

DESCRIPTION

METHOD FOR TRANSPORTING FLUID CATALYTIC CRACKING CATALYST

Technical Field

5 [0001] The present invention relates to a method for transporting a fluid catalytic cracking catalyst in a fluid catalytic cracking process for a heavy oil such as residue.

Background Art

10 [0002] Demand for a hydrocarbon oil product containing a fraction having a boiling point equal to or less than that of light oil has relatively increased due to environmental concern and availability, and how to convert heavy oil to light oil has been an important issue. In the circumstance, importance of fluid catalytic cracking (FCC) using heavy oil has grown as a heavy oil treatment process. Herein, the fluid
15 catalytic cracking refers to a method of decomposing heavy oil (petroleum hydrocarbon) by bringing it into contact with a fluid catalytic cracking catalyst (hereinafter, referred to also as a "FCC catalyst ") to provide products such as gasoline, liquefied petroleum gas, an feed stock of alkalized and a middle distillate mixture.

20 [0003] In this method, since the heavy oil contains metals such as nickel, vanadium, iron and copper, these metals deposit on the FCC catalyst during fluid catalytic cracking of heavy oil. This phenomenon is significantly observed. These metals are present in heavy oil, which are derived from crude oil and provided by being in contact with a
25 transport apparatus, a storage apparatus or treatment units, and are usually present in heavy oil as organic metal compounds having a

porphyrin ring structure and others. Therefore, when the heavy oil comes into contact with an FCC catalyst at a high temperature, the organic metal compounds are decomposed and these metals deposit on the FCC catalyst.

[0004] When these metals deposit on the FCC catalyst, not only the activity of the FCC catalyst but also the selectivity thereof decreases. To explain this more specifically, since these metals are capable of causing hydrogenation and dehydrogenation reactions, the dehydrogenation reactions of hydrocarbons are accelerated in the reaction conditions of fluid catalytic cracking. As a result, yields of unfavorable products such as hydrogen gas and coke increase; whereas, yields of favorable liquefied petroleum gas, gasoline and kerosene oil decrease.

[0005] To avoid such yield reductions of the liquefied petroleum gas, gasoline and kerosene oil, it is known to employ a method using a magnetic separation apparatus when heavy oil and residual oil containing a large amount of metals are subjected to fluid catalytic cracking. In the method, a part of an FCC catalyst present in a circulation system, in other words, an FCC catalyst reduced in activity and selectivity, is periodically or constantly removed and a fresh FCC catalyst is supplied to maintain the activity of the FCC catalyst in the circulation system to be constant as a whole (see, for example, Patent Document 1).

Patent Document 1: Japanese Patent Application Publication No. 2006-187761

Disclosure of the Invention

[0006] Note that, in order to remove an FCC catalyst or the like reduced in activity and supply a fresh FCC catalyst in place, it is necessary to transport the FCC catalyst in a dry state. Usually, in the step of transporting the FCC catalyst, the FCC catalyst is transported by blowing dry air. However, the FCC catalyst hits the wall surface of a curved portion of a transport pipe when it passes through the curved portion of the transport pipe and wears out the transport pipe to occur a problem that a hole is formed in the curved portion of the transport pipe.

[0007] An object of the present invention, therefore, is to provide a method for transporting a fluid catalytic cracking catalyst, capable of significantly reducing abrasion of a curved portion of a transport pipe in transporting a fluid catalytic cracking catalyst (FCC catalyst) in a dry state.

[0008] The method for transporting a fluid catalytic cracking catalyst according to the present invention includes a step of transporting the fluid catalytic cracking catalyst with the help of gas by flowing the gas into a transport pipe having a curved portion, in which the transport pipe is formed of a metal material; the curved portion is constituted of a first portion in the form of a linear pipe and a second portion in the form of a linear pipe communicating with the first portion; in the transport step, the superficial velocity of the gas is set to 5 m/s or more and 20 m/s or less; the angle of the flow direction of the gas flowing in the second portion with respect to the flow direction of the gas flowing in the first portion is set to 45° or more and 90° or less, and the content of the fluid catalytic cracking catalyst in the gas is set to 5 g/l or more and 10 g/l or less, or 15 g/l or more and 20 g/l or less.

