摘要

石腦油裂解後產生約占總質量的 15~25%副產品碳五混合物，此混合物富含極具附加價值的原料，包含異戊二烯(IP)、間戊二烯(PD)、環戊烯(CP)和環戊二烯(CPD)等。由於碳五物質的沸點相近且其中有些成分具共沸關係，難以普通的蒸餾方式分離，因此在工業上一般是以燃料燃燒方式處理而未能充分利用。另一普遍使用的方式是將 CPD 進行二聚反應後產生高沸點的碳十雙環戊二烯(DCPD)，再以蒸餾方式與其它碳五成分進行分離回收，或是利用萃取蒸餾的方式分離高純度的 IP。但此程序皆需複雜的反應與蒸餾分離，且採用回流反應物之方式以提高反應轉化率，此亦容易造成整體製程操作上有滾雪球效應，使整廠製程難以控制，因此，整廠製程具有大幅簡化及強化的空間。在傳統碳五分離製程簡化方面，本研究將反應區域由 2 區簡化至 1 區，操作單元由 8 個簡化到 6 個。此簡化製程可以使整體設備成本大幅降低，並使整廠製程更加容易操作，亦增加產品回收率及濃度，其中，DCPD 的濃度從 85.00~92.00wt%到至少 98.00wt%以上；IP 產物維持高濃度(99.75wt%)；PD 和 CP 混和產物濃度也維持在需求 89.90wt%以上。在製程強化方面，本研究進一步利用隔牆蒸餾塔和外部熱整合進行強化，使整廠製程的能耗大幅下降。透過模擬結果顯示，此研究改善了現有的碳五分離系統，降低了總成本和操作成本，讓產品擁有更大的附加價值，並使整廠製程在工業上具有更大的競爭力。

關鍵字：強化製程、穩態模擬、全廠碳五製程、外部熱整合、隔牆蒸餾版

Abstract

C5 fraction, which accounts for 15-25% in naphtha, consists of molecules such as isoprene (IP), pentadiene (PD), cyclopentene (CP), and cyclopentadiene (CPD) can be used to manufacture petroleum resin and other high value-added products. Yet it is often burned as fuel and not fully utilized because separation of these products with close boiling points is difficult. One common process is to react CPD itself to form high boiling dicyclopentadiene (DCPD) so that it can be separated from the other C5 molecules. In addition, extractive distillation is also used to recover alkynes from light ends. Such a process involves the use of multiple separation columns and reaction zones. Furthermore, it is found that the reactor is highly coupled with one of the separation columns by two recycle streams which may lead to snowball effect and difficulty in control. Hence a wide range of opportunities for process integration and intensification is available. We find that the entire process with reaction and separation can be substantially simplified by reducing the number of reaction zones from 2 to 1 and number of columns from 8 to 6. Such a simplification increases not only process operability but also product concentration of DCPD from a range between 85wt% and 92wt% to at least 98wt%, while maintains the

high purity (>99.75 wt %) for the IP stream and specified purity (>89.90 wt %) for the PD plus CP stream. In addition, capital cost can be greatly decreased for the simplified process. This process can be further intensified by using thermal coupling and external heat integration. Much energy saving can be achieved for the intensified process. Simulation results demonstrate that the proposed simplified and intensified process can substantially reduce capital cost, operating cost as well as improve process operability for the separation of a C5 mixture.

Keywords: Intensification, steady-state simulation, plant-wide process, heat integration, thermal coupling.