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A Comparative Study on the Use of Domestic and Imported Catalysts in the Horizone Process

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Keywords: Gas-phase polypropylene; BCM-100H domestic catalyst; Catalytic activity; Hydrogen sensitivity; Operational stability

Abstract: This paper systematically compares the overall performance difference between domestic BCM-100H catalyst and imported JHC catalyst in Horizone gas phase process technology for UHMWPE fiber production, and provides a technical reference on the application of domestic substitutes for catalysts. Based on the operation data of industrial facilities, the superiority and inferiority of domestic and imported catalysts were compared in 4 aspects,the catalyst's activity, sensitivity to hydrogen adjustment, product mechanical properties and the stability of process operation. The activity of domestic BCM-100H catalyst is about 9% to 11% higher than the imported catalyst, the consumption of triethylaluminum is about 5% to 8% less than that of the imported catalyst and the consumption of modifiers is about 9% to 30% less,The fluctuation of stirring power in the first reactor is only about 60% to 65% of that of the imported catalyst, hydrogen consumption in the first reactor increased by 13% to 44% and in the second reactor by 16% to 116% for domestic BCM-100H catalyst,The BCM-100H catalyst had a distinct advantage in activity below 70℃, but it still requires optimization for high-temperature stability. Domestic catalysts meet the technical requirement to substitute the imported product in specific consumption, activity, and operational stability,but continuous improvement is needed in high-temperature polymerization, and progress is needed for ultra-high end-grade products.

1. Introduction

Polypropylene (PP), as one of the most widely produced and applied general-purpose thermoplastic resins globally, is extensively used in the automotive, home appliance, packaging, building materials, and medical fields due to its low density, corrosion resistance, ease of processing, and excellent mechanical properties. With the advancement of the "dual carbon" goals and the implementation of the strategy for the localization of high-end chemical materials, China's polypropylene industry is rapidly developing toward large-scale, continuous, and high-end production. The gas-phase polypropylene process has become the mainstream technology for global polypropylene production due to its advantages of a simple process flow, solvent-free operation, low energy consumption, flexible product switching, and the ability to produce multiple grades of products. Gas-phase processes such as Unipol, Novolen, Horizone[1]and Innovene account for a significant share of global polypropylene production capacity . As a core technological element in polypropylene production, the catalyst directly determines plant operating efficiency, product quality, and production costs.

In the polypropylene industry chain, catalysts are the core of polypropylene technology, and their performance directly determines polymerization efficiency, product composition, reactor operating conditions, and production costs. For a long time, domestic gas-phase polypropylene plants have generally relied on imported catalysts, which not only come at a high procurement cost but also pose risks to supply chain security. In recent years, domestic catalyst technology has made significant strides. Catalysts of grades such as HR, CS-G, and BCK [2]have been successfully applied in industrial-scale operations across multiple domestic gas-phase plants. Their performance in terms of activity, particle morphology, and versatility is gradually approaching international advanced levels. However, due to the lack of systematic industrial comparative studies, enterprises still harbor doubts regarding the performance limits, applicable conditions, and economic advantages of domestic catalysts under varying load, grade, and temperature conditions. However, for practical production applications, such as long plant operation, multi-grade switching, energy cost control, there is almost no basic and easily obtained industrial information on overall performance of domestic versus imported catalysts in practical production, and it is not beneficial to promoting large-scale domestic substitution in totality Based on operational data from industrial units at multiple enterprises and laboratory polymerization evaluation results, conducts a systematic comparison of the domestic catalyst BCM-100H and the imported catalyst JHC across dimensions such as catalytic activity, sensitivity to hydrogen adjustment, product performance, and reactor operational stability.

To conduct a detailed comparison between the domestically produced catalyst BCM-100H and the imported catalyst JHC, this paper uses actual production data from the gas-phase polypropylene (JPP) unit at Hainan Refining & Chemical Co., Ltd. Representative operational parameters and specialized laboratory test results were selected to evaluate the catalysts across four aspects: catalytic activity, sensitivity to hydrogen adjustment, product performance, and operational stability in the first and second reactors, as well as thermal stability. A comprehensive evaluation was made of the adaptability and overall performance of the two catalysts in the Horizone gas-phase process. The research results provide reliable technical basis and practical references for enterprises producing polypropylene materials in catalyst selection, process optimization, and domestic substitution.

