JCNaR
Journal of Chemical Natural Resources
Journal homepage: https://jcnar.usu.ac.id

Optimizing CCR Platforming Conditions for Platformate Quality

Hersa Rizki Rahkmatullah, Martomo Setyawan*, and Siti Jamilatun
Department of Chemical Engineering, Faculty of Industrial Technology, Universitas Ahmad Dahlan, Yogyakarta 55191, Indonesia
*Corresponding Author: martomo@che.uad.ac.id

ARTICLE INFO

Article history:
Received 30 June 2026
Revised 25 July 2026
Accepted 04 August 2026
Available online 05 August 2026

E-ISSN: 2656-1492
P-ISSN:

How to cite:
Hersa Rizki Rahkmatullah, Martomo Setyawan, Siti Jamilatun. Optimizing CCR Platforming Conditions for Platformate Quality. Journal of Chemical Natural Resources. 2025, 7(2):150-156.

https://doi.org/10.32734/jcnar.v7i2.26716

ABSTRACT

The CCR Platforming unit converts hydrotreated naphtha into platformate as a high-octane gasoline blending component. This study evaluates the effects of reactor temperature and catalyst circulation rate on platformate quality, represented by Research Octane Number (RON), and coke tendency, represented by carbon spent. Operating and laboratory data from reactor section 14-R-601/602/603 were grouped at average temperatures of 510, 515, and 520°C with catalyst rates of 60% and 65%. The variables were processed using average data analysis, graphical interpretation, multiple linear regression, and validation against laboratory RON with a maximum allowable error of 5%. The condition of 520°C at 60% catalyst rate produced the best platformate quality, with average RON of 100.00, but carbon spent was relatively high at 6.207 wt%. Increasing the catalyst rate to 65% at 510°C improved the frequency of RON ≥ 100; however, at 515 and 520°C the RON did not increase significantly because higher feed flow increased reaction load and coke formation. Model validation gave a MAPE of 0.481% and maximum error of 1.751%. These results indicate that CCR Platforming optimization requires balancing RON target, feed load, catalyst circulation, coke formation, and regeneration effectiveness.

Keyword: CCR Platforming, Platformate, RON, Catalyst rate, Carbon Spent

ABSTRAK

Unit CCR Platforming mengonversi naphtha hasil hydrotreating menjadi platformate sebagai komponen bensin beroktan tinggi. Penelitian ini mengevaluasi pengaruh temperatur reaktor dan laju sirkulasi katalis terhadap kualitas platformate, yang dinyatakan sebagai *Research Octane Number (RON*), serta kecenderungan coke yang dinyatakan sebagai *carbon spent*. Data operasi dan laboratorium *reactor section* 14-R-601/602/603 dikelompokkan pada temperatur rata-rata 510, 515, dan 520°C dengan *rate* katalis 60% dan 65%. Data diolah menggunakan analisis rata-rata, interpretasi grafik, *regresi linear* berganda, dan validasi terhadap RON laboratorium dengan batas galat maksimum 5%. Kondisi 520°C pada *rate* katalis 60% menghasilkan rata-rata RON terbaik sebesar 100,00, namun *carbon spent* relatif tinggi sebesar 6,207 %wt. *Rate* katalis 65% pada 510°C meningkatkan frekuensi pencapaian RON ≥ 100, tetapi pada 515 dan 520°C RON tidak meningkat signifikan karena *flow feed* yang lebih tinggi meningkatkan beban reaksi dan pembentukan *coke*. Validasi model menghasilkan MAPE 0,481% dan galat maksimum 1,751%. Hasil ini menunjukkan bahwa optimasi CCR *Platforming* perlu menyeimbangkan target RON, bahan baku, sirkulasi katalis, pembentukan coke, dan efektivitas regenerasi.

