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COUNTER-CURRENT FLOW RADIAL AMMONIA SYNTHESIS REACTOR[1]

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SUMMARY

GIAP pioneered the counter-current flow radial reactor more than ten years ago. We first tested it on an industrial scale ammonia unit in 1982. The radial counter-flow reactor contains a few partitions, dividing the radial catalyst bed into the sectors. The flows of the reagents bifurcates before entering the catalyst bed with equal flow of both currents in the adjacent sectors in counter directions. The intense heat exchange occurs through the diathermy partition walls, creating a favourable temperature field in the catalyst bed. A low pressure drop and an optimal temperature field allow the use of counter-current flow radial reactor for numerous catalytic reactions especially in an environmentally protected field. Moreover, it is possible to use a catalyst with small pellet size and obtain some high conversion grades in such a reactor. A large surface for heat exchange and flow arrangement gives the possibility of heat saving in the catalyst bed. The necessity for the preliminary warming of a feed flow disappears. It is a new way for creating some catalyst reactors that are useful for different exothermic reactions.

The calculations show that using counter-current flow radial reactor allows the increase of axial reactor capacity by 25 to 30% with pressure drop three to four times less. For example, the pressure drop of the conventional axial reactor for ammonia synthesis (capacity: 1360 t/day) is 7-10 bar. The pressure drop of the modernized reactor will be only 2.5-3 bar. The heat exchanger of the counter-current flow reactor takes less than 2% of reactor volume, whereas conventional tubular heat exchanger takes more than 20% of the reactor volume. On the whole, the counter-current flow reactor has an efficiency of 15% more than the radial reactor with intermediate heat exchangers.

RESUME

Le GIAP a été à l'origine du réacteur à flux radial à contre-courant il y a plus de 10 ans. Il a été d'abord testé sur une unité d'ammoniac industrielle en 1982. Le réacteur à flux radial à contre-courant contient plusieurs cloisons où le lit de catalyseur radial est réparti. Le flux de réactif bifurique avant d'arriver sur le lit de catalyse et des parties égales du flux va vers les secteurs adjacents dans des directions contraires. L'échange intense de chaleur se produit à travers les cloisons de partition diathermique, créant une température ambiante favorable dans le lit de catalyse. Une faible baisse de pression et un intervalle de température optimum permettent d'employer le réacteur à flux radial à contre-courant pour les nombreuses réactions catalytiques surtout dans un domaine de protection de l'environnement. De plus, on peut utiliser un catalyseur à faible granulométrie et obtenir des taux élevés de conversion dans ce réacteur. Une grande surface d'échange de chaleur et une disposition des flux permettent d'économiser de la chaleur dans le lit de catalyse. La nécessité d'un chauffage préliminaire du flux d'alimentation disparaît. C'est un nouveau moyen de créer certains réacteurs à catalyse, utilisés pour la réalisation des diverses réactions exothermiques.

Les calculs montrent que l'emploi de réacteur à flux radial à contre-courant permet d'augmenter la capacité d'un réacteur axial de 25 à 30 % avec une baisse de pression 3 ou 4 fois moindre. Par exemple, la baisse de pression dans un réacteur axial classique pour la synthèse d'ammoniac (capacité 1360 t/j) est de 7-10 bar. Cette baisse pour un réacteur modernisé est de seulement 2,5-3 bar. L'échangeur de chaleur d'un réacteur à flux à contre-courant prend moins de 2 % du volume du réacteur, tandis que l'échangeur de chaleur tubulaire classique prend plus de 20 % du volume du réacteur. Dans l'ensemble, le réacteur à flux à contre-courant a un rendement supérieur de 15 % au réacteur radial avec échangeurs de chaleur intermédiaires.

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[1] *Réacteur de synthèse d'ammoniac à flux radial à contre-courant*

Counter-current Flow Radial Reactor

GIAP had carried out research with counter-current flow radial reactors more than fifteen years ago. The basic principle is described in the abstract.

