Thus, due to insufficient feedstock heating rate in tubular furnaces duration of pyrolysis process increases, which results in a situation, when formed at initial stages olefins reside in the reactor furnace for sufficiently long time to begin entering into secondary reactions thus considerably reducing the outcome of a target product. One of secondary products is coke, which causes heat transfer problems in tubes and fouling of the downstream equipment.

Additionally, in existing reactor solutions temperature gradients are very high. Thus, the temperature along the reactor walls is typically very high in comparison to its' center (as viewed along the entire reaction chamber). Since the fluid flow is faster in the center than in the areas adjacent to the reactor walls, large temperature gradient causes severe coking problems.

Furthermore, in existing reactor solutions residence times (times that the feedstock-containing process fluid spends in the reaction space) remain outside the scope of optimization.

Traditional technology does not offer reasonable solutions to the problems mentioned above due the fact that at a time being the conventional pyrolysis furnaces have already reached their technical limits, in terms of modifying heat transfer rates and/or adjusting the reaction temperature parameters and the reaction outcome, accordingly.

Traditional process for producing low-molecular weight hydrocarbons by thermal degradation thus encounters a major problem of lack of controllability over an entire process, therefrom a range of the secondary problems arises as follows: 1. poor performance factor for tubular furnace reactors; 2. loss of valuable feedstock material; 3. long reaction times; 4. high secondary reactions rates; 4. high energy consumption; 5. non-optimum (less than possible) product yield and selectivity.

SUMMARY OF THE INVENTION

Embodiments of the present invention solve or to at least mitigate each of the problems arising from the limitations and disadvantages of the related art. Various embodiments disclose an apparatus for conducting chemical reactions in a process fluid, related arrangement, method and uses.

According to a first aspect of the present invention, there is provided an apparatus for conducting chemical reactions in a process fluid, the appraratus including: a central shaft with a number of axial-radial rotors mounted thereon, each said rotor comprises a plurality of axial-radial rotor blades arranged over a circumference of a disk mounted onto the central shaft, a plurality of stationary vanes disposed upstream of the rotor, and a mixing space provided as a vaneless or vaned mixing space disposed downstream of the rotor, wherein the mixing space is configured to convert mechanical energy imparted to the process fluid by the rotor into internal energy of said process fluid and to establish conditions for an at least one chemical reaction in the process fluid to occur.

In an embodiment, that said apparatus comprises at least two rotors mounted onto the central shaft one after another.

The plurality of stationary vanes, the plurality of axial-radial rotor blades and the mixing space establish, in some embodiments, a process stage configured to mediate a complete energy conversion cycle.

In an embodiment, in said apparatus, the stationary vanes are preferably inlet guide vanes configured to direct a process fluid flow into the rotor in a predetermined direction such, as to control the specific work input capability of the rotor. Said stationary vanes are prefereably further configured to direct the process fluid flow, with a preswirl, into the rotor in a direction essentially along a meridional axisymmetric plane X – r.

In an embodiment, in said apparatus, the rotor blades are configured, upon rotation of the rotor, to receive the essentially axial process fluid flow from the stationary vanes and to further turn said flow, with a swirl, into an essentially radial direction, thus imparting mechanical energy to the process fluid by increasing tangential velocity thereof.

In an embodiment, in said apparatus, the rotor is further configured, in terms of profiles and dimensions of the rotor blades and disposition thereof on the disk, to control mechanical energy input to the process fluid.

In an embodiment, the at least one rotor provided in the apparatus comprises a shroud configured to cover the plurality of the rotor blades.

In an embodiment, in said apparatus, the mixing space is preferably configured to convert kinetic energy or mechanical energy of the process fluid into internal energy of said process fluid. Said mixing space is preferably established by a conduit comprising at least a bend section followed by a return channel section. In an embodiment, the mixing space within each stage is configured adjustable in terms of its geometry and/or dimensional parameters. In said mixing space, any one of the bend section and the return channel section is preferably configured adjustable in terms of at least shape, length, cross-section and spatial disposition within the apparatus.

In some embodiments, the mixing space further comprises an at least one additional component including, but not limited to a stationary vane or vanes, a turbulator device, a throttle device, a gauze, a flow guide, slots and insertable and/or removable components, and the like. The mixing space can further comprise a diffuser, which can be vaned or vaneless.