Kata Kunci: CCR Platforming, Platformate, RON, Laju katalis, *Carbon Spent*

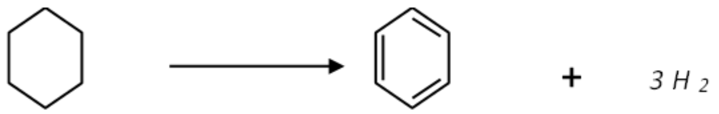
1. Introduction

Catalytic reforming is a key upgrading process in petroleum refining used to convert low-octane hydrotreated naphtha into high-octane reformate or platformate. In a Continuous Catalyst Regeneration (CCR) Platforming unit, hydrotreated naphtha is contacted with a bifunctional catalyst under a hydrogen atmosphere. The metallic function of the catalyst mainly promotes hydrogenation and dehydrogenation reactions, whereas the acidic function promotes isomerization, cyclization, and limited cracking reactions. Through this combination of reaction pathways, paraffinic and naphthenic hydrocarbons are converted into aromatics and isoparaffins, which have higher octane values and therefore improve the Research Octane Number (RON) of the reformate [1-5].

The main chemistry of CCR Platforming can be explained through six representative reaction groups, namely dehydrogenation of naphthenes, dehydrocyclization of paraffins, isomerization of paraffins, hydrocracking, dealkylation or demethylation, and coke formation. To improve readability, each representative reaction is presented separately in Figures 1-5 and is briefly described as follows.

1.1. Dehydrogenation of naphthenes

Dehydrogenation converts naphthenic molecules into aromatic compounds and simultaneously produces hydrogen. This is one of the most desirable reactions in reforming because aromatic products have high octane numbers and the generated hydrogen supports recycle gas requirements in the unit. Because this reaction proceeds readily on the metallic function of the catalyst, it is a major contributor to platformate quality improvement. The representative dehydrogenation reaction of naphthenes in CCR Platforming is presented in Figure 1.

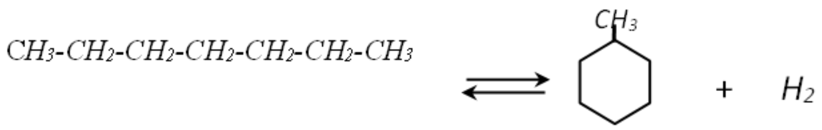


Cyclohexane Benzene Hydrogen

Figure 1. Representative dehydrogenation reaction of naphthenes in CCR Platforming.

1.2. Dehydrocyclization of paraffins

Dehydrocyclization converts normal paraffins into aromatic compounds through cyclization followed by dehydrogenation. Although this pathway is generally more severe than naphthene dehydrogenation, it significantly contributes to octane enhancement when paraffinic naphtha is processed. The formation of aromatics from paraffins is therefore an important mechanism for increasing RON in CCR Platforming. The representative dehydrocyclization reaction of paraffins in CCR Platforming is shown in Figure 2.

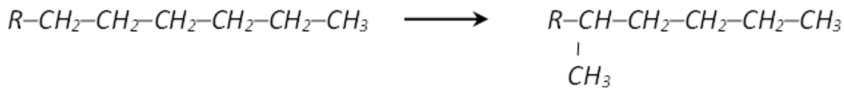


n-heptane toluene hydrogen

Figure 2. Representative dehydrocyclization reaction of paraffins in CCR Platforming.

1.3. Isomerization of paraffins

Isomerization rearranges normal paraffins into branched isoparaffins without changing the carbon number. This pathway improves octane quality because branched paraffins have higher octane values than their normal counterparts. In practice, isomerization provides a supportive contribution to RON improvement, particularly when operation is maintained at moderate severity. The representative isomerization reaction of paraffins in CCR Platforming is illustrated in Figure 3.



n-parafin Iso-parafin

Figure 3. Representative isomerization reaction of paraffins in CCR Platforming.

1.4. Hydrocracking

Hydrocracking breaks larger hydrocarbon molecules into lighter hydrocarbons in the presence of hydrogen. This reaction may help reduce heavier components, but excessive hydrocracking is generally less favorable because it increases gas formation and reduces liquid reformate yield. Therefore, hydrocracking must remain limited so that platformate yield and quality can be balanced. The representative hydrocracking reaction in CCR Platforming is displayed in Figure 4.

