

Research on the methanation properties of biomass gasification simulation based on alkali-modified Ni/Al₂O₃ catalysts

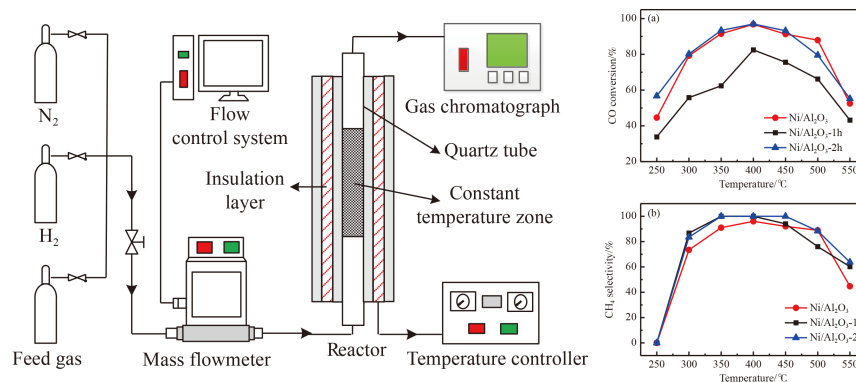
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Abstract: In this paper, the Ni/Al₂O₃ monolithic catalyst with 15% Ni content was prepared using cordierite as a matrix, and the catalyst was modified with 10% NaOH to study the methanation performance of biomass gasification simulated gas based on alkali-modified Ni/Al₂O₃ monolithic catalyst. BET, TEM, H₂-TPR, XRD,

CO₂-TPD and TG were used to characterize the physicochemical properties of the catalyst before and after modification. The results indicated that the CO conversion rate trends of unmodified and modified Ni/Al₂O₃ monolithic catalysts over 2 h were fundamentally consistent. However, the Ni/Al₂O₃ catalysts modified for 2 h demonstrated significantly enhanced performance compared to those modified for 1 h. Regarding CH₄ selectivity, the modified Ni/Al₂O₃ catalyst exhibited markedly better performance than the unmodified Ni/Al₂O₃ catalyst, confirming the enhanced methane performance of the alkali-modified Ni/Al₂O₃ monolithic catalyst. Under optimized conditions (H₂/CO volume ratio of 3:1, space velocity of 10000 mL/(g·h), and temperature of 400 °C), the methanation performance of the Ni/Al₂O₃ monolithic catalyst modified for 2 h reached its peak, achieving a CO conversion rate of 97% with 100% CH₄ selectivity.

Key words: biomass gasification; methanation; cordierite; monolithic catalyst



As oil resources are increasingly depleted, the importance of developing alternative energy sources is becoming increasingly urgent. China has abundant biomass resources, but the simple and extensive use of these carbon-containing resources has caused significant waste and environmental pollution. The pyrolysis and gasification of biomass, combined with catalytic conversion for synthetic methane production, are highly compatible with fossil fuel utilization. This approach can compensate for petroleum resource shortages and represents a more realistic and feasible pathway for near-term fossil energy replacement^[1].

Therefore, biomass methanation technology can serve as an important supplement to conventional natural gas and become an effective means to address natural gas supply shortages.

For CO methanation reactions, the catalyst typically uses Ni as the active component and Al₂O₃ as the support. To enhance its catalytic performance, researchers have attempted to incorporate various additives^[2–7]. The additives themselves may not have a catalytic effect and only play an auxiliary role in the reaction. However, their incorporation can modify the physicochemical properties of the catalyst,

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thereby enhancing its activity and stability. It is found that the introduction of alkali metals and alkaline earth metals (such as Na, Mg, etc.) can effectively improve the methanation performance of the catalyst, and the alkali modification of the catalyst can not only change the pore structure of the catalyst, but also reduce the acidity of the catalyst to a certain extent, thereby increasing the number of alkaline sites and boosting catalytic activity. Additionally, this method can selectively remove Si atoms from the catalyst, creating structural defects that induce a mesoporous structure and enhance molecular transport within the pore system. The primary objective of modifying the pore structure, acidity, and alkalinity is to achieve more uniform distribution of active sites on its surface, enhance reactant diffusion and methane selectivity, while suppressing carbon deposition^[4-7].

