TSCFA台灣超臨界流體協會
Taiwan Supercritical Fluid Association

電子報第 203 期

活動訊息

- ***International Chemical Engineering Symposia 2024***

  日期：**18-20 March, 2024**

  地點：Nakamozu Campus, Osaka Metropolitan University

  CHAIR：Prof. Hirohisa UCHIDA

  ※海外線上參加，免費註冊!!!

  IChES - International Chemical Engineering Symposia (scej.org)

  議程：https://www4.scej.org/meeting/89a/ICprog/en_session_K-3.html

- ***19 TH ISSF, (European Meeting on Supercritical Fluids EMSF)***

  日期：**26-29 MAY 2024**

  地點：MARIBOR, SLOVENIA

  CHAIR：ZELJKO KNEZ, SLOVENIA

  Scientific Meetings – ISASF (supercriticalfluidsociety.net)

- ***14 TH ISSF(International Symposium on Supercritical Fluids)***

  日期：**JUNE 2025**

  地點：BALI

  CHAIR：JAEHOON KIM, SOUTH KOREA

  Scientific Meetings – ISASF (supercriticalfluidsociety.net)

會員動態

- 賀本會團體會員亞果生醫取得美國『去細胞器官之製備及應用』核准專利！

淨零永續

- **生醫製品產業低碳轉型推動計畫-綠色生產的實踐：低碳製程技術應用共學會**

  日期：**113 年4月2日 (星期二) 13:30**

  地點：產業學院台北學習中心 (台北市復興南路二段 237 號 4 樓)

- IDB 產業節能減碳資訊網 INDUSTRIAL ENERGY SAVING AND CARBON REDUCTION INFORMATION WEB

  https://ghg.tgpf.org.tw/

- 淨零永續學校

  https://college.itri.org.tw/nzschool/

團體會員介紹

- 台灣中油股份有限公司 綠能科技研究所

教育訓練班

- (夜間班)高壓氣體特定設備操作人員安全衛生教育訓練班 04/01~04/14
- (日間班)高壓氣體特定設備操作人員安全衛生教育訓練班 04/22~04/26

技術文摘

- An Experimental Investigation of Supercritical Methane Injection Characteristics in a CO_2 Environment (CO_2 環境 下注入超臨界甲烷特性實驗研究)
- Assessing CO_2 geological storage in Arbuckle Group in northeast Oklahoma (評估奧克拉荷馬州東北部 Arbuckle Group 的 CO_2 地質封存)
- Assessment of Part-Load Operation Strategies of Supercritical Power Cycles Using Carbon Dioxide Mixtures in CSP Plants, Including Air-Cooled Condenser Optimisation (評估 CSP 發電廠中使用二氧化碳混合物的超臨界動力循環之部分負載運行策略，包括風冷冷凝器優化)
- CFD prediction of heat transfer at supercritical pressure with rough walls: Parametric analyses and comparison with experimental data (粗壁超臨界壓力熱傳之 CFD 預測：參數分析及與實驗數據的比較)
- Exploration of optimal preparation strategy of Chenpi (pericarps of *Citrus reticulata* Blanco) flavouring essence with great application potential in sugar and salt-reduced foods (*低糖低鹽食品中具有巨大應用潛力的陳皮*調味香精優化製備策略探索)
- Numerical simulation of flow and heat transfer performance during supercritical water injection in vertical wellbore: A parameter sensitivity analysis (直井超臨界注水之流動與熱傳性能數值模擬：參數敏感度分析)
- Preparation of Mesophase Pitch through Supercritical Fluid Extraction of Coal Tar Pitch (超臨界流體萃取煤焦油瀝青製備介相瀝青)

台灣超臨界流體協會
電話：(07)355-5706　E-mail：tscfa@mail.mirdc.org.tw

生醫製品產業低碳轉型推動計畫

-綠色生產的實踐：低碳製程技術應用共學會

主辦單位：財團法人生物技術開發中心

指導單位：經濟部產業發展署

會議日期：113 年 4 月 2 日 (星期二) 13:30

會議地點：產業學院台北學習中心 (台北市復興南路二段 237 號 4 樓)