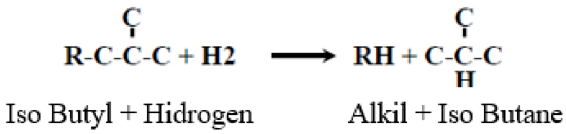


Figure 4. Representative hydrocracking reaction in CCR Platforming.

1.5. Dealkylation or demethylation

Dealkylation changes alkyl aromatic compounds into lighter aromatic species and small paraffinic molecules, such as methane. This pathway may occur under relatively severe conditions and affects aromatic distribution in the reformate product. Although it may contribute to product composition adjustment, excessive occurrence is not generally preferred when liquid product retention is important. The representative dealkylation/demethylation reaction in CCR Platforming is depicted in Figure 5.

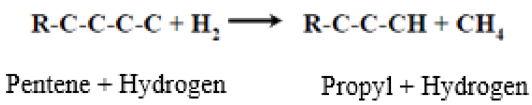


Figure 5. Representative dealkylation/demethylation reaction in CCR Platforming.

1.6. Coke formation

Coke formation is an undesired side reaction caused by condensation, polymerization, and deep dehydrogenation of heavier hydrocarbon species on the catalyst surface. The resulting coke covers catalyst active sites, decreases catalyst activity, and increases the burden on the regeneration section. In this study, coke deposition was considered still manageable when carbon spent remained below approximately 7 wt%; above this level, the opportunity to further increase operating severity becomes more limited [4-6].

The Platforming Unit of Fuel Oil Complex I at PT Kilang Pertamina Internasional RU IV Cilacap produces platformate (14SN-6) as High Octane Motor Gasoline Component (HOMC). The product specification requires platformate with a minimum RON of 100. Reactor temperature is one of the most influential operating variables because increasing temperature raises reaction severity and promotes octane-forming reactions. However, higher temperature also increases the tendency for coke formation. For this reason, the temperature evaluated in this study was limited to 510, 515, and 520°C. The upper evaluation point was set at 520°C because coke deposition and operational safety margins had to be considered, while the reactor section maximum temperature is approximately 540°C. Thus, the selected range provides a practical operating window for evaluating the balance between RON improvement and coke formation tendency.

The feed flow and feed quality were assumed not to vary significantly during the observation period because the processed feed originated from the same source. Therefore, the feed variable in this study mainly represents changes in feed load rather than major shifts in feed composition. Likewise, catalyst activity was assumed to be relatively stable because the CCR configuration continuously regenerates the catalyst and returns regenerated catalyst to the reactor section. These assumptions make it possible to focus the analysis on the effects of average reactor temperature and catalyst circulation rate on platformate quality and carbon deposition tendency.

Based on those considerations, this study aims to evaluate the effect of reactor temperature and catalyst circulation rate on platformate quality in reactor section 14-R-601/602/603. The analysis was conducted using operating data, laboratory RON data, and coke-related indicators represented by carbon spent and carbon regent. In addition, a regression-based prediction model was used to compare predicted RON with actual average RON as part of model validation. The results are expected to provide an operational reference for identifying favorable CCR Platforming conditions that maintain product octane quality while controlling coke formation and regeneration load [3-7].

2. Methodology

The study used operating and laboratory data from the CCR Platforming reactor section 14-R-601, 14-R-602, and 14-R-603. The observation data were grouped into six operating conditions consisting of average reactor temperatures of 510, 515, and 520 °C with catalyst circulation rates of 60% and 65%. The measured variables included feed flow, individual reactor temperatures, average reactor temperature, catalyst circulation rate, actual RON, carbon spent, and carbon regent.

The data were processed by calculating the average values of feed flow, RON, carbon spent, and carbon regent for each operating condition. RON values recorded as greater than 100.0 were converted conservatively to 100.0 to enable consistent numerical analysis. This approach was used because the operating target is defined by minimum RON specification, and values above the upper reporting limit cannot be quantitatively differentiated from the laboratory notation.