Traditional particle catalysts suffer from significant drawbacks, including substantial bed pressure drop, pronounced temperature gradients, and uneven reactant distribution across the catalytic surface. In contrast, monolithic catalysts featuring a honeycomb ceramic structure exhibit superior mechanical strength, reduced bed stratification, and enhanced mass transfer efficiency, effectively mitigating the limitations of conventional catalysts. Furthermore, their low production cost and readily available organizational architecture ensure broad applicability across diverse fields, particularly in exhaust gas treatment^[8]. In recent years, cordierite ($2\text{MgO} \cdot 2\text{Al}_2\text{O}_3 \cdot 5\text{SiO}_2$) has become an excellent choice for molding matrices due to its special structure, which has the advantages of high mechanical strength, low pressure drop, and good thermal stability^[9-10]. The cordierite monolithic catalyst exhibits superior catalytic activity and long-term high-temperature stability owing to its honeycomb structure, which enhances mass transfer efficiency during reactions. The uniform gas flow facilitates improved contact between reactants and the catalyst surface, thereby elevating overall catalytic efficiency and CO methanation performance^[11-13]. Therefore, cordierite has been extensively adopted as a monolithic catalyst matrix material^[14].

The distinct advantages of monolithic catalysts and base modification for nickel-based methanation catalysts have been well documented. However, their synergistic effects on methanation performance remain insufficiently investigated. Hence, this study systematically examines the influence of alkali modification on the catalytic properties of integral methanation catalysts. A $\text{Ni}/\text{Al}_2\text{O}_3$ monolithic catalyst was synthesized using biomass gasification simulated syngas as feedstock, with nickel as the active component, alumina as the support, and cordierite as the structural matrix. The catalyst was subjected to alkaline modification using a 10% NaOH solution, and comprehensive characterization techniques including BET, TEM and XRD were employed to analyze structural evolution, methanation activity, and stability before and after the modification process.

1 Experimental

1.1 Catalyst preparation

1.1.1 Cordierite matrix pretreatment

In this experiment, cylindrical cordierite honeycomb ceramics (diameter 50 mm) were employed as catalyst substrates. Prior to experimentation, the cordierite honeycomb ceramics underwent pretreatment with a dilute nitric acid solution. The specific steps are as follows: cordierite is immersed in a nitric acid solution with a concentration of 20%, soaked at room temperature for 12 h, then washed with deionized water until neutral, dried in an oven to remove the surface moisture, and placed in a drying dish to seal and store for later use.

1.1.2 Preparation of 15%Ni/ Al_2O_3 catalyst

Nickel nitrate and aluminum nitrate were mixed in a molar ratio of 10:3 (Ni) in a 500 mL beaker, followed by the addition of 250 mL deionized water with continuous stirring. The pretreated cordierite honeycomb ceramic substrate was fully immersed in this mixed solution for 12 h. After removal, the material underwent drying at 105 °C for 12 h, followed by calcination at 500 °C in a muffle furnace for 4 h, and repeated the above operation twice to obtain a $\text{Ni}/\text{Al}_2\text{O}_3$ integral honeycomb catalyst, which was recorded as $\text{Ni}/\text{Al}_2\text{O}_3$ catalyst.

1.1.3 Preparation of alkali-modified 15%Ni/ Al_2O_3 catalysts

Nickel nitrate and aluminum nitrate with a molar ratio of 10:3 (Ni) were placed in a 500 mL beaker, and 250 mL of deionized water was added with continuous stirring. Subsequently, a 0.2 mol/L NaOH solution was introduced, and the mixture was heated to 80 °C under magnetic stirring. The solution was maintained at this temperature with stirring durations of 1 and 2 h, respectively, before cooling to room temperature. The pretreated cordierite honeycomb ceramic substrate was then fully immersed in the mixed solution for 12 h. After removal, the material underwent drying at 105 °C for 12 h, followed by calcination at 500 °C in a muffle furnace for 4 h. Then, the above operation was repeated twice after calcination at 500 °C for 4 h in the muffle furnace to obtain two $\text{Ni}/\text{Al}_2\text{O}_3$ catalysts with 15% Ni content after different modification times, which were denoted as $\text{Ni}/\text{Al}_2\text{O}_3$ -1h and $\text{Ni}/\text{Al}_2\text{O}_3$ -2h, respectively.

1.2 Experimental system and process

The methanation performance evaluation system of biomass gasification simulated gas is shown in Figure 1.