2. Experimental Section

2.1. Catalyst Samples

The catalysts compared in this study include: the domestic BCM-100H catalyst [1](Sinopec Catalyst Co., Ltd., Beijing Aoda Branch) and the corresponding imported reference JHC catalyst (a proprietary catalyst jointly developed by Toho Titanium and JPP),Both catalysts are spherical high-efficiency supported catalysts suitable for the Horizone gas-phase process. They feature well-defined particle size, uniform activity distribution, and adaptability to continuous gas-phase polymerization. They can be directly switched between industrial units without requiring modifications to the main plant structure, providing excellent foundational conditions for this comparative study.

2.2. Polymerization Process and Equipment

Industrial application tests were conducted in gas-phase polypropylene unit. The polymerization conditions were obtained according to the criteria of design for each process unit. The reaction temperature range was 60℃–85℃and the reaction pressure range was 2.0 MPa–2.6 MPa. The unit was equipped with some apparatus of online instrument (temperature measuring, stirrer power measuring, and tail gas detecting), so as to obtain the actual operation data online in real time. The test process kept constant the factors of reaction load, feeder ratios, ethylene feed rate, hydrogen adjusting ways to avoid the influence of process fluctuations on catalyst testing performance, thus certifying the correctness and integrity of difference of catalyst performance to make accurate results.

2.3. Analytical and Testing Methods

The melt flow rate (MFR) of polypropylene was determined in accordance with the GB/T 3682.1—2018 [5]standard; ash content was determined in accordance with GB/T 9345.1— 2008; flexural modulus was determined in accordance with GB/T 9341—2008 [6]; the notched beam impact strength was determined according to GB/T 1043.1—2008[7]; the particle size distribution of the polymer powder was analyzed using the sieving method; the polymerization activity of the catalyst was calculated based on the mass of polymer produced per unit mass of catalyst; and the operational stability of the reactor was evaluated through indicators such as reactor temperature fluctuations and stirrer power.

2.4. Comparison of Catalytic Activity and Reactor Thermal Stability

Catalytic activity is the primary indicator for evaluating catalyst performance and is directly related to catalyst consumption and production costs.

Table 1 JHC Catalyst

Q1 quench liquid flow rate (m^3/h)	Qulant flow rate, Reactor 2 (m^3/h)	JHC Catalyst Feed Rate (kg/h)	Triethylaluminum Feed Rate (kg/h)	Modifier feed rate (kg/h)
355.68	135.96	36.98	3.37	1.04
355.43	134.65	37.13	3.38	1.06
354.75	137.96	37.39	3.40	1.09

Table 2 BCM catalyst

First-stage quench liquid flow rate, m^3/h	Second-stage quench liquid flow rate, m^3/h	BCM catalyst feed rate (kg/h)	Triethylaluminum feed rate kg/h	Modifier feed rate (kg/h)
359.68	144.85	33.46	3.15	0.95
362.63	146.70	33.85	3.22	0.98
356.98	147.54	33.77	3.21	0.98

The intensity of the reaction in the JPP unit can be determined by the injection rate of the quench liquid (cooling via the vaporization of liquid propylene). A high quench liquid flow rate indicates that the catalyst has good reactivity. Domestic catalysts exhibit higher activity levels: under higher reaction loads (the quench liquid volumes in both the first and second reactors are higher than those of the JHC catalyst, corresponding to higher propylene gasification rates),the BCM catalyst's specific consumption is only 33.46 kg/h to 33.85 kg/h, a reduction of approximately 9% to 11% compared to the JHC catalyst's 36.98 kg/h to 37.39 kg/h, while the consumption of triethylaluminum and modifiers was reduced by approximately 5%–8% and 9%–13%, respectively. At equivalent production rates, the BCM catalyst exhibits lower additive consumption and superior catalytic activity; however, higher activity is not necessarily better. Excessively high initial activity may lead to localized overheating, catalyst particle breakage, and an increase in fine powder, which in turn affects the reactor’s fluidization state and powder conveying stability, thereby increasing operational risks.