In an embodiment, the stationary vanes and/or the rotor blades within said apparatus are preferably configured to vary within each stage in terms of at least dimensions, alignment and spatial disposition thereof, as preset or as manufactured. In an embodiment, said stationary

vanes and/or the rotor blades are configured individually adjustable within each stage, in terms of at least dimensions, alignment and spatial disposition thereof, during the operation of the apparatus.

In an embodiment, the apparatus further comprises a housing configured to enclose the central shaft and the at least one stage.

In an embodiment, the apparatus is configured as a modular structure, wherein the housing is established by number of modules disposed one after another. The apparatus is further configured to comprise at least one non-exhaust module and an exhaust module.

In an embodiment, the exhaust module comprises an at least one exit line for process fluid discharge arranged in circumferential direction with regard to a horizontal axis of the apparatus defined by the central shaft, and in which exhaust module the mixing space is an exhaust mixing space provided inside the exit line. Said exhaust module can further comprise an at least one additional component including, but not limited to an injection port, a pipe, a manifold, and the like.

In some embodiments, in the abovementioned modular structure the stage is established by the at least one module.

In an embodiment, the apparatus is further configured to comprise an inlet module disposed most upstream in a direction of fluid flow and configured to receive a feedstock-containing process fluid via an at least one intake line arranged in a circumferential direction with regard to a horizontal axis of the apparatus defined by the central shaft.

In an embodiment, the stage is established by the inlet module and the exhaust module.

In an embodiment, the number of modules within the modular structure is adjustable by addition, replacement and/or removal of the at least one non-exhaust module provided between the inlet module and the exhaust module.

In an embodiment, the housing of the apparatus is configured to closely adjoin the stationary vanes, the axial-radial rotor blades and the mixing space.

In a further embodiment, the housing further comprises an upper portion and a lower portion as viewed along a horizontal cross section of the apparatus, and wherein said upper portion is configured to encompass at least the bend section of the channel forming the mixing space within each module.

In an embodiment, said upper portion is further configured to encompass at least a part of the return channel section.

In an embodiment, said upper portion of the housing, within each individual module, is configured detachable and replaceable.

In an embodiment, in said apparatus, the housing can be further configured with walls having thickness of at most 30 mm, preferably, within a range of 5 – 20 mm.

In an embodiment, the the apparatus is configured with a number of catalytic surfaces.

In an embodiment, in said apparatus, each process stage and/or each module is established, in terms of its' structure and/or controllability over the operation thereof, independently from the other stages and/or modules.

In an embodiment, the apparatus further comprises an additional facility, such as a refinery- and/or a heat exchanger facility, connectable to the at least one non-exhaust module disposed between the inlet module and the exhaust module.

According to a second aspect of the present invention, there is provided an use of said the above apparatus for thermal- or thermochemical cracking of hydrocarbon-containing feedstock.

According to a third aspect of the present invention, there is provided an arrangement comprising at least two of the above apparatuses functionally connected in parallel or in series.

According to a fourth aspect of the present invention, there is provided a method for conducting chemical reactions in a process fluid, the method including: obtaining an apparatus including: a central shaft with a number of axial-radial rotors mounted thereon, each said rotor comprises a plurality of axial-radial rotor blades arranged over the circumference of a disk mounted onto the central shaft, a plurality of stationary vanes disposed upstream the rotor, and a mixing space disposed downstream of the rotor, wherein the plurality of stationary vanes, the plurality of axial-radial rotor blades and the mixing space establish a process stage; adjusting the rotation speed of the rotor to a predetermined speed or a speed range to reach the process fluid flow rate that satisfies the requirements imposed by the process; adjusting a preheating level of the feedstock containing process fluid; directing a feedstock containing process fluid flow subsequently through the at least one stage such, that in the mixing space mechanical energy imparted to the process fluid by the rotor is converted into internal energy of said process fluid, thus promoting chemical reactions in the process fluid to occur.

The utility of the present invention arises from a variety of reasons depending on each particular embodiment thereof. Modular structure of the reactor, according to the present disclosure, allows for provision of tailored solutions customized such, as to meet specific demands of the customer. Thus, the solution disclosed hereby allows for addition and removal, optionally accompanied by replacement, of separate modules within the reactor,