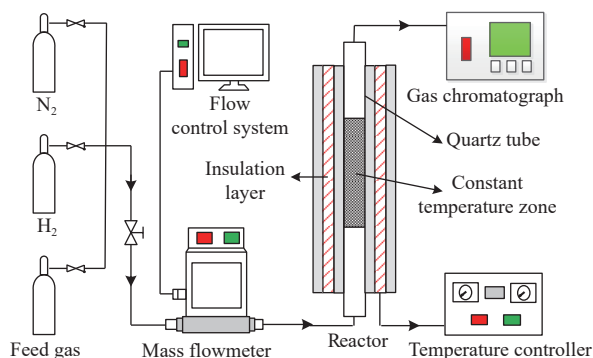


Fig. 1 Schematic diagram of the experimental system

The experimental system primarily consists of three integrated components: an air intake system, a reaction system, and a detection system. The air intake system incorporates feed gas sources, mass flow meters, and their corresponding control devices. The reaction system features a fixed-bed reactor equipped with a temperature controller. The detection system is predominantly based on gas chromatography for analytical purposes.

The raw gas of this experiment was H_2/CO mixture (volume ratio was 3:1), the space velocity was $10000 \text{ mL}/(\text{g}\cdot\text{h})$, and the reaction temperature was $250\text{--}550^\circ\text{C}$. The experimental steps were as follows: firstly, the catalyst was placed in the constant temperature zone of the quartz tube of the methanation reactor, the reaction system was purged and heated with $150 \text{ mL}/\text{min}$ N_2 , and when the temperature rose to 470°C , H_2 was introduced into the catalyst at a flow rate of $50 \text{ mL}/\text{min}$ to reduce the catalyst for 3 h. Upon completion of the reduction process, the temperature is adjusted to the designated reaction temperature. The raw gas is then introduced into the system, and the product composition and concentration resulting from the methanation reaction are subsequently analyzed using the gas chromatography.

1.3 Catalyst characterization methods

The specific surface area and pore structure of the catalyst were analyzed by using a V-Sorb2800 specific surface and pore size analyzer; TF20 transmission electron microscope was used to analyze the microscopic morphology of the catalyst; the reduction properties of the catalyst were examined by the Micromeritics AutoChem1 II 2920 Chemisorption-Analyzer; the crystalline phase composition was characterized by a Shimadzu XRD-7000S X-ray diffractometer under the following conditions: Cu $K\alpha$ radiation (40 kV , 40 mA), 2θ scanning range of $5^\circ\text{--}90^\circ$, and

scanning speed of $5^\circ/\text{min}$; the amount of carbon deposits in the catalyst after the reaction was tested using a thermogravimetric analyzer with model QMA200M; the catalyst was subjected to CO_2 temperature-programmed desorption tests using the AutoChem II 2920 chemisorption instrument.

2 Results and discussion

2.1 Catalyst characterization

2.1.1 Specific surface area and pore structure analysis

The specific surface area and pore size structure of the reduced monolithic catalyst are shown in Table 1. Compared to cordierite, the acid-treated cordierite exhibited approximately 1.5-fold and 12-fold increases in specific surface area and pore volume, respectively. Among the catalysts, the $Ni/Al_2O_3\text{-1h}$ specimen demonstrated the lowest specific surface area ($4.519 \text{ m}^2/\text{g}$), while the $Ni/Al_2O_3\text{-2h}$ catalyst displayed the highest values ($8.549 \text{ m}^2/\text{g}$ for specific surface area and $0.020 \text{ cm}^3/\text{g}$ for pore volume) alongside the smallest pore size (5.666 nm). Analysis of pore size distributions before and after modification suggests that alkali treatment may induce pore size reduction in the catalyst structure. Figure 2 shows the isothermal curve and pore size distribution of the N_2 adsorption-desorption catalyst. As can be seen from Figure 2(a), the adsorption curves of the catalyst before and after modification are all type IV isotherms, and there is an H3 hysteresis ring, indicating that the catalyst is a slit pore with layered structure aggregation, with obvious mesoporous characteristics and a pore structure with sheet particle aggregation. Moreover, most of the pore widths of the three catalysts are concentrated between 2 and 20 nm (Figure 2(b)), and all of them belong to mesoporous structure, which is consistent with the analysis results in Table 1.

2.1.2 Microscopic topography analysis

The reduced $Ni/Al_2O_3\text{-2h}$ and Ni/Al_2O_3 catalysts were characterized by TEM and the particle size distribution was compared, and the results are shown in Figure 3. The results indicated that the Ni particles are uniformly distributed on the surface of the support, and the Ni particle size is between 0 and 8 nm , with an average of 4.10 nm (Figures 3(a)₁ and 3(a)₂).