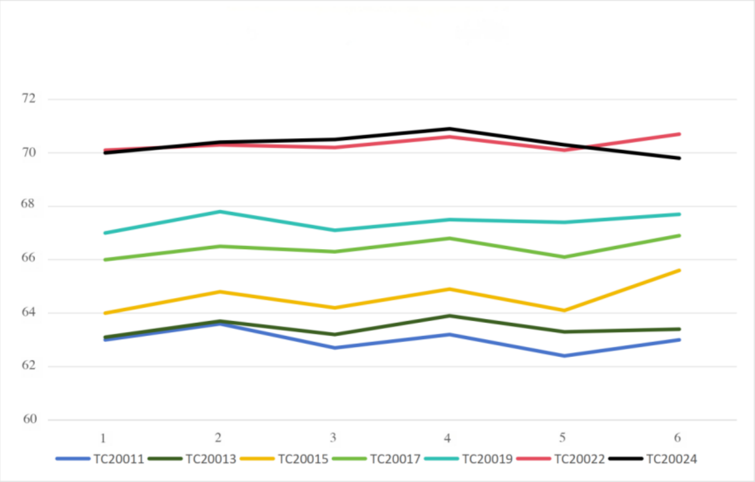

Figure 1: First-Reaction Temperature Profile of the JHC Catalyst

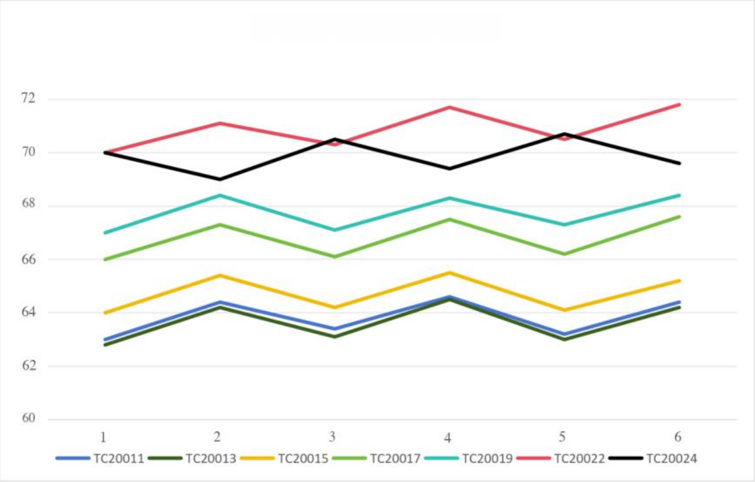

Figure 2: First-Reaction Temperature Profile of the BCM Catalyst

The first reactor of the gas-phase polypropylene unit has 14 temperature measurement points, designated TC20011 through TC20024. By comparing six representative temperature measurement points and observing the fluctuation range, the thermal stability of the two catalysts is evaluated. Figure 1 shows the temperature profile of the first reactor during the reaction with the JHC catalyst, with temperature fluctuations ranging from 0.2 ℃ to 0.9 ℃. Figure 2 shows the temperature curve of the first reactor during the reaction with the BCM-100H catalyst, with temperature fluctuations ranging from 1.0 ℃ to 1.5 ℃.

Studies have shown that the polymerization reaction rate of domestically produced catalysts follows a declining trend: while they exhibit strong initial activity and can rapidly drive the reaction, their ability to maintain activity is weak, making it impossible to sustain stable heat generation. In the high-temperature polymerization range, the rate of catalyst activity decline accelerates, which further amplifies temperature fluctuations and affects the steady-state operation of the reactor. This places higher demands on the thermal stability of the reactor [2] .

2.5. Comparison of Stirring Power

Fluctuations in stirring power are a key indicator of the operational stability of gas-phase reactors. Excessive power fluctuations can easily lead to issues such as particle breakage, increased fine powder, reactor caking, and shortened continuous operation cycles. Reactor stability is assessed based on the amplitude of stirring power fluctuations under identical production conditions.

