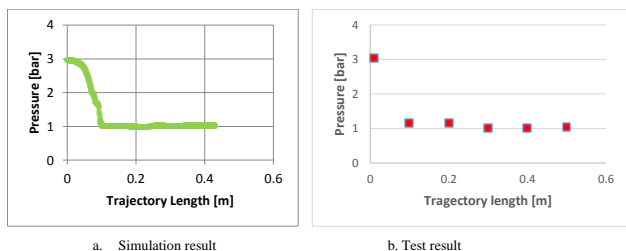


Fig. 7 Pressure vs. trajectory length with the suction diameter ( $d=20$  mm)

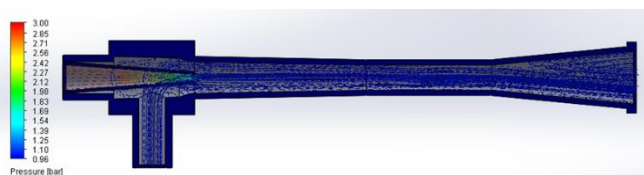


Fig. 8 Streamline with suction diameter ( $d=10$  mm)

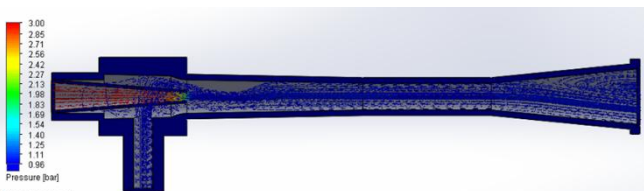


Fig. 9 Streamline with suction diameter ( $d=15$  mm)

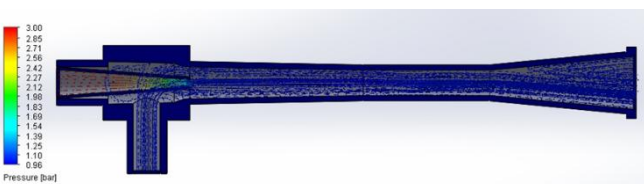


Fig. 10 Streamline with suction diameter ( $d=20$  mm)

Figures 8, 9, and 10 show the uniformity of flow streamlines in the injector, especially around the axis along the path for the three variations of the injector suction diameter. However, Figure 9 shows a slight difference in flow, namely the occurrence of shock in the area of about 10 mm of the primary nozzle. This is influenced by the injector suction side diameter and complies with the previous research results [18], [19].

Simulation of working fluid flow in the injector has been carried out using ANSYS 16.0 and validated through testing on an injector testing installation which has dimensions: suction chamber diameter 28 mm, nozzle inlet diameter 14 mm, suction chamber length 58 mm, secondary fluid inlet diameter,  $d$  (10, 15, and 20 mm), the nozzle outlet diameter is 5 mm, the mixing

chamber length is 130 mm, the throat length is 95 mm, the diffuser length is 130 mm, and the injector outlet side diameter is 40 mm. Figures 2 to 7 show the pressure contour, and the match between the simulation results and the test results is obtained. Therefore, the streamlined simulation results shown in Figures 8 to 10 are also quite accurate. The findings obtained from the results of this study are shown in Figure 11.

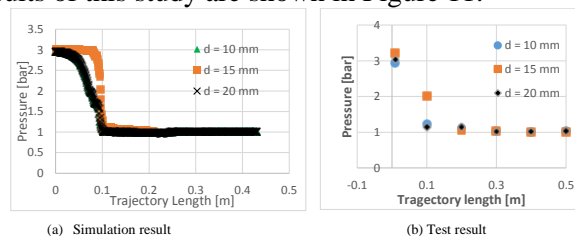


Fig. 11 Pressure vs. trajectory length with the suction diameter ( $d$ )

Figure 11 shows the suction side diameters 10 mm and 20 mm have the same trend of pressure profile, but the 15 mm suction side diameter shows different things. This means that the injector geometry is very influential on the fluid flow, which will also affect the performance of the VCR-SJR refrigerating machine. These results are in line with the previous research results [20].

## 5. Conclusion

The simulation results of working fluid flow in the injector using ANSYS 16.0 and validation through testing on a testing installation of a convergent-divergent injector concluded that, in general, the injector geometry, especially suction side diameter, affects the flow profile of the working fluid in the injector. Validation is carried out by testing an injector that has dimensions: suction chamber diameter 28 mm, nozzle inlet diameter 14 mm, suction chamber length 58 mm, secondary fluid inlet diameter (10, 15, and 20 mm), nozzle outlet diameter 5 mm, mixing chamber length 130 mm, throat length 95 mm, diffuser length 130 mm, and injector outlet side diameter 40 mm. The profile of working fluid flow and pressure in the convergent-divergent injector with variations in the suction injector diameter had been determined. The pressure drops drastically at a certain position and then tends to be constant until the injector exits. However, the suction side diameter affects the flow profile of the working fluid in the injector. It is concluded that the characteristics of the working fluid flow in the injector on the VCR-SJR refrigeration machine are different at the various diameters of the suction side.