A multiple linear regression model was developed to estimate RON as a function of average reactor temperature, catalyst circulation rate, feed flow, carbon spent, and carbon regent. The predicted RON was compared with actual laboratory RON using absolute error and percentage error. The model was considered acceptable when each prediction error was below the maximum allowable value of 5%. This validation approach provides a practical check for the consistency of the data-based model within the observed operating range [7,8].

3. Results and Discussion

The averaged operating data are summarized in Table 1. The data show that each change in temperature and catalyst circulation rate produced different responses in RON and carbon spent. The best average RON was obtained at 520°C and 60% catalyst circulation rate, whereas the lowest carbon spent was observed at 510°C and 60% catalyst circulation rate. These two responses indicate that platformate optimization involves a compromise between product quality and coke control.

Table 1. Summary of operating conditions and product quality.

Temperature. (°C)	Rate (%)	n	Feed (t/d)	RON	C spent (wt%)	C regent (wt%)	RON ≥100
510	60	7	1508.10	99.39	4.350	0.059	1/7
515	60	9	1508.64	98.90	5.787	0.072	0/9
520	60	7	1512.65	100.00	6.207	0.050	7/7
510	65	9	1508.82	99.24	4.991	0.050	5/9
515	65	6	1525.22	99.15	6.218	0.061	4/6
520	65	5	1520.30	99.08	6.424	0.054	2/5

At 60% catalyst circulation rate, the average RON increased to 100.00 when the reactor temperature reached 520°C, as depicted in Figure 6. This condition indicates that the severity was sufficient to promote reactions that increase octane quality. However, at 515°C, the average RON decreased to 98.90, while at 510°C it reached 99.39. The non-linear pattern confirms that RON is not controlled by temperature alone. Feed characteristics, hydrogen-to-hydrocarbon ratio, catalyst activity, and short-term operating stability may also influence the observed RON response [3,4,9].

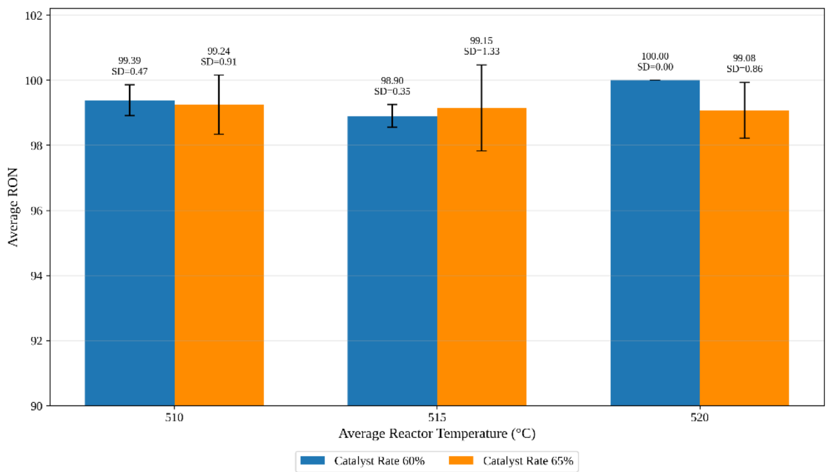


Figure 6. Average RON comparison based on reactor temperature and catalyst circulation rate.

At 65% catalyst circulation rate, the average RON at 510, 515, and 520°C was 99.24, 99.15, and 99.08, respectively. The increase in catalyst circulation rate did not produce a significant increase in RON at higher temperatures. This behavior was associated with the higher feed flow at the 515 and 520°C operating conditions. Average feed flow increased from approximately 1508.82 t/d at 510°C and 65% catalyst rate to 1525.22 t/d at 515°C and 1520.30 t/d at 520°C. A higher feed input increases hydrocarbon load to the reactor section and may reduce effective contact between feed and catalyst. As a result, the positive effect of higher temperature and faster catalyst circulation was partly offset by the increase in feed load.

