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From noise to information: a new technology of olefin polymerization fluidized bed reactor based on acoustic emission

Key words: Fluidized bed, Acoustic emission, Agglomeration, Meso-scale, Scale-up

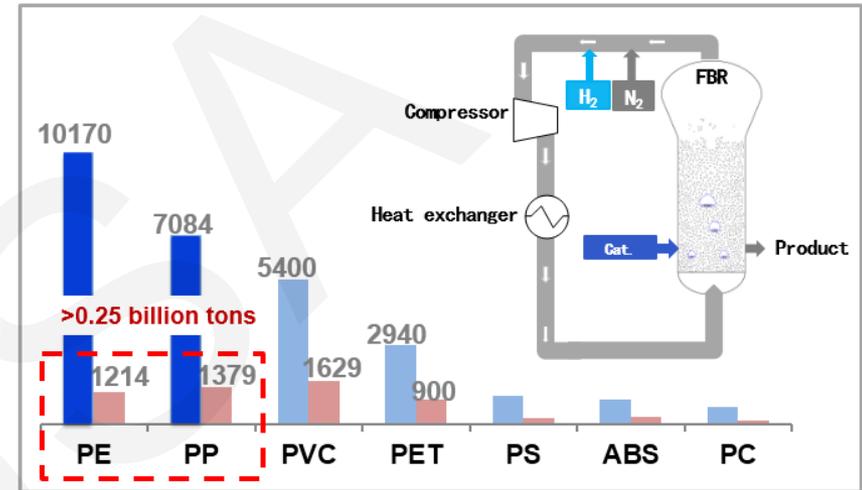
RESEARCH BACKGROUND AND THE TECHNICAL CHALLENGES

- Of all the global synthetic resins, polyolefin production has topped the list, and played an important role in national economic construction and social development. When heat transfer is blocked, particles are easily melted and agglomerated, and may even cause the industrial reactor to shut down.

- In solving the problem of agglomeration in the process of polymerization, there are three difficulties:

(1) the in-situ characterization of particles and agglomerates in the fluidized bed is changeable and difficult to detect (2) the on-line intervening mechanism of particle melting agglomeration is unclear and difficult to control (3) strong coupling of flow and heat transfer process and the reactor scale-up law is unknown

- We try to solve these three difficulties and the general idea of the invention is listed as follows:
In response to the first difficulty, we developed fluidized bed acoustic emission detection technology. In view of the second difficulty, we invented the fluidized bed agglomeration fault self-repair technology. Aiming at the third difficulty, a mathematical model of direct scale-up technique of the fluidized bed was invented.



Capacity of synthetic resin in 2015 ■ World ■ Mainland China

Fig. 1 Capacity distribution of synthetic resin in 2015

ACOUSTIC EMISSION DETECTION TECHNOLOGY

In the complex flow of the fluidized bed environment, given the lack of in-situ detection technology and effective information extraction, we completed the following two tasks.

- (1) A multi-scale analysis method of acoustic emission signals was established. The acoustic emission signals were decomposed into micro-scale, meso-scale and macro-scale signals by wavelet decomposition and R/S classification and reconstruction. Thus, the corresponding relationship between multi-scale of acoustic signals and multi-scale of flow structure was established, which solves the problem of effective information extraction.
- (2) A new technique for the acoustic emission measurement of particle parameters was developed, which included 14 parameters including micro-scale particle size distribution, mesoscopic granular agglomeration and macroscopic particle flow pattern. This has realized real-time on-line measurement of the particle parameters of the fluidized bed reactor

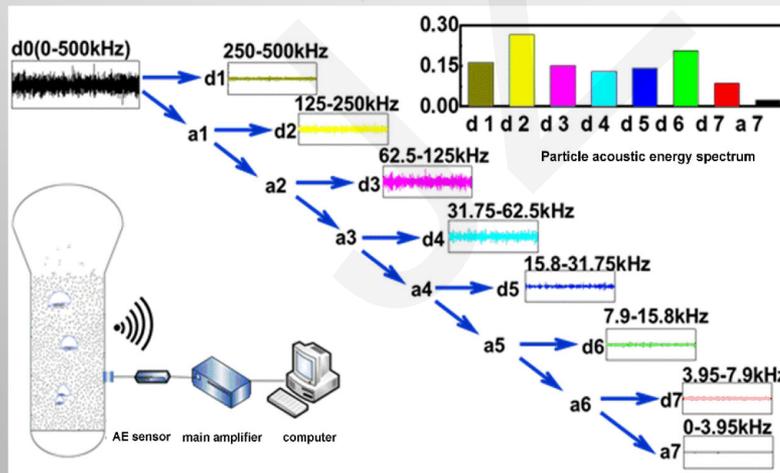


Fig. 2 Acoustic emission measurement system and signal multi-scale resolve analysis method, each particle size with a characteristic energy spectrum

REACTOR OPERATION OPTIMIZATION TECHNIQUE

A soft measurement method of condensate flowrate based on acoustic emission detection was developed. We used acoustic emission detection to get the dew point temperature of the circulating gas, so as to do component correction, and to achieve the condensate flowrate and accurately measure other key parameters. The process parameters, thermodynamics, polymerization kinetics and CFD simulation were used to establish the monitoring system for the production process, and this effectively solved the problem of the lack of accurate quantitative monitoring technology.