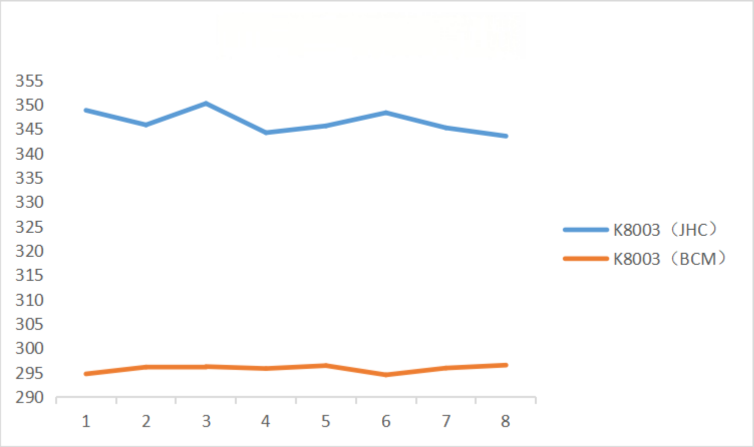

Figure 3: Power Curve for the First Reactor Stirrer

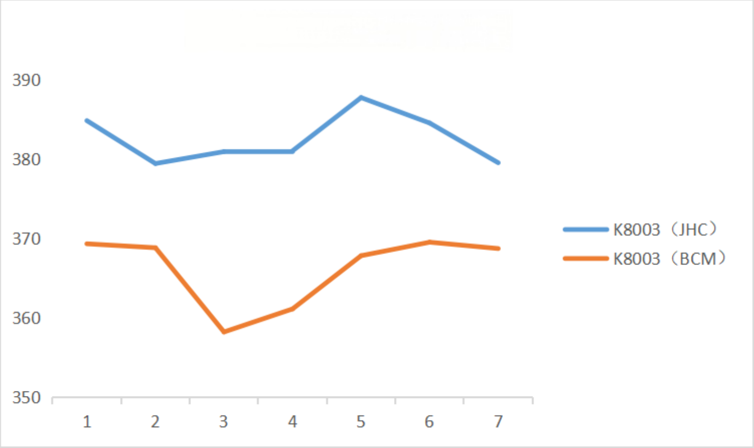

Figure 4: Power Curve for the Second Reactor Stirrer

The comparison between Figure 3 and Figure 4 shows that in the first reactor, the fluctuation amplitude of the stirring power for the BCM catalyst was only 60%–65% of that for the JHC catalyst, demonstrating a significant advantage in operational stability. However, in the second reactor, the fluctuation amplitude of the BCM catalyst was slightly higher than that of the JHC catalyst, indicating slightly lower stability.

The stirring power of the BCM catalyst in the first reactor is 15%–20% lower than that of the JHC catalyst, and in the second reactor, it is 4%–6% lower. The BCM catalyst demonstrates superior energy-saving characteristics, which is significant for reducing plant energy consumption and enhancing economic efficiency.

2.6. Comparison of Hydrogen Sensitivity

Hydrogen sensitivity is one of the core properties of polypropylene catalysts [10], referring to the ability of hydrogen to regulate polymer molecular weight and melt flow rate (MFR). The higher the hydrogen sensitivity, the less hydrogen is required to achieve the same MFR, and the more precise the molecular weight control [3].

Hydrogen is the key chain transfer agent used to regulate molecular weight (and consequently MFR) in polypropylene production, as shown in Table 3, Table 4, Table 5, Table 6.