[0009] In the method for transporting a fluid catalytic cracking catalyst according to the present invention, since the fluid catalytic cracking catalyst is transported under the aforementioned specific conditions in the step of transporting the fluid catalytic cracking catalyst with the help of gas by flowing the gas into a transport pipe formed of metal material and having a curved portion, the frictional force of the fluid catalytic cracking catalyst applied to the transport pipe can be reduced. As a result, abrasion at the curved portion of the transport pipe can be significantly reduced.

Effect of the Invention

[0010] According to the present invention, it is possible to provide a method for transporting a fluid catalytic cracking catalyst, capable of significantly reducing abrasion at a curved portion of a transport pipe when a fluid catalytic cracking catalyst (FCC catalyst) is transported in a dry state.

Brief Description of the Drawings

[0011] Figure 1 is a view showing the structure of a fluid catalytic cracking system 1;

Figure 2 is a view of showing a part of a transport pipe;

Figure 3 is a view illustrating an abrasion resistance test of a test piece;

Figure 4 is a graph showing the relationship between the angle of inclination and abrasion rate when a SiC particle is used;

Figure 5 is a graph showing the relationship between superficial velocity and abrasion rate when a SiC particle is used;

Figure 6 is a graph showing the relationship between the

concentration of SiC particles and abrasion rate;

Figure 7 is a graph showing the relationship between the angle of inclination and abrasion rate when an FCC catalyst is used; and

5 Figure 8 is graph showing the relationship between the superficial velocity and abrasion rate when an FCC catalyst is used.

Description of Symbols

[0012] 1: fluid catalytic cracking system, 10: reactor, 12: regeneration tower, 14: magnetic separation apparatus, 16: transport pipe, 18: curved portion, 18a: first portion, 18b: second portion, 20: test piece, 22: nozzle.

10 Best Modes for Carrying Out the Invention

[0013] A preferred embodiment of the present invention will be described with reference to the drawings.

[0014] (Structure of fluid catalytic cracking system)

15 First, referring to Figure 1, the structure of a fluid catalytic cracking system 1 will be described. The fluid catalytic cracking system 1 has a reactor 10, a regeneration tower 12 and a magnetic separation apparatus 14. Note that, in Figure 1, the streams of raw-material oil and gasoline are indicated by broken lines and the stream of an FCC catalyst is indicated by a solid line.

20 [0015] In the reactor 10, gasoline is produced by reacting feed oil with a fluid catalytic cracking catalyst (FCC catalyst) transported from the regeneration tower 12. The FCC catalyst used in this reaction is again transported to the regeneration tower 12. As a system for bringing the feed oil, the FCC catalyst and additives into contact with each other, a
25 system using a fluidized bed of the FCC catalyst or a system, such as riser cracking, in which the FCC catalyst is moved through a pipe

together with the feed oil, are known. The present invention can be applied to either one of the systems.

[0016] The reaction conditions in the reactor 10 are not particularly limited and reaction conditions usually used are employed. For example, a reaction temperature can be set to about 480°C to 650°C. The pressure of the reactor 10 can be set to about 0.1 MPa to 0.3 MPa. The ratio between an FCC catalyst and feed oil (FCC catalyst/feed oil) can be set to about 1 to 20. The contact time can be set to about 0.1 second to 10 seconds.

[0017] In this embodiment of the invention, as a feed oil serving as heavy oil, a heavy oil containing heavy metals such as nickel and vanadium, and distillation residue such as asphaltene can be used. Specifically, residue of crude oil treated by normal pressure distillation or reduced pressure distillation, or hydrogenated products of these, or mixtures of these are mentioned. Any FCC catalyst is acceptable as long as it is usually used for catalytic cracking of feed oil. For example, a zeolite catalyst and the like are mentioned. The particle size of an FCC catalyst is not particularly limited; however, it is usually about 5 μm to 200 μm , and preferably about 20 μm to 150 μm .

[0018] In the regeneration tower 12, the FCC catalyst used in the reaction with the feed oil in the reactor 10 is subjected to a regeneration treatment. Specifically, since coke, which is inevitably and simultaneously produced in the catalytic cracking of the feed oil, deposits on the surface of the FCC catalyst reacted with the feed oil in the reactor 10, the FCC catalyst is heated at a high temperature to burn coke on the surface of the FCC catalyst. The FCC catalyst is

regenerated in this way, transported to the reactor 10 and again used for catalytic cracking of feed oil.