Table 1 Specific surface area and pore size structure data of catalysts

Sample	$S_{BET}/(\text{m}^2 \cdot \text{g}^{-1})$	$v_p/(\text{cm}^3 \cdot \text{g}^{-1})$	d_p/nm
Cordierite	3.513	0.010	8.373
Acid-treated cordierite	5.399	0.123	7.207
Ni/Al_2O_3	7.139	0.017	9.764
$Ni/Al_2O_3\text{-1h}$	4.519	0.019	9.533
$Ni/Al_2O_3\text{-2h}$	8.549	0.020	5.666

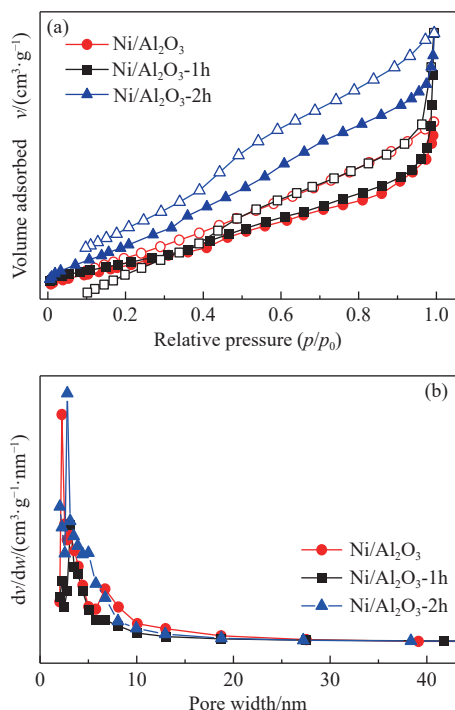


Fig. 2 Adsorption/desorption isotherms (a) and BJH pore size distributions (b) of catalysts

As can be seen from Figures 3(b₁) and 3(b₂), the Ni/Al₂O₃-2h catalyst has agglomeration, with a Ni particle size of 0–25 nm and an average size of 4.10 nm. Comparing the TEM and particle size distribution results of the two catalysts, the particle size distribution of the unmodified Ni/Al₂O₃ catalyst was more uniform than that of the modified Ni/Al₂O₃ catalyst at 2 h, suggesting superior dispersion characteristics in the unmodified system.

2.1.3 Phase analysis

The XRD spectra of the reduced catalyst are shown in Figure 4.

The XRD patterns of the unmodified Ni/Al₂O₃ catalyst^[15] exhibited exclusively NiO diffraction peaks at 2θ positions of 37°, 43° and 62.5°, with an average Ni particle size of merely 4.10 nm.

This observation may be attributed to the exceptionally small particle size of Ni and its high dispersion on the Al₂O₃ support, rendering them below the detection threshold of XRD^[16]. Additionally, the relatively large crystallite size of NiO, which potentially obscures the Al₂O₃ diffraction peaks through signal overlap combined with H₂-TPR, the NiO belongs to the active component Ni with strong interaction with the support β -NiO or γ -NiO, which is difficult to be reduced. The XRD spectra of the Ni/Al₂O₃-1h exhibited solely the characteristic Ni diffraction peak at $2\theta = 43^\circ$, while NiO peaks were notably absent. The reason was analyzed by the H₂-TPR results of the catalyst: the diminished NiO diffraction signal suggests weakened NiO-Al₂O₃ interaction, facilitating extensive reduction of NiO species during pretreatment. Consequently, the XRD pattern predominantly reflects the metallic Ni phase formed through this reduction process. In the XRD spectra of the Ni/Al₂O₃-2h, only the characteristic diffraction peak of NiO was detected at the diffraction angle of $2\theta=43^\circ$, and the reasons were analyzed by the H₂-TPR results of the catalyst: (1) The absence of Al₂O₃ peaks was attributed to the large grain size of NiO, which effectively obscured the Al₂O₃ diffraction signals; (2) The H₂-TPR data indicated that the NiO species predominantly existed as the active β -NiO phase, characterized by strong metal-support interactions that conferred enhanced reducibility resistance.