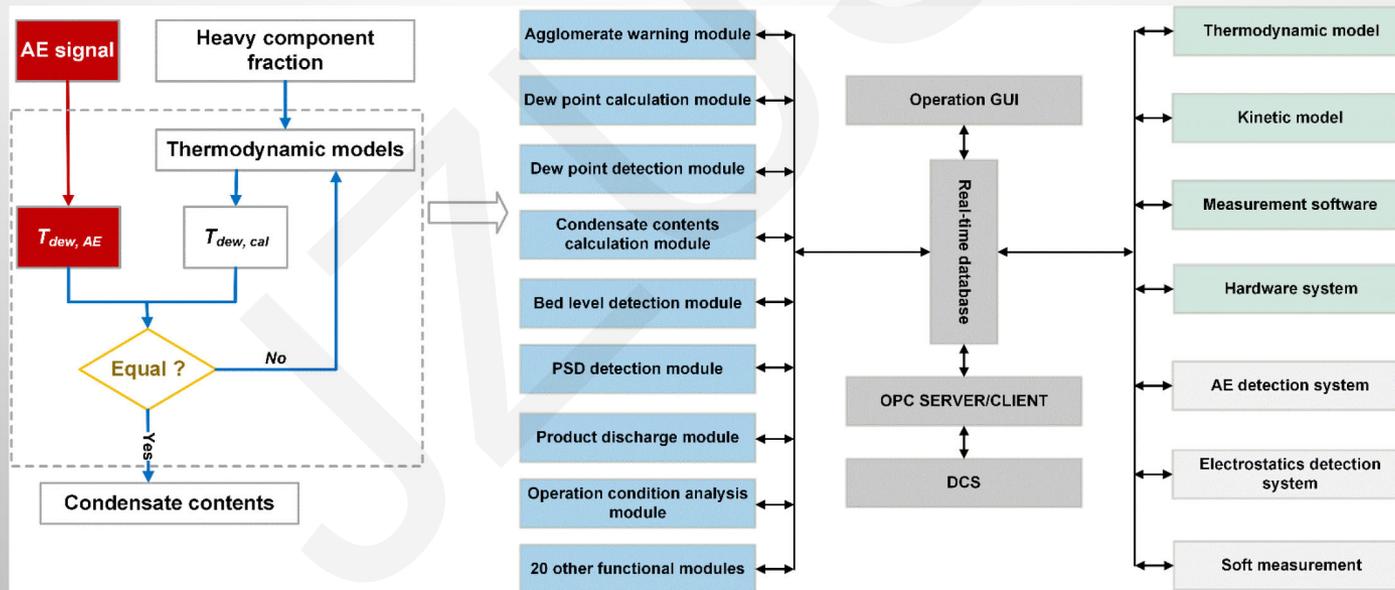


Fig. 3 The monitoring system for the production process of the polymerization fluidized bed reactor combining AE detection, thermodynamics, polymerization kinetics and CFD simulation

REACTOR SCALE-UP TECHNIQUE

- This invention includes a new technology of structural scale-up of the polyolefin fluidized bed reactor. It aims to tackle the problem of strong coupling of flow-heat transfer process and unclear scale-up of the reactor. We propose a reactor scale-up technique based on acoustic emission detection, which has two aspects:
- A direct scale-up method based on acoustic emission detection was developed. We use the acoustic emission technique to obtain the important data of the critical space-time yield of different sizes. The mathematical model of the space-time yield (STY) is established with the scale-up law of equal STY and operation law of unequal STY, achieving a direct scale-up of the reactor.

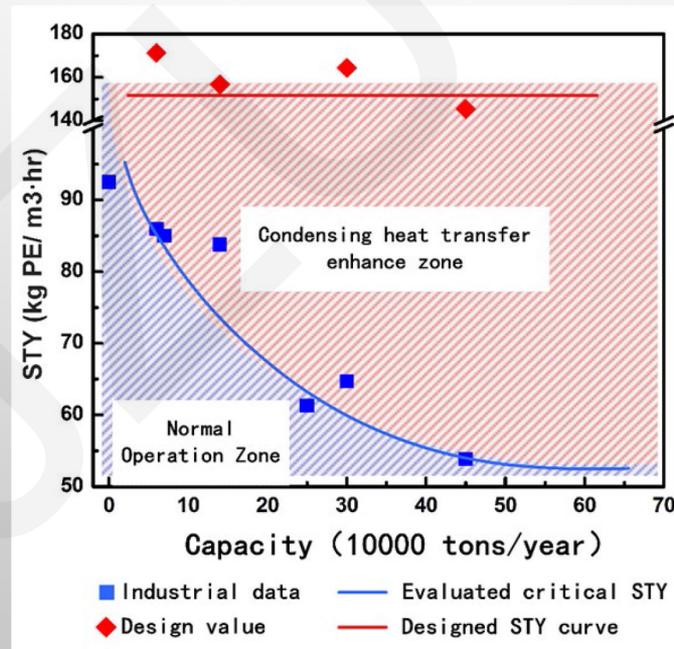


Fig. 4 Different operation zones under normal conditions and condensing mode

INDUSTRIAL APPLICATIONS AND ACHIEVEMENTS

- The newly invented technology has been successful used in the 300,000 tons/year ethylene polymerization fluidized bed reactor in Tianjin as the state key project of "Eleventh Five-Year".
- This indicates that China's gas phase polyethylene industry, for the first time, has a complete set of domestic technology. The results show that the main technical and economic indices, such as total monomer consumption, catalyst consumption and comprehensive energy consumption, have reached an internationally advanced level, implying the full satisfaction of the long-term operational requirement and a reliable auxiliary equipment for the downstream ethylene process.
- The operating cycle can be extended to 38 months, an increase of nearly 50%, given that the traditional process can smoothly operate for about 18 to 20 months (data from Tianjin Petrochemical Engineering Co. LTD, SINOPEC).
- The design and construction has expanded to 14 sets of large-scale olefin polymerization plant, and achieved the efficient production of polyolefins. This is also recognized as an important symbol for the synthetic resin industry in China and has been listed as the national science and technology support project many times.