Table 3 Process Parameters for the Production of K8009 Using JHC Catalyst

Hydrogen concentration in the first reactor (vol%)	Hydrogen feed rate (Nm ^{3}/h)	Hydrogen concentration in the second reactor(vol%)	Hydrogen feed rate to Reactor 2 (Nm ^{3}/h)
5.256	50.980	0.782	2.501
5.501	51.480	0.841	2.237
5.550	50.470	0.842	2.200

Table 4 Process Parameters for the Production of K8009 Using BCM Catalyst

Hydrogen concentration in Reactor 1 (vol%)	Hydrogen feed rate to Reactor 1 (Nm ^{3}/h)	Hydrogen concentration in the second reactor (vol%)	Hydrogen gas feed rate(Nm ^{3}/h)
7.590	58.950	0.802	3.407
7.668	59.160	0.803	3.411
7.812	58.010	0.802	3.345

Table 5 Process Parameters for the Production of K8003 Using JHC Catalyst

Hydrogen concentration in Reactor 1 (vol%)	Hydrogen feed rate to Reactor 1 (Nm ^{3}/h)	Hydrogen concentration in the second reactor (vol%)	Hydrogen feed rate to Reactor 2 (Nm ^{3}/h)
1.751	19.670	0.403	1.085
1.609	20.520	0.419	0.856
1.576	23.880	0.397	0.569

Table 6 Process Parameters for the Production of 3Using BCM Catalyst

Hydrogen concentration in Reactor 1 (vol%)	Hydrogen feed rate to Reactor 1 (Nm ^{3}/h)	Hydrogen concentration in the second reactor (vol%)	Hydrogen feed rate to Reactor 2 (Nm ^{3}/h)
2.504	28.060	0.625	1.417
2.456	28.250	0.615	1.228
2.436	27.130	0.635	1.355

During the production of PPB-M09-G (K8009), the hydrogen consumption of the BCM-100H catalyst was significantly higher than that of the JHC catalyst: the hydrogen feed rate in the first reactor was approximately 13%–17% higher, and in the second reactor, approximately 34%–55% higher.

During the production of the PPB-M03 (K8003) grade, the hydrogen feed rate for the BCM-100H catalyst in the first reactor was approximately 14%–44% higher than that of the JHC catalyst, and approximately 66%–116% higher in the second reactor.

This indicates that the JHC catalyst is more sensitive to hydrogen, requiring a lower hydrogen feed rate to achieve the same MFR. Compared to domestic catalysts, the total hydrogen feed rate required to achieve the same MFR is reduced by approximately 14%–18% in the first reactor and by approximately 16%–45% in the second reactor, offering greater cost and control advantages in the production of high-melt-flow-rate grades.

2.7. Product Performance Comparison

Table 7: Comparison of Performance Characteristics between JHC and BCM Catalysts (Laboratory Data)

	First batch of K8003 produced with BCM	BCM production of K8003, second batch	BCM production of K8003, third batch	JHC's First Batch of K8003	JHC's Second Batch of K8003	JHC produces the third batch of K8003
Black granules per kg	0	0	0	0	0	0
Chromosome count (per kg)	0	0	0	0	0	0
Large and small grains/kg	0	0	0	0	0.5	0
Melt flow rate (g/10 min)	2.52	2.65	2.65	2.81	2.40	2.51
Ash content% (mass fraction)	0.022	0.022	0.022	0.021	0.019	0.020
Tensile yieldstress MPa	23.3	23.3	23.0	23.7	23.7	23.5
Bending modulus MPa	1070	1070	1090	1110	1110	1110
Notched impact strength of hollow-core beams(23 ℃) kJ/m^3	73	73	74	69	72	72
Notched impact strength of hollow-core beams (-20 ℃) kJ/m^3	7.1	7.1	8.5	7.8	7.8	8.7
Load-deflection temperature (Tf0.45) ℃	88	88	88	87	88	86
Molding Shrinkage Rate SM	1.2	1.2	1.2	1.2	1.2	1.2
Molding shrinkage	1.2	1.2	1.2	1.2	1.2	1.2
Rockwell Hardness (R Scale)	83	83	83	85	85	85

Impact-resistant copolymer polypropylene [8]PPB-M03 (K8003) produced using the JHC catalyst exhibits a higher flexural modulus than products made with the BCM catalyst under identical ethylene concentrations in the gas-phase reactor, while the notched beam impact strength is comparable, as shown in Table 7,. This indicates that the JHC catalyst offers advantages in controlling the distribution of the EPDM phase and achieving a balance between stiffness and toughness.