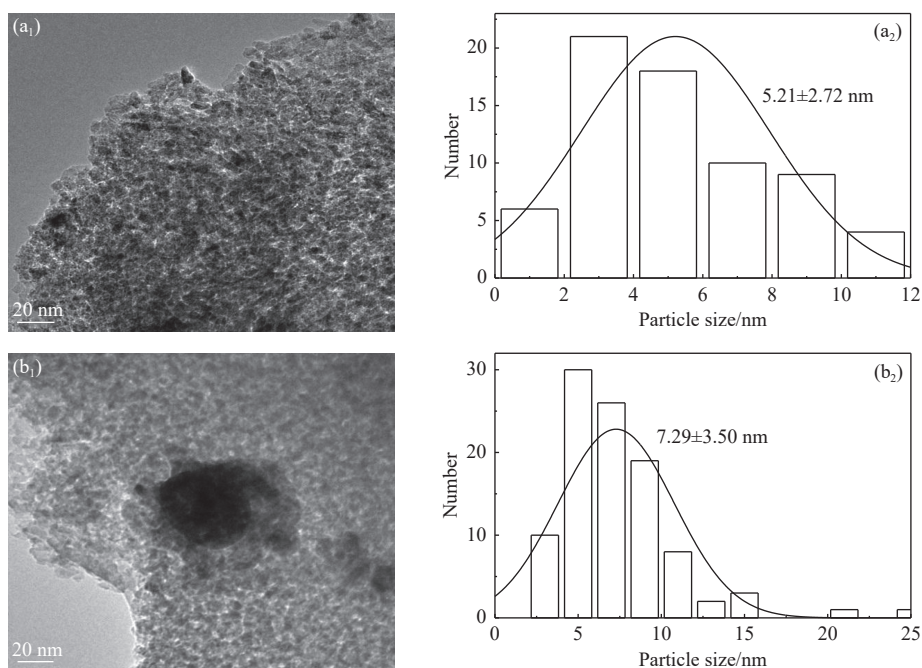


Fig. 3 TEM diagrams of catalysts after reduction ((a₁), (a₂) Ni/Al₂O₃, (b₁), (b₂) Ni/Al₂O₃-2h)

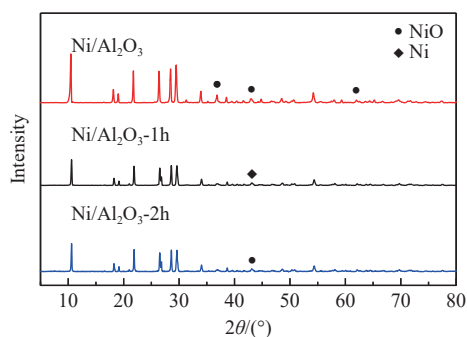
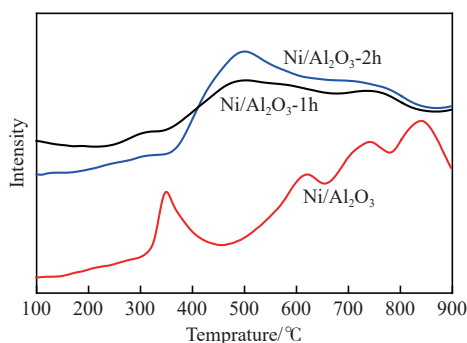


Fig. 4 XRD patterns of the catalysts after reduction

2.1.4 Reduction characterization analysis

The H_2 -TPR results of catalysts before and after modification are shown in Figure 5. In general, the reduction peak at low temperature (250–400 °C) belonged to the α -NiO species, which had a weak interaction with the support and a larger particle size of the reduced Ni particles. In the medium temperature region (400–600 °C), the reduction peak is β -NiO species, and its interaction with the support is of medium intensity, and the γ -NiO is the least difficult to be reduced in the high temperature region (>600 °C)^[17]. The reduction peaks of the unmodified Ni/Al₂O₃ catalyst at 350 °C corresponded to α -NiO, and the remaining reduction peaks at 620, 760 and 850 °C belonged to the γ -NiO species with the highest intensity of interaction with the support. For Ni/Al₂O₃-1h, there were relatively weak reduction peaks at 310, 500 and 750 °C, respectively, and the corresponding NiO species were α -NiO, β -NiO and γ -NiO. In addition to a reduction peak at 530 °C, the Ni/Al₂O₃-2h also exhibited a weak reduction peak at 750 °C, corresponding to β -NiO and γ -NiO, respectively. Analysis of the reduction peaks in Figure 5 revealed that most reduction peaks shift toward lower temperatures after alkali modification, indicating a reduction in the reduction temperature of the catalyst. Consequently, by adjusting the reduction temperature to 530 °C, the reduced catalyst exhibits more active sites, thereby enhancing its catalytic performance.