The carryout of this research will be applied as technological innovation of the VCR-SJR combination refrigeration machine using a convergent-divergent type injector in the SJR unit and the VCR unit using MC 22 refrigerant.

## Acknowledgment

The authors would like to thank the Ministry of Research, Technology, and Higher Education for its support in the National Strategic Research

## References

- [1] SUVARNAKUTA N, PIANTHONG K, SRIVEERAKUL T, & SEEHANAM W. Performance analysis of a two-stage ejector in an ejector refrigeration system using computational fluid dynamics. *Engineering Applications of Computational Fluid Mechanics*, 2020, 14(1): 669-682.
- [2] SHET U S P, SUNDARARAJAN T, & MALLIKARJUNA JM. *Refrigeration Cycles*. Madras: Indian Institute of Technology, 2014
- [3] SIOUD D, GARMA R, & BELLAGI A. Optimization of Steam Ejector Design and Performance. *International Journal of Scientific Research & Engineering Technology*, 2019, 9: 1-5.
- [4] KEERATIYADATHANAPAT N, SRIVEERAKUL T, SUVARNAKUTA N, & PIANTHONG K. Experimental and Theoretical Investigation of s Hybrid Compressor and Ejector Refrigeration System for Automotive Air Conditioning Application. *Engineering Journal*, 2017, 21(5): 105-123.
- [5] HADJ A, & BOULENOUAR M. CFD analysis of operating condition effects on optimum nozzle exit position of a supersonic ejector using the refrigerant 134a. *Comptes Rendus Mecanique*, 2021, 349(1): 189-202.
- [6] MOGHADDAM HA, SHFAEE M, & RIAZI R. Numerical Investigation of a Refrigeration Ejector: Effects of Environment-Friendly Refrigerant and Geometry of the Ejector Mixing Chamber. *European Journal of Sustainable Development Research*, 2019, 3(3), em0090: 0-17.
- [7] SAHNI R. Ejector Expansion Refrigeration Systems Research Invent. *International Journal of Engineering and Science*, 2015, 5(2): 25-29.
- [8] BAZAGNI G, MEREU R, & INZOLI F. Ejector Refrigeration: A comprehensive Review. *Journal of Renewable and Sustainable Energy Reviews*, 2016, 53: 373-407.
- [9] ELBARGHTHI A F A, MOHAMED S, NGUYEN V V, & DVORAK. V CFD Based Design for Ejector Cooling System Using HFOS (1234ze(E) and 1234yf). *Energies*, 2020, 13, 1408: 1-19.
- [10] ALDAS K, SEN F, & OZKUL I. The Investigation of Gas Ejector Performance using CFD Modelling. *TEM Journal*, 2013, 2(2): 130-135.
- [11] KOH J H, ZAKARIA Z, & VEERASAMY D. Hydrocarbons as Refrigerants-A Review. *ASEAN Journal of Science and Technology for Development*, 2017, 34(1): 35-50.
- [12] FIRMAN F., & ANSHAR M. Experimental Investigation of Boiling Heat Transfer Coefficient of MC-22 on Horizontal Copper Rod. *Proceedings of 7<sup>th</sup> Annual Southeast Asian International Seminar*, Bogor, Indonesia, 2018: 7-8.
- [13] CHUNNANNOND K, & APHORNRATANA S. Ejectors. *Journal of Renewable and Sustainable Energy; Reviews*, 2004, 8: 129-155.
- [14] MUHAMMAD, H.A. et al. Numerical Modeling of Ejector and Development of Improved Methods for the Design of Ejector-Assisted Refrigeration System. *Energies*,

2020, 13, 5835: 1-19.

- [15] MA ZH, BAO H, & ROSKILLY A P. Thermodynamic modelling and parameter determination of ejector for ejection refrigeration systems. *International Journal of Refrigeration*, 2017, 75: 117-128.
- [16] FIRMAN F, & ANSHAR M. Study on steam pressure characteristics in various types of nozzles. *Journal of Physics: Conference Series*, 2018, 979: 012084. The 2nd International Conference on Science, 2-3 November 2017, Makassar, Indonesia,
- [17] NARAYANA K S, & REDDY K S. Simulation of Convergent Rocket Nozzle using CFD Analysis. *IOSR Journal of Mechanical and Civil Engineering*, 2016, 13(4) Ver. I: 58-65.
- [18] VENKATESH V, & REDDY C J P. Modelling and Simulation of Supersonic Nozzle Using Computational Fluid Dynamics. *International Journal of Novel Research in Interdisciplinary Studies*, 2015, 2(6): 16-27.
- [19] SUDHAKAR B V V N, SEKHAR B P C, MOHAN P N, & AHMAD MT. Modelling and simulation of Convergent-Divergent Nozzle Using Computational Fluid Dynamics. *International Research Journal of Engineering and Technology*, 2016, 03(08): 346-350.
- [20] PATEL A R, and KHUNT M J. Performance Optimization of Steam Jet Ejector using CFD. *International Journal for Innovative Research in Science & Technology*, 2015, 2(1): 1275-1278.