Industrial Tests

To evaluate the efficacy of the counter-current flow radial reactor we designed a test model for ammonia synthesis on an industrial unit with a capacity 50 tonnes per day. The Nevinnomyssk Azot company was the owner of this ammonia production unit (Nevinnomyssk, Stavropol's region, Russia). The aims of the tests were:

1. To obtain the experimental data on the temperature distribution, the coefficients of heat exchange and grades of conversion;
2. To obtain experience on operation and control;
3. To examine the behaviour of the construction design and material under actual conditions of ammonia synthesis. The test reactor was manufactured by GIAP's workshop. It was transported to Nevinnomyssk then and placed into the shell of one of the operating reactors instead a conventional tubular filling. The test reactor had been operating for one year. Then the filling was removed from shell for the construction design and material examination. It was found that the condition of the construction design and material both were excellent. Figures 1 and 2 show a sketch of the test reactor and the temperature distribution in the catalyst beds in the adjacent sectors. The test reactor demonstrated a capacity 40% more than the conventional reactor during the entire operation.

Results and Applications

The results of the pilot and industrial investigations as well as the software for calculations show the possibility for numerous applications for such kind of reactor.

1. Modernization of the Large Axial Reactors

Calculations show that using a counter-current flow radial reactor allows an increase of axial reactor capacity by 25 or 30% and a pressure drop three to four times. For example the pressure drop of the conventional axial reactor for ammonia synthesis (capacity- 1360 tonnes per day) is 7-10 bar. The pressure is only 2.5-3 bar in this modernized reactor. The heat exchanger of the counter-current flow reactor takes less than 2% of the reactor volume, whereas conventional tubular heat exchanger takes more than 20% of the bed volume. On the whole using radial counter-current flow bed we can design reactor of two beds instead three beds with the same capacity and effectiveness.

2. Development of the Ammonia Synthesis Loop under Low Pressure

The small pressure drop and high effectiveness of the counter-current flow radial reactor give a possibility to use it in the ammonia synthesis loop under low pressure (less 80 bar). In this case the counter-current flow reactor processes with conventional iron catalyst.

3. The others applications

The counter-current flow reactor is especially useful in processing a flow with a small hydraulic pressure. Thus, it can process the gaseous wastes that have very small pressure and small concentration of the admixtures. Since the counter-current flow reactor has a large internal surface for the heat exchange, the reaction heat is saved and there is a favorable temperature field in the catalyst bed. It is not necessary to assemble large external heat exchangers or use external heat sources.

Figure 1
Two adjacent sectors of counter-current flow radial reactor

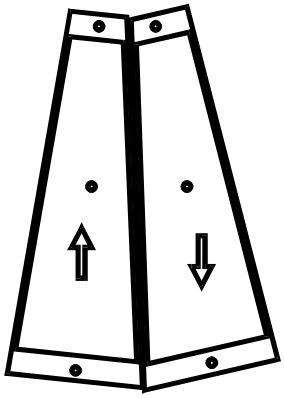
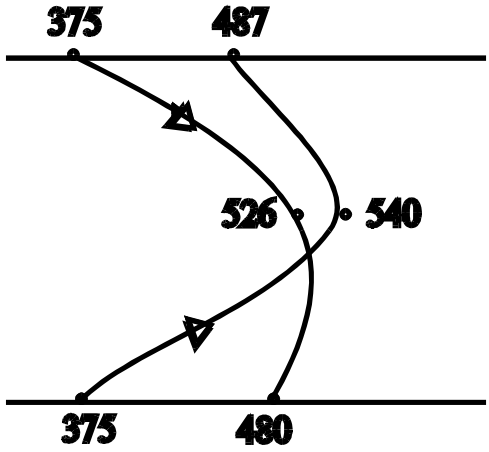
Figure 2
The experimental temperature distribution over catalyst's bed