Fig. 5 H_2 -TPR curves of the catalysts

2.1.5 Thermogravimetric analysis

In the process of industrial application of methanation,

the catalyst is required to demonstrate not only excellent reactivity and stability but also superior resistance to carbon deposition. The deposition of carbon on the catalyst surface during the methanation reaction mainly comes from the disproportionation of CO and the cleavage of CH₄^[17]. When the temperature is lower than 200 °C, the weight loss of the catalyst is mainly caused by the evaporation of the adsorbed water on the surface and the bound water inside. The weight gain after 400 °C is mainly due to the oxidation of the active component Ni at high temperatures^[18]. In order to test the degree of carbon deposition of the catalyst before and after modification, thermogravimetric analysis of the catalyst after 320 min of reaction was performed, and the results are shown in Figure 6. The product weight loss rate of the unmodified Ni/Al₂O₃ catalyst is merely 1%, with the catalyst mass exhibiting fundamental stability at 400 °C. In contrast, the Ni/Al₂O₃-1h catalyst demonstrates a weight loss rate of approximately 0.9%, achieving mass stabilization at temperatures exceeding 450 °C. However, the Ni/Al₂O₃-2h catalyst manifests a significantly higher weight loss rate of 1.6%, indicating severe carbon deposition during the reaction process. This behavior is likely caused by Ni particle agglomeration during catalytic operation, leading to increased particle size. Analysis of catalyst characterization data combined with performance test results indicates that the degree of carbon deposition does not directly determine the catalytic activity.

2.1.6 Alkalinity analysis of catalyst surface

The basic surface properties of the catalyst were characterized by CO₂-TPD, with the types of alkaline sites on the catalyst surface identified based on the peak desorption temperature. Higher desorption temperatures indicate stronger alkalinity, accompanied by an increased CO₂ adsorption rate and elevated total alkalinity^[19]. In the CO₂-TPD curve, the low-temperature desorption peak (<200 °C) belongs to the desorption of CO₂ at the weakly basic site on the catalyst surface; the medium-temperature desorption peak (200–400 °C) belongs to the desorption of CO₂ at the moderately basic site on the catalyst surface; and the high-temperature desorption peak (>400 °C) belongs to the desorption of CO₂ at the strongly basic site on the catalyst surface^[20]. The CO₂-TPD curves of the catalyst before and after modification are presented in Figure 7.