## 参考文献:

- [1] SUVARNAKUTA N 、 PIANTHONG K 、 SRIVEERAKUL T 和 SEEHANAM W. 使用计算流体力学对喷射器制冷系统中的两级喷射器进行性能分析。计算流体力学的工程应用, 2020, 14(1): 669-682.
- [2] SHET U S P 、 SUNDARRARAJAN T 和 MALLIKARJUNA JM. 制冷循环。马德拉斯: 印度理工学院, 2014
- [3] SIOUD D、GARMA R 和 BELLAGI A. 蒸汽喷射器设计和性能的优化。国际科学研究与工程技术杂志, 2019, 9: 1-5.
- [4] KEERATIYADATHANAPAT N、SRIVEERAKUL T 、SUVARNAKUTA N 和 PIANTHONG K. 用于汽车空调应用的混合压缩机和喷射器制冷系统的实验和理论研究。工程杂志, 2017, 21(5): 105-123.
- [5] HADJ A 和 BOULENOUAR M. 差价合约分析运行条件对使用制冷剂 134a 的超音速喷射器的最佳喷嘴出口位置的影响。机械报告, 2021, 349(1): 189-202.
- [6] MOGHADDAM HA、SHFAEE M 和 RIAZI R. 制冷喷射器的数值研究: 环保制冷剂的影响和喷射器混合室的几何形状。欧洲可持续发展研究杂志, 2019, 3(3), em0090: 0-17.
- [7] SAHNI R. 喷射膨胀制冷系统研究发明。国际工程与科学杂志, 2015, 5(2): 25-29.
- [8] BAZAGNI G、MEREU R 和 INZOLI F. 喷射制冷: 综合评论。可再生和可持续能源评论杂志, 2016, 53: 373-407.
- [9] ELBARGHTHI A F A、MOHAMED S、NGUYEN V V 和 DVORAK. V 使用 HFOS (1234ze(E) 和 1234yf)

的喷射器冷却系统的基于差价合约的设计。能源, 2020, 13, 1408: 1-19。

[10] ALDAS K、SEN F 和 OZKUL I. 使用差价合约建模研究气体喷射器性能。透射电镜杂志, 2013, 2(2): 130-135.

[11] KOH J H、ZAKARIA Z 和 VEERASAMY D. 碳氢化合物作为制冷剂——综述。东盟科技促进发展杂志, 2017, 34(1): 35-50.

[12] FIRMAN F., 和 ANSHAR M. 水平铜棒上 MC-22 沸腾传热系数的实验研究。第七届东南亚国际研讨会论文集, 印度尼西亚茂物, 2018: 7-8.

[13] CHUNNANNOND K 和 APHORNRATANA S. 喷射器。可再生和可持续能源杂志; 评论, 2004, 8: 129-155.

[14] MUHAMMAD, H.A.等。喷射器的数值建模和改进的喷射器辅助制冷系统设计方法的开发。能源, 2020, 13, 5835: 1-19。

[15] MA Z H, BAO H, 和 ROSKILLY A P. 喷射制冷系统喷射器的热力学建模和参数确定。国际制冷杂志, 2017, 75: 117-128。

[16] FIRMAN F, 和 ANSHAR M. 各种类型喷嘴的蒸汽压力特性研究. 物理学杂志: 系列会议, 2018, 979: 012084。第二届国际科学会议, 2017 年 11 月 2-3 日, 印度尼西亚望加锡,

[17] NARAYANA K S 和 REDDY K S. 使用差价合约分析模拟会聚火箭喷嘴。IOSR 机械与土木工程杂志, 2016, 13(4) Ver.我: 58-65。

[18] VENKATESH V, 和 REDDY C J P. 使用计算流体力学对超音速喷嘴进行建模和仿真。国际跨学科新研究杂志, 2015, 2 (6) : 16-27。

[19] SUDHAKAR B V V N、SEKHAR B P C、MOHAN P N 和 AHMAD MT. 使用计算流体力学对收敛-发散喷嘴进行建模和仿真。国际工程技术研究杂志, 2016, 03(08): 346-350.

[20] PATEL A R 和 KHUNT M J. 使用差价合约对蒸汽喷射器进行性能优化。国际科技创新研究杂志, 2015, 2 (1) : 1275-1278。