適合對象： ESG 永續部門、製造相關部門之管理層及人員、有興趣之生技醫藥業者

優先，報名錄取將於會前 2 日以 Email 通知

活動議程：

時間	主題	講者
13:00-13:30	貴賓報到	
13:30-13:35	開場致詞	經濟部產業發展署 王薇鈞 技士
13:35-14:25	**超臨界二氧化碳在生技醫藥原料的低碳萃取與純化之應用**	**喬璞科技** **梁明在 總經理**
14:25-15:15	低碳萃取製程薄膜技術開發	中原大學薄膜研發中心 張雍 主任
15:15-15:30	綜合討論	
15:30-15:45	茶敘交流	
15:45-16:05	廢熱回收、廢水減量暨碳捕捉再利用	細胞製氣 張兆綱 總經理
16:05-16:25	開發農業低碳新材料，打造可溯源及碳足跡之數位平台	正瀚生技 林雅玲 董事長特助
16:25-16:40	綜合討論	
16:40	會議結束	

- 主辦單位保留接受報名與否之最終權利，及最終解釋、取消、終止、修改、暫停本活動之權利，如有未盡事宜或受疫情影響，主辦單位有權隨時補充或修正，並公佈於活動網站
- 若有任何問題，請洽財團法人生物技術開發中心 李經理，電話: (02) 2655-8133 #113 ；周經理，電話: (02) 2655-8133 #102

Gtr GREEN TECHNOLOGY RESEARCH INSTITUTE 台灣中油 綠能科技研究所

成立宗旨

為配合政府推動再生能源、高值低碳及環保節能之新能源政策，於 100 年 9 月 1 日成立籌備處，101 年 3 月 1 日正式成立綠能科技研究所，104 年 6 月 16 日與新材料試量產及認證中心合併。為本公司再生能源、高值低碳及環保節能產業之研發樞紐，以及試量產平台。期將現有資本、設備、勞力之生產型態，加值轉型為知識、技術、創意之經營模式。

經營願景

配合政府推動綠色能源產業及「新材料循環經濟產業研發專區」的政策，建構「綠色材料研製中心」、「海洋資源開發」、「綠色能源研發」及「碳循環應用」四大領域做為發展項目，致力於循環經濟發展與新材料應用，創造資源循環再利用的價值，進行價值創造與技術深耕，期能引領中油邁向高值低碳、環保節能綠色產業領域，奠定企業永續發展基礎。

未來目標

建立短期核心技術，逐年增加可商業化產品與技術之產出，預期每年可推出 3~5 件專利或可商業化之產品與技術。

公司拓展現有之營業範疇，逐步邁入再生能源、高值低碳及環保節能之綠能產業，並進行試量產及效益評估，以適時推出具競爭力之綠能產業商業化製程及產品。

角色定位

經由創能(生質能、零碳電能)、儲能(儲電、儲氫)、節能(有效燃燒、省電照明、隔熱降溫、廢熱利用)之三能並進，開創研發、創新、永續之再生能源、高值低碳、環保節能之綠能產業。

研發策略

以科技整合及策略聯盟，厚植綠能科技產業研發，建立核心技術，加值綠色產品與技術開發之商業價值，提供國內外產、官、學、研之綠能科技研究整合平台，配合公司經營策略及政府新能源政策，以自行研究、委託研究、合作研究之整合模式來推動綠能產業。

研發方向

「減碳、節能、淨能」是綠能所研發主軸，將研發成果試量產，以達成「新產品商業化、新技術工程化」的終極目標，綠能所研究主題之擬定原則為：

✓ 配合國家能源政策，而有生質能、太陽光電等新能源之相關研究。

✓ 延伸中油本業，如以自有料源、或獨有的資源為著眼點，以掌握發展利基。

✓ 導入綠能技術，因應節能減碳環保課題，研發儲能/節能產品，以因應產業發展趨勢。

產業未來規劃

- 生質能（柴/航/燃)生產技術開發
- 生質醇生產技術開發
- 太陽能光電技術開發
- 氫能與燃料電池技術開發
- 生質化學品及生質高分子材料開發
- 電池儲能材料開發(LTO、LMNO)
- 環保節能隔熱塗覆材料開發
- 奈米光觸媒之綠色產品開發
- 海藻培育減碳技術開發
- 循環經濟技術開發