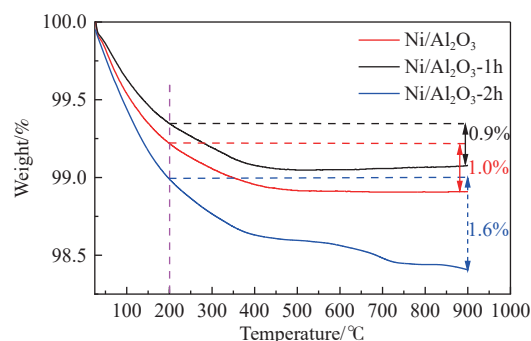


Fig. 6 TG curves of the catalysts after reaction

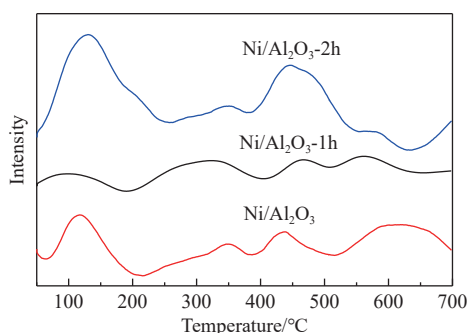


Fig. 7 CO₂-TPD curves of the catalysts after reduction

The analysis reveals four distinct CO₂ desorption peaks in the profiles of all three catalysts. The first peak corresponds to CO₂ desorption from weak basic sites on the catalyst surface, while the second peak is assigned to CO₂ desorption from moderately basic sites. The third and fourth peaks are attributed to CO₂ desorption from strongly basic sites on the catalyst surface. The desorption temperatures of the four peaks for Ni/Al₂O₃ were measured at 123, 350, 440 and 625 °C, respectively. In the case of Ni/Al₂O₃-1h, the corresponding desorption peaks appeared at 105, 330, 475 and 570 °C, exhibiting a distinct shift toward higher temperatures. For Ni/Al₂O₃-2h, the desorption peaks were observed at 130, 352, 450 and 580 °C, respectively, where the high-temperature shift trend was more pronounced. Notably, the desorption peak at 130 °C, attributed to weakly basic sites, demonstrated the strongest signal intensity among all samples. Wang et al.^[21] and Gao et al.^[22] also demonstrated that weak and moderately basic sites facilitate CO₂ adsorption and activation, whereas CO₂ adsorbed at strong basic sites remains inert toward methanation reactions. Therefore, according to the CO₂-TPD characterization, the basic strengths of these catalysts are Ni/Al₂O₃-2h > Ni/Al₂O₃ > Ni/Al₂O₃-1h.

2.2 Methanation performance analysis

The methanation performance of the Ni/Al₂O₃ monolithic catalyst before and after modification at different temperatures is presented in Figure 8.

The reaction was performed at atmospheric pressure, the reaction temperature was 250 to 550 °C, the space velocity was 10000 mL/(g·h), v_{H_2}/v_{CO} volume ratio=3:1. As depicted in Figure 8, the CO conversion and CH₄ selectivity trends of the catalysts exhibit comparable behavior between the two modification methods. Within the temperature range of 250 to 400 °C, both CO conversion rate and CH₄ selectivity demonstrate an increasing trend with rising temperature. Conversely, in the range of 400 to 550 °C, these parameters show a decreasing trend with increasing temperature. Overall, Ni/Al₂O₃-2h gained the best methanation performance, and the CO conversion and CH₄ selectivity reached the highest at 400 °C, which were 97% and 100%, respectively.

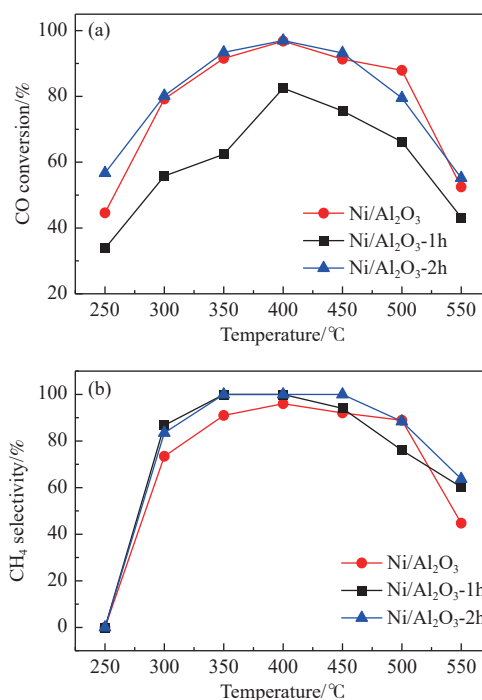


Fig. 8 CO conversion rates (a) and CH₄ selectivities (b)

Compared with the unmodified catalyst, the CO conversion rate of Ni/Al₂O₃-2h approached that of the pristine material, whereas the catalyst of Ni/Al₂O₃-1h exhibited inferior performance. In contrast, both modified catalysts demonstrate significantly enhanced CH₄ selectivity relative to the unmodified catalyst. These results indicate that optimal alkali modification can effectively improve catalytic activity and methanation performance. A detailed comparative analysis of CO methanation performance with literature data is presented in Table 2, which reveals that the modified 15%Ni/Al₂O₃ monolithic catalyst subjected to 2 h treatment in this study exhibits particular advantages in terms of CH₄ selectivity.

2.3 Catalyst stability analysis

The reaction conditions were maintained at 400 °C with a H₂/CO volume ratio of 3:1, space velocity of 10000 mL/(g·h), using CO conversion as the evaluation metric. Catalyst stability tests were conducted before and after alkali modification, with the results presented in Figure 9. During the initial 100 min of reaction, both preparation methods exhibited fluctuating CO conversion rates. Beyond this period, the conversion rates of both catalysts stabilized without significant decline. The unmodified Ni/Al₂O₃ catalyst maintained stable CO conversion at approximately 95%, while the Ni/Al₂O₃-2h catalyst achieved stable conversion at around 98%, demonstrating superior stability and methanation performance.