Carbon spent increased consistently with increasing reactor temperature for both catalyst circulation rates, as shown in Figure 7. At 60% catalyst rate, carbon spent increased from 4.350 wt% at 510°C to 5.787 wt% at 515°C and 6.207 wt% at 520°C. At 65% catalyst rate, carbon spent also increased from 4.991 wt% at 510°C to 6.218 wt% at 515°C and 6.424 wt% at 520°C. These results indicate that higher reactor temperature increases coke formation tendency. This is consistent with the role of temperature in increasing reaction severity and promoting side reactions that form carbonaceous deposits on the catalyst [5,6].

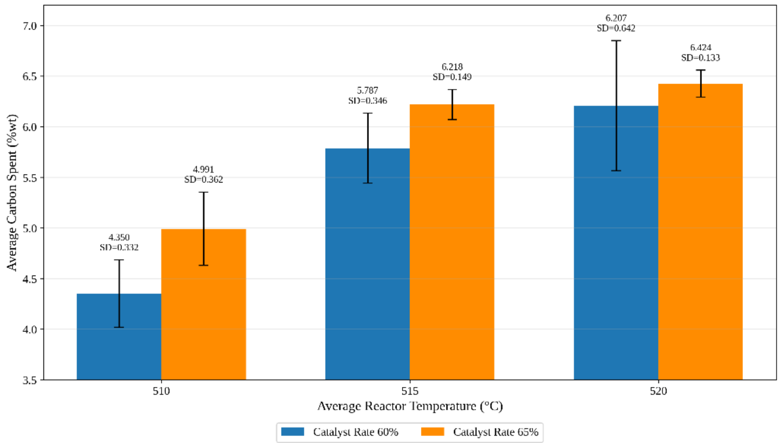


Figure 7. Average carbon spent comparison based on reactor temperature and catalyst circulation rate.

The carbon spent value at 65% catalyst circulation rate was consistently higher than that at 60% for the same temperature. This suggests that faster catalyst circulation may maintain reaction activity, but it can also increase coke tendency when combined with high severity and high feed load. Therefore, increasing catalyst circulation rate is not automatically beneficial unless it is supported by feed flow control, hydrogen availability, and effective catalyst regeneration. The operating decision must balance higher RON achievement with acceptable coke formation and regeneration load.

Figure 8 compares the predicted RON and actual average RON for all average operating groups. The points were close to the ideal fit line, indicating that the regression model captured the main trend of RON changes within the observed operating window. Based on the average groups, the absolute error remained below 0.70 RON and the percentage error remained below 0.67%. In the full validation dataset, all prediction errors were below the maximum allowable value of 5%, with a MAPE of 0.481% and maximum error of 1.751%.