再生能源
- 生質精煉技術
- 生質物熱裂解技術
- 薄膜太陽能電池技術
- 氫能燃料電池

太陽能維運中心
- 太陽光電技術及監測管理

材料科技
- 環保高性能塗覆材料
- 鋰酸鋰儲能材料

環保科技
- LNG冷排水利用之海藻養殖技術研發

方法工程
- 碳五提純
- 精製瀝青
- 非晶型碳材

試量產
- Pilot 驗證

品保驗證
- 委託檢驗服務
- 檢驗方法建立

企劃行銷
- 研發方向規劃
- 研發成果推廣

TSCFA 台灣超臨界流體協會
Taiwan Supercritical Fluid Association

(夜間班)高壓氣體特定設備操作人員安全衛生教育訓練班

需要有操作證照的單位，歡迎向協會報名。

●上課日期：**(夜班)04/01~4/14 18:30~21:30；04/13~4/14 08:00~17:00(實習)**

●上課時數：高壓氣體特定設備操作人員安全衛生教育訓練課程時數 35 小時＋2 小時(測驗)。

●課程內容：高壓氣體概論 3HR、種類及構造 3HR、附屬裝置及附屬品 3HR、自動檢查與檢點維護 3HR、安全裝置及其使用 3HR、操作要領與異常處理 3HR、事故預防與處置 3HR、安全運轉實習 12HR、高壓氣體特定設備相關法規 2HR，共 35 小時。(另加學科測驗 1 小時及術科測驗約 1~2 小時)

●上課地點：高雄市楠梓區高楠公路 1001 號【金屬工業研究發展中心研發大樓 2 樓　產業人力發展組】

●參加對象：從事高壓氣體特定設備操作人員或主管人員。

●費　　用：本班研習費**新台幣 7,000 元整**，**本會會員享九折優惠**。

●名　　額：每班 30 名，額滿為止。

●結訓資格：期滿經測驗成績合格者，取得【高壓氣體特定設備操作人員安全衛生訓練】之證書。

●報名辦法：1.傳真報名：(07)355-7586台灣超臨界流體協會
2.報名信箱：tscfa@mail.mirdc.org.tw
3.研習費請電匯至 兆豐國際商銀 港都分行(代碼017)
戶名：社團法人台灣超臨界流體協會 帳號：002-09-018479（註明參加班別及服務單位）或以劃線支票抬頭寫「台灣超臨界流體協會」連同報名表掛號郵寄台灣超臨界流體協會，本會於收款後立即開收據寄回。

※洽詢電話：(07)355-5706 吳小姐繳交一吋相片一張及身份證正本

報　　名　　表

課程名稱	高壓氣體特定設備操作人員安全衛生教育訓練			上課日期	113 年 04/01~04/14	
姓　　名	出生年月日	身份證字號	手機號碼	畢業校名		公司產品
服務單位					電　　話	
服務地址	□□□				傳　　真	
發票住址	□□□				統一編號	
負 責 人	人	訓練聯絡人 / 職稱		email：		
參加費用	共　　元	參加性質		□公司指派　□自行參加		
繳費方式	□郵政劃撥　□支票　□附送現金			報名日期	年　月　日	

※ 出生年月日、身份證字號、畢業校名、電話、地址須詳填，以利製作證書。

上課日期時間表

課程名稱：(日間班)高壓氣體特定設備操作人員安全衛生教育訓練班

2024/04/01 (一)	18:30 ~ 21:30
2024/04/02 (二)	18:30 ~ 21:30
2024/04/03 (三)	18:30 ~ 21:30
2024/04/08 (一)	18:30 ~ 21:30
2024/04/09 (二)	18:30 ~ 21:30
2024/04/10 (三)	18:30 ~ 21:30
2024/04/11 (四)	18:30 ~ 21:30
2024/04/12 (五)	18:30 ~ 21:30
2024/04/13 (六)	08:00 ~ 17:00 (實習第 1 組)
2024/04/14 (日)	08:00 ~ 14:00 (實習第 1 組)

TSCFA台灣超臨界流體協會
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(日間班)高壓氣體特定設備操作人員安全衛生教育訓練班

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戶名：社團法人台灣超臨界流體協會 帳號：002-09-018479（註明參加班別及服務單位）或以劃線支票抬頭寫「台灣超臨界流體協會」連同報名表掛號郵寄台灣超臨界流體協會，本會於收款後立即開收據寄回。