Table 2 Comparison of CO methanation performance

Catalyst	Reaction conditions	CO conversion/%	CH ₄ selectivity/%	Ref.
15%Ni/Al ₂ O ₃ -2h	400 °C, 10000 mL/(g·h), $v_{H_2}/v_{CO}=3:1$	97	100	this work
15%Ni/Al ₂ O ₃	400 °C, 10000 mL/(g·h), $v_{H_2}/v_{CO}=3:1$	96.8	96	this work
Ni/Al ₂ O ₃ (Powder)	400 °C, 20000 mL/(g·h), $v_{H_2}/v_{CO}=3:1$	~98	~80	[2]
Ni/Al ₂ O ₃ (Ni-NH ₄ C precipitant)	280 °C, 1200 mL/(g·h), $v_{H_2}/v_{CO}=3:1$	78.8	87.9	[23]

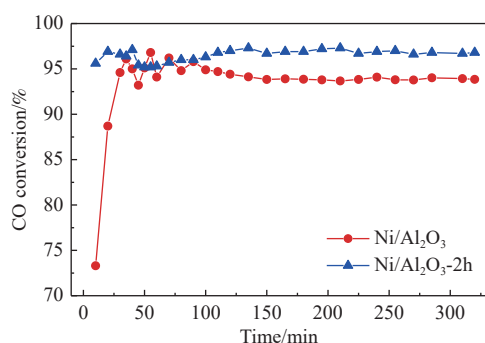


Fig. 9 Stability testing of catalysts

3 Conclusion

In conclusion, a Ni/Al₂O₃ monolithic catalyst with controlled Ni content was synthesized using biomass gasification simulated syngas H₂/CO (the volume ratio is 3:1) as the feed gas, where Ni served as the active component, Al₂O₃ functioned as the support, and cordierite acted as the matrix. The catalyst was subsequently modified with 10% NaOH solution. Through comprehensive characterization techniques, the influence of alkali modification on the catalyst's structural properties, methanation performance, and stability was systematically investigated. The main conclusions are as follows:

(1) Compared to the unmodified 15%Ni/Al₂O₃ monolithic catalyst, the 15%Ni/Al₂O₃-2h specimen exhibited enhanced specific surface area, catalytic activity, and alkaline site density, demonstrating that the 2 h treatment with 10% NaOH significantly improved the structural characteristics of the catalyst.

(2) Under the reaction conditions of v_{H_2}/v_{CO} volume ratio = 3:1 and space velocity of 10000 mL/(g·h), the methanation performance of the 15%Ni/Al₂O₃ monolithic catalyst modified for 2 h reached the best at 400 °C, achieving CO conversion and CH₄ selectivity of 97% and 100%, respectively. These results demonstrate that alkali modification effectively enhances CH₄ selectivity of 15%Ni/Al₂O₃ monolithic catalyst.

(3) Comparative stability analysis revealed that the CO conversion rate of the 2 h modified 15%Ni/Al₂O₃ monolithic catalyst remained stable at approximately 98%, exhibiting excellent catalytic stability and methanation performance. The findings confirm that 2 h treatment with 10% NaOH significantly improves both the methanation

performance and stability of 15%Ni/Al₂O₃ monolithic catalysts.

Declaration of Competing Interest

The authors declare no conflict of interest.

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基于碱改性 Ni/Al₂O₃ 催化剂的生物质气化模拟气甲烷化性能研究

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摘 要: 本工作以堇青石为基体制备了 Ni 含量为 15% 的 Ni/Al₂O₃ 整体式催化剂, 并用 10% NaOH 对催化剂进行改性, 基于碱改性 15Ni/Al₂O₃ 整体式催化剂进行了生物质气化模拟气甲烷化性能研究。采用 BET、TEM、H₂-TPR、XRD、CO₂-TPD 和 TG 等手段表征了改性前后催化剂的结构和性能。结果表明, 对于 CO 转化率, 未改性和改性 2 h 的 Ni/Al₂O₃ 催化剂的 CO 转化率随温度的变化趋势基本一致, 改性 2 h 的 15Ni/Al₂O₃ 催化剂明显优于改性 1 h; 对于 CH₄ 选择性, 碱改性 Ni/Al₂O₃ 整体式催化剂的 CH₄ 选择性优于未改性 Ni/Al₂O₃ 催化剂。当 H₂ 与 CO 的体积比为 3:1、空速为 10000 mL/(g·h)、温度为 400 °C 时, 碱改性 2 h 的 15Ni/Al₂O₃ 催化剂的甲烷化性能达到最佳, CO 转化率为 97%, CH₄ 选择性为 100%。

关键词: 生物质气化; 甲烷化; 堇青石; 整体式催化剂

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