論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Material Development of Calcium Oxide-Based Media for Thermochemical Energy Storage
著者(和文)	GuoRui
Author(English)	Rui Guo
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第11824号, 授与年月日:2022年3月26日, 学位の種別:課程博士, 審査員:加藤 之貴,小林 能直,塚原 剛彦,原田 琢也,吉田 克己
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第11824号, Conferred date:2022/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	応用化学 原子核工学	系 コース
学生氏名： Student's Name	GUO Rui	
申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	(Engineering)
指導教員（主）： Academic Supervisor(main)	加藤之貴 教授	
指導教員（副）： Academic Supervisor(sub)		

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The goals of zero-carbon emission, low cost and high energy efficiency, have attracted increasing attention due to the growing productivity and population in the world. To improve the energy efficiency and reduce the negative effects to environments, thermochemical energy storage (TCES) is regarded as one of the possible solutions. For example, it can improve gross energy efficiency by wasted heat reutilization, and it is able to facilitate the flexible operations of nuclear power plants. $CaO/Ca(OH)_2$ material is considered as one of the promising materials and exhibits many merits as TCES media, e.g., low cost, no pollution, wide applicable temperature range, etc. However, TCES system has not been widely and commercially constructed yet because of its limitation and unsatisfying performance. To be specific, the raw materials exhibit agglomeration problem, bulk volume change issue, low mechanical stability characteristics and low thermal conductivity shortcomings, which cause problems in durability and reactivity, thus decreasing the feasibility in application. With the modification by appropriate additives, the issues or drawbacks from raw materials can be alleviated in some extent. Therefore, the objective of this study is to develop calcium oxide-based composite materials with upstanding reactivity, superior output/storage density, and adequate mechanical stability. In addition, to further understand the performances of the TCES system combined with nuclear power plants, one Nuclear-TCES combined system is proposed and evaluated environmentally and economically.

In Chapter 1, the main topic focused on the introduction of $CaO/Ca(OH)_2$ thermochemical energy storage. First, in the section of research background, the urgent need and importance to improve energy efficiency and reduce greenhouse gas emission were explained. TCES was regarded as one of the promising solutions to improve gross energy efficiency by energy storage/output processes to reuse heat from the renewables, nuclear power plants and industry processes. Next, the principles, advantages and challenges were specified, e.g., agglomeration problem, bulk volume change issue, low thermal conductivity and poor mechanical stability characteristics. After introduction of previous study, the main objective of this study was illustrated, that were, synthesis, evaluation and analysis of composite calcium oxide-based materials to compensate the above issues.

In Chapter 2, composite materials with modification of TEOS-SCA (50wt%:50wt%) were introduced to improve the heat output performances in close-to-equilibrium conditions. The modification of 0.6wt%, marked as C1-0.6, was evaluated as best materials among examined modification ratio from 0.3wt%-2.0wt%. C1-0.6 exhibited at most 1.9 times heat output density compared with that of reference material. The morphological analysis revealed that the agglomeration problem was alleviated in modified materials compared with raw material. In addition, it was identified that the optimized additive was Ca_2SiO_4, which contributed to agglomeration alleviation by its pinning effect.

In Chapter 3, a composite pellet was introduced to alleviate bulk volume change issue during cyclic operations. The material synthesis process was described. The morphology observation and compositional analysis were conducted to compare the difference before and after modification, where the mechanism was revealed. Finally, the cyclic performances and the heat output/storage performances were compared and discussed.

In Chapter 4, the silicon carbide diesel particulate filter (SiC-DPF) was introduced to improve

the mechanical stability and heat transfer efficiency. Two shelled composite materials were synthesized. SiC-DPF was introduced as matrix or side shell in shelled composite powder or shelled composite pellet materials to enhance the gross structural stability and improve the entire heat transfer efficiency. The structural stability and the cyclic performances were compared and discussed. Finally, the structural stability of shelled composite pellet was evaluated by crushing strength measurements.

In Chapter 5, the kinetics study by JMAK theory were applied in both reference pellet and composite pellet of hydration and dehydration reactions appropriately. The reaction could be divided into three stages: nucleation, growth, and impingement. Finally, after comparing the experimental data and calculated data, reaction mechanisms of hydration, dehydration were proposed.

In Chapter 6, a Nuclear-TCES combined electricity-providing system by LFR and $CaO/Ca(OH)_2$ TCES system was introduced. To evaluate the performance economically and environmentally, the total cost, amounts of CO_2 emission, and demand-supply (d-s) efficiency were discussed in case study. The Nuclear-TCES combined system realized relatively higher d-s efficiency with low cost, zero CO_2 emission compared with electricity provided by combination of nuclear energy and coal. Furthermore, the shelled composite pellet required relatively lower volume in the above system among performed materials, where a more compact system with lower cost could be realized.

In Chapter 7, the conclusions of each chapter were presented.