Mechanical Properties: Products produced with the JHC catalyst exhibit higher flexural modulus, tensile strength, and Rockwell hardness [9], as well as greater rigidity and surface hardness, making them more suitable for products requiring high stiffness and wear resistance;

Processing stability: Products produced with the BCM catalyst exhibit smaller batch-to-batch variations in melt flow rate and heat deflection temperature, and their room-temperature impact toughness is slightly higher than that of JHC products, which is more conducive to stable control of downstream processing [4];

Products produced using both catalysts have low ash content and are free of visual defects such as black specks or discoloration. There is no significant difference in their low-temperature impact resistance, and both meet the quality requirements for industrial applications. The JHC catalyst offers superior performance in enhancing product stiffness and strength, while the BCM catalyst demonstrates better performance in terms of batch consistency and room-temperature toughness.

3. Conclusions

Comparative tests based on actual production parameters and laboratory data revealed differences between the domestically produced BCM-100H catalyst and the imported JHC catalyst across five key areas: catalytic activity, plant operation, particle characteristics, sensitivity to hydrogen adjustment, and product performance. These findings highlight the strengths and weaknesses of the domestic catalyst in gas-phase reaction systems, point the way toward future improvements in domestic catalyst process technology, and provide a basis for industrial practice regarding the domestic substitution of polypropylene catalysts.

Test results confirm that the domestic BCM-100H catalyst exhibits higher activity than the imported JHC catalyst, with an increase of approximately 9% to 11%. The consumption of the two additives—triethylaluminum and the modifier—was also reduced by approximately 5% to 8% and 9% to 13%, respectively. Furthermore, the domestic catalyst offers a price advantage and better value for money. Significant improvements were observed in material cost control. In a comparison of operational stability in the first reactor, the domestically produced BCM catalyst exhibited lower energy consumption for stirring, with fluctuations in stirring power ranging from only 60% to 65% of those of the JHC catalyst. However, in the second reactor, the fluctuation range of the BCM catalyst was slightly higher than that of the JHC catalyst, indicating slightly lower stability. When producing high-impact polypropylene material with the grade designation PPB-M03 (K8003), the product’s appearance quality and low-temperature impact performance show no significant difference from those of products made with imported catalysts. Furthermore, it demonstrates superior batch consistency and room-temperature toughness, which facilitates more stable control of downstream processing. In routine industrial production, it meets customer quality requirements.

Domestic BCM catalyst granules lack sufficient mechanical strength and exhibit weaker resistance to fragmentation compared to imported catalysts. Under high-agitation conditions, they are prone to generating fine powder, which tends to accumulate and clump, clogging catalyst nozzles, pipelines, and cyclone separators, thereby preventing the unit from operating continuously at optimal capacity. The activity of BCM catalysts declines relatively quickly; while performance in the first reactor is acceptable, significant fluctuations in agitator power occur in the second reactor, indicating that process adaptability requires optimization; In contrast, imported catalysts exhibit superior resistance to friction and fragmentation, maintaining high activity even upon entering the second reactor, making them more suitable for producing products with higher total ethylene content and rubber phase content. The domestically produced BCM-100H catalyst has low sensitivity to hydrogen adjustment and insufficient precision in molecular weight control; its ability to regulate rigidity and strength in the production of high-end grades is inferior to that of imported catalysts.

Additionally, the domestic BCM catalyst exhibits low sensitivity to hydrogen adjustment and insufficient precision in molecular weight control, resulting in inferior control capabilities regarding rigidity and strength compared to imported catalysts in the production of high-end grades.

In summary, the domestically produced BCM-100H catalyst can replace imported catalysts under normal operating conditions. It allows for direct online switching and ensures stable production, offering the advantages of low catalyst and additive consumption as well as low energy consumption for mixing, thereby achieving cost reduction and efficiency improvements. However, further efforts are needed to address three key shortcomings—particle strength, sensitivity to hydrogen adjustment, and high-temperature process adaptability—by optimizing the catalyst preparation process and the structure of its active sites. This will further enhance its adaptability to various operating conditions and its performance in producing high-end products, thereby promoting the comprehensive localization of high-performance polypropylene catalysts.

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