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姓　　名	出生年月日	身份證字號	手機號碼	畢業校名		公司產品
服務單位				電　　話		
服務地址	□□□			傳　　真		
發票住址	□□□			統一編號		
負 責 人	人	訓練聯絡人 / 職稱		email：		
參加費用	共　　元	參加性質		□公司指派　　□自行參加		
繳費方式	□郵政劃撥　□支票　□附送現金			報名日期	年　　月　　日	

※ 出生年月日、身份證字號、畢業校名、電話、地址須詳填，以利製作證書。

上課日期時間表

課程名稱：(日間班)高壓氣體特定設備操作人員安全衛生教育訓練班

2024/04/22 (一)	08:00 ~ 17:00
2024/04/23 (二)	08:00 ~ 17:00
2024/04/24 (三)	08:00 ~ 17:00
2024/04/25 (四)	08:00 ~ 17:00 (實習第 1 組)
2024/04/26 (五)	08:00 ~ 14:00 (實習第 1 組)

An Experimental Investigation of Supercritical Methane Injection Characteristics in a CO_2 Environment

CO_2 環境 下注入超臨界甲烷特性實驗研究

By **Ritesh Ghorpade, Gihun Kim, K. R. V. Manikantachari (Raghu), Joshua Weiner, Daniel T. Banuti, Subith Vasu**

Center for Advanced Turbomachinery and Energy Research (CATER), University of Central Florida, Orlando, FL 32816

Abstract

Clean energy generation is gaining significant attention from industries, academia, and governments across the globe. The Allam cycle is one such technology that has been under focus due to its efficiency, environmental friendliness, and economics. This is a direct-fired cycle operating at supercritical conditions using carbon dioxide as a working fluid. Fuel or oxidizer jet mixing with CO_2 is a vital phenomenon that governs combustion efficiency, and it is not well understood for the Allam cycle conditions. This paper experimentally investigated the jet characteristics of a methane jet injected into a subcritical to supercritical carbon dioxide environment. A wide range of injection pressures and temperatures were targeted between subcritical to supercritical conditions. Unlike previous studies, the current work focused on injecting lower-density (methane) jets into higher-density (carbon dioxide) environments. Schlieren imaging and methane absorption measurements were simultaneously performed with a CMOS high-speed camera and a 3.39 μm infrared laser. Specifically, we looked at the classical injection parameter of jet spreading angle, which was classically established to be mainly a density ratio function. Here, the jet cone angle was obtained from the postprocessed schlieren imaging. The jet cone angle is a critical characteristic parameter that describes the entrainment rate in a jet; thus, it is a crucial parameter in understanding the nature of the jet. The laser measurements were only used as an additional check to confirm the entry time of methane into the chamber filled with carbon dioxide. Notably, this paper makes a detailed comparison between the jet cone angles of jets with a density ratio. The result showed that the classical correlations, such as Abramovich's theory applied to submerged turbulent gas jets developed for low-density ratio jets, were unsuitable for higher-density ratio jets. It was also observed that the divergence angles were dependent not only on density ratio but also on other parameters such as pressure ratios and reduced pressures.

Keywords: jet spreading, supercritical CO_2, methane injection, subcritical region

資料來源： https://doi.org/10.1115/1.4055632

Assessing CO_2 geological storage in Arbuckle Group in northeast Oklahoma

評估奧克拉荷馬州東北部 Arbuckle Group 的 CO_2 地質封存

By **Benmadi Milad [a] [b], Rouzbeh G. Moghanloo [a], Nicholas W. Hayman [b]**

[a] Mewbourne School of Petroleum and Geological Engineering, Mewbourne College of Earth and Energy, The University of Oklahoma, United States

[b] Oklahoma Geological Survey, Mewbourne College of Earth and Energy, The University of Oklahoma, United States

Abstract

This paper examines a rigorous site characterization and analysis of geological storage capacity of CO_2 in Arbuckle Group in the north part of Oklahoma to accelerate Carbon Capture and Storage (CCS) and Utilization (CCUS) technology deployment. Data obtained from the core, logs, and historic wastewater injection and production data were used to build and validate a geological model. Subsurface structure, depth required to attain supercritical CO_2, rock properties and required caprock criteria were applied to Arbuckle geological model to identify suitable region for geological storage of CO_2. The model estimates that the western Osage County has a storage capacity of > 50 million metric tons of CO_2. More specifically, two sweet spots with a higher potential for CO_2 storage were identified. The presence of several anthropogenic CO_2 sources in the vicinity of site, existing pipelines, and compression infrastructure are the significant elements of a techno-economic analysis of the prospect storage project(s). This study demonstrates that the carbonate Arbuckle Group could be a strategic geological unit for CO_2 sequestration, thus contributing toward emissions reduction from nearby industrial complex.