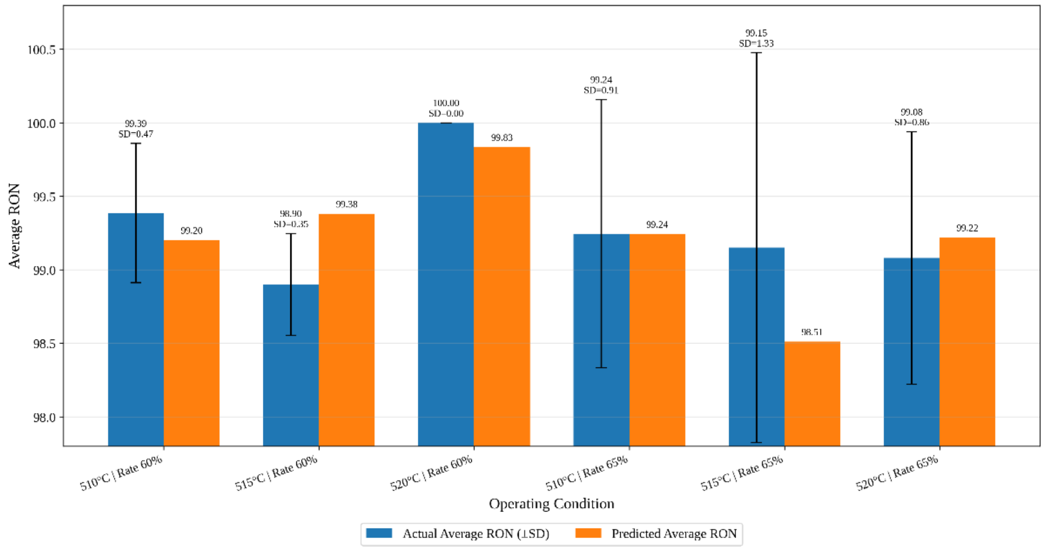


Figure 8. Comparison of actual and predicted average RON by operating conditions

Although the regression result was acceptable for this dataset, the model should be used as an operating evaluation tool rather than a universal prediction equation. The reason is that RON may also be affected by variables not fully represented in the average data, such as detailed feed composition, reactor pressure, recycle gas rate, hydrogen purity, catalyst age, and transient changes in unit operation. The model is therefore valid for interpreting the observed operating range and supporting operating decisions within similar conditions.

4. Conclusion

The operating condition of 520°C at 60% catalyst circulation rate produced the best platformate quality, with an average RON of 100.00 and all observations meeting the minimum RON specification. However, this condition was also accompanied by higher carbon spent, indicating that higher temperature improves RON but increases coke formation tendency. Next, at 65% catalyst circulation rate, increasing temperature from 510 to 515 and 520°C did not significantly improve average RON because feed flow was higher. The higher feed input increased reaction load on the catalyst and contributed to higher carbon spent. Thus, catalyst circulation rate must be optimized together with feed flow and reactor temperature rather than adjusted independently. Overall, the optimization of CCR Platforming operation requires a balance between RON achievement, feed load, catalyst circulation rate, coke formation, and regeneration section effectiveness. The validated regression model can be used as an operating evaluation approach within the observed data range, as all errors were below the maximum allowable limit of 5%.

5. Aknowledgements

The authors express their appreciation to the Department of Chemical Engineering, Faculty of Industrial Technology, Universitas Ahmad Dahlan, and to PT Kilang Pertamina Internasional Unit IV Cilacap for the support and availability of process and laboratory data used in this study.

6. Conflict of interest

The authors declare no conflict of interest related to this manuscript.

References

[1] Speight JG. Handbook of petroleum refining. Boca Raton: CRC Press; 2016.
[2] Aznárez A, Korili SA, Gil A. Progress and recent novelties in naphtha reforming catalysts. Journal of Environmental Chemical Engineering. 2024;12(3):113066. doi:10.1016/j.jece.2024.113066.
[3] Pasandide P, Rahmani M. Simulation and optimization of continuous catalytic reforming: reducing energy cost and coke formation. International Journal of Hydrogen Energy. 2021;46(58):30005-30018. doi:10.1016/j.ijhydene.2021.06.151.
[4] Atarianshandiz M, McAuley KB, Shahsavand A. Modeling and parameter tuning for continuous catalytic reforming of naphtha in an industrial reactor system. Processes. 2023;11(10):2838. doi:10.3390/pr11102838.
[5] Zhou J, Zhao J, Zhang J, Zhang T, Ye M, Liu Z. Regeneration of catalysts deactivated by coke deposition: a review. Chinese Journal of Catalysis. 2020;41(7):1048-1061. doi:10.1016/S1872-2067(20)63552-5.

[6] Nazarova GY, Ivashkina EN, Ivanchina ED, Vosmerikov AV, Vosmerikova LN, Antonov AV. A model of catalytic cracking: product distribution and catalyst deactivation depending on saturates, aromatics and resins content in feed. Catalysts. 2021;11(6):701. doi:10.3390/catal11060701.
[7] Montgomery DC, Peck EA, Vining GG. Introduction to linear regression analysis. 6th ed. Hoboken: John Wiley & Sons; 2021.
[8] Montgomery DC, Runger GC. Applied statistics and probability for engineers. 7th ed. Hoboken: John Wiley & Sons; 2018.
[9] Honeywell UOP. General operating manual platforming process unit. Des Plaines: Honeywell UOP; 2018.
[10] PT Kilang Pertamina Internasional RU IV Cilacap. Laporan operasi Unit Platforming Fuel Oil Complex I. Cilacap: PT KPI RU IV; 2020.