[0019] In the magnetic separation apparatus 14, the FCC catalyst reduced in activity and selectivity (hereinafter, referred to also as a "deteriorated catalyst") is selectively separated and discarded. Specifically, metals such as nickel, vanadium, iron and copper contained in the feed oil deposit on the FCC catalyst and deteriorate the catalyst when fluid catalytic cracking of feed oil is performed in the reactor 10. Therefore, focusing on the metal content of the FCC catalyst, the deteriorated catalyst is separated by means of magnetization. The FCC catalyst (FCC catalyst not reduced in activity and selectivity) which is not removed as a deteriorated catalyst in the magnetic separation apparatus 14 is transported to the regeneration tower 12, and thereafter, transported again to the reactor 10 and used for catalytic cracking of feed oil.

[0020] Note that, in the fluid catalytic cracking system 1, a deteriorated catalyst is discarded in the magnetic separation apparatus 14 as mentioned above. Therefore, to maintain a constant amount of FCC catalyst in the regeneration tower 12, a fresh FCC catalyst (hereinafter, referred to also as a "fresh catalyst") is supplied to the regeneration tower 12 depending upon the amount of deteriorated catalyst discarded. Furthermore, in the fluid catalytic cracking system 1, the FCC catalyst is discarded from the regeneration tower 12 at random regardless of whether activity or selectivity of an FCC catalyst is reduced or not.

[0021] Next, referring to Figure 2, we will discuss a transport pipe for supplying a fresh catalyst to the regeneration tower 12, a transport pipe

for discarding an FCC catalyst from the regeneration tower 12, a transport pipe for transporting the FCC catalyst of the regeneration tower 12 to the magnetic separation apparatus 14, a transport pipe for transporting an FCC catalyst not reduced in activity or selectivity from the magnetic separation apparatus 14 to the regeneration tower 12, and a transport pipe for discarding a deteriorated catalyst from the magnetic separation apparatus 14 (hereinafter, these are collectively referred to as a "transport pipe") 16. Note that, Figure 2 shows a part of the transport pipe 16.

[0022] The transport pipe 16 is used for transporting an FCC catalyst. Gas is used for transporting the FCC catalyst. When the gas contains water beyond necessity, the FCC catalyst absorbs water. As a result, the FCC catalyst hardly flows in the reactor 10 or the regeneration tower 12. When the FCC catalyst containing water is exposed to a high temperature, the FCC catalyst causes hydrothermal deterioration. Because of this, dry gas (for example, dry air) containing water in an amount of less than 1% by volume is preferably used. The transport pipe 16 is formed of a metal material such as stainless steel and carbon steel. Note that, when the transport pipe 16 is formed of a material other than a metal material, such as acryl and vinyl chloride, it melts by an FCC catalyst of a high temperature. Therefore, these materials cannot be employed.

[0023] The transport pipe 16 has a curved portion 18 constituted of a first portion 18a in the form of a linear pipe and a second portion 18b in the form of a linear pipe. The first portion 18a and the second portion 18b are joined, for example, by welding.

[0024] As shown in Figure 2, in the transport pipe 16, dry air is flown from the first portion 18a toward the second portion 18b. At this time, the angle of the flow direction of gas flowing through the second portion 18b with respect to the flow direction of gas flowing through the first portion 18a (hereinafter, referred to simply as an "angle") θ is set to 45° or more and 90° or less. When the angle θ is 25° or more and less than 45° , abrasion at the curved portion 18 of the transport pipe 16 caused by impingement of the FCC catalyst to the transport pipe tends to increase. When the angle θ is less than 25° , abrasion at the curved portion 18 of the transport pipe 16 is not so significant; however, the layout of the transport pipe 16 is complicated and thereby economic efficiency tends to decrease. When the angle θ exceeds 90° , the transport pipe 16 is not employed by reason of layout.

[0025] The superficial velocity of gas in the transport pipe 16 is set to 5 m/s or more and 20 m/s or less. When the superficial velocity is less than 5 m/s, it tends to be difficult to transport the FCC catalyst. When the superficial velocity exceeds 20 m/s, abrasion at the curved portion 18 of the transport pipe 16 caused by impingement of the FCC catalyst to the transport pipe tends to increase. Note that, the "superficial velocity" is a value obtained by dividing the flow rate [m^3/s] of dry air per unit time