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Assessment of Part-Load Operation Strategies of Supercritical Power Cycles Using Carbon Dioxide Mixtures in CSP Plants, Including Air-Cooled Condenser Optimisation

評估 CSP 發電廠中使用二氧化碳混合物的超臨界動力循環的之部分負載運行策略，包括風冷冷凝器優化

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Abstract

This manuscript, developed in the framework of SCARABEUS project, presents an assessment of the part-load performance of a transcritical Recompression cycle running on a 80%CO_2-20%SO_2 mixture under different load-control schemes.

The first part of the paper describes the computational platform of the integrated system, implemented in Thermoflex but with profuse use of in-house scripts, in order to accurately describe the off-design performance of key components when operating on CO_2 mixtures with non-ideal gas behaviour. These off-design models make use of performance maps for turbomachinery — provided by the SCARABEUS partners — whereas the Conductance Ratio Method employed to model the counter-current heat exchangers is calibrated with in-house tools. The paper is specifically focused on the Heat Rejection Unit, for which a specific design tool accounting for accurate heat transfer between working fluid and cooling medium (air) and for auxiliary power consumption — both in off-design — has been developed by the authors.

In the second part of the paper, different operating strategies of the power cycle are considered, based on keeping one of the following three parameters constant: turbine inlet temperature, turbine outlet temperature or return temperature of molten salts. Globally, plant operation is constrained by the need to keep the temperature of cold HTF returning to the storage system as close as possible to its rated (design) value and by the need to keep turbine outlet temperature below 450°C to avoid the installation of an external cooling system in the low pressure section of this equipment. Therefore, the trade-off between these two parameters and system net efficiency are assessed in the paper. Regarding the Air-Cooled Condenser, the optimal operation strategy of this component found to be based on a combination of Single-speed and Variable Frequency Driver fans.

The results show that the operation at constant turbine inlet temperature leads to the highest net efficiency of the power block, closely followed by the control scheme based on constant return temperature of the heat transfer fluid. Nevertheless, this latter option enables a perfect control on the other two figures of merit. As a consequence, the identification of the best operation strategy must be addressed in future works by means of a thorough techno-economic assessment considering the annual yield of the plant.

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CFD prediction of heat transfer at supercritical pressure with rough walls: Parametric analyses and comparison with experimental data

粗壁超臨界壓力熱傳之 CFD 預測：參數分析及與實驗數據的比較

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Abstract

In this paper, a low-Reynolds number turbulence model developed by the authors in past activities for rough walls is used for predicting heat transfer at supercritical pressure in the presence of different degrees of surface finishing. The model, able to reproduce the typical trends of friction factors from classical data reported by Nikuradse and summarised in the Moody diagram, is based on a simple-minded description of the effect of wall protrusions through the boundary layer on turbulence production.

Though prior validation of the model only on the basis of friction factor data did not assure any basis for achieving accuracy in heat transfer prediction, a sensitivity analysis is firstly presented in order to characterise the obtained predictions at variable values of the roughness parameter, in particular concerning the possible suppression of deteriorated heat transfer by roughened surfaces. These analyses are extended to different fluids, making use of a fluid-to-fluid similarity theory recently proposed by the authors in order to establish similar boundary conditions and predicted phenomena.

The results obtained by these analyses can be considered interesting, especially in view of the design of supercritical water-cooled nuclear reactors; however, an assessment against experimental data was obviously necessary. Experimental carbon dioxide data published in a very recent archival paper were thus addressed and were found useful in this regard. Considering these data allowed to extend the above analysis to provide confirmation of the promising features of the model in comparison with wall temperature values obtained with different boundary conditions. The model here described appears promising not only for its capability to predict experimentally measured effects, but also for the perspective to be used in the study of the behaviour of purposely roughened surfaces reducing the probability of occurrence of deteriorated heat transfer.

Keywords: Supercritical pressure, Heat transfer, Rough surfaces, Heat transfer deterioration

資料來源：https://doi.org/10.1016/j.anucene.2023.109815

Exploration of optimal preparation strategy of Chenpi (pericarps of *Citrus reticulata* Blanco) flavouring essence with great application potential in sugar and salt-reduced foods

*低糖低鹽食品中具有巨大應用潛力的陳皮*調味香精優化製備策略探索

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Abstract

To obtain flavouring essence with application potential in sugar and salt-reduced foods, the optimal strategy for extraction and microencapsulation of essential oil (EO) from Chenpi was investigated. UPLC-QTOF-MS/MS and liquid–liquid-extraction-GC–MS confirmed the selectivity for volatiles ranked in hydrodistillation > supercritical fluid extraction > solvent extraction. The aroma characteristic of Chenpi EO was distinguished by 33 key volatiles (screened out via headspace-SPME-GC–MS) and quantitative descriptive analysis. EO extracted by supercritical fluid extraction was preferred for preserving the original aroma of Chenpi and displaying more fruity, honey and floral. Chenpi flavouring essence with superior encapsulation efficiency, particle size, water dispersibility, and thermostability was obtained through optimally microencapsulating EO with gum arabic and maltodextrin (1:1) by high-pressure homogenization coupled with spray drying. Chenpi flavouring essence was able to reduce the usage of sugar and salt by 20 % via enhancing flavour perception of sweetness and saltiness. This study first developed a flavouring essence promisingly effective in both sugar and salt-reduced foods.

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Numerical simulation of flow and heat transfer performance during supercritical water injection in vertical wellbore: A parameter sensitivity analysis

直井超臨界注水之流動與熱傳性能數值模擬：參數敏感度分析

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Abstract

Supercritical water injection is a promising technology for heavy oil thermal recovery. Predicting and regulating the thermophysical parameters of supercritical water at bottomhole are the prerequisite for achieving high recovery efficiency. In this paper, a novel numerical model was proposed to simulate wellbore flow and heat transfer of supercritical water injection. A modified correlation of frictional coefficient was developed to calculate water flow resistance near its critical point, where its properties change abruptly. The unsteady heat loss to the formation was calculated directly by solving two-dimensional unsteady heat conduction equations. They were respectively coupled in momentum and energy balance equations using an iterative scheme. This model was proved to be accurate by two oilfield cases in which the relative errors of wellbore fluid pressure and temperature are less than 1%. Then parameters sensitivity analysis of the injection pressure, temperature, mass flux and the apparent heat conductivity of insulating tube was conducted. The results indicated that the temperature variation of wellbore fluid depended on both enthalpy drop (or heat loss) and Joule-Thomson effect. An abnormal phenomenon that the fluid temperature increased with wellbore depth near the critical and pseudo-critical points was found because of the sudden increase in high heat capacity and Joule-Thomson coefficient of water. Raising the bottomhole fluid temperature was the key to enhanced oil recovery by supercritical water injection. Low apparent heat conductivity of insulating tube contributed richly to raise bottomhole fluid temperature by enlarging thermal resistance and reducing wellbore heat loss. There existed an optimal mass flux for maximizing bottomhole temperature, because when the mass flux increased, the shortened resident time within wellbore and the decreased fluid pressure favored temperature increase and decrease respectively. Selecting an injection pressure near the critical or pseudo-critical point and raising the injection temperature would increase the bottomhole temperature and reduce relative fluid heat loss.

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Preparation of Mesophase Pitch through Supercritical Fluid Extraction of Coal Tar Pitch

超臨界流體萃取煤焦油瀝青製備介相瀝青

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Abstract

This paper explores the preparation of mesophase pitch by employing supercritical fluid extraction on coal tar pitch sourced from a coal chemical company. The raw material undergoes pretreatment using various extraction solvents, and the resulting refined components are thermally polycondensed in a laboratory microreactor to create mesophase pitch. Qualitative and quantitative analyses of the mesophase pitch's structure are conducted through polarized light microscopy, X-ray diffraction (XRD), scanning electron microscopy (SEM), Raman spectroscopy, and other analytical methods to identify an optimal supercritical fluid extraction pretreatment solvent for coal tar pitch. The results reveal that using n-hexane solvent in the supercritical fluid extraction process yields a mesophase pitch with a remarkable mesophase content of 90.07%, displaying excellent optical texture distribution, superior directional arrangement and order, the closest lamellar accumulation, and the highest degree of anisotropy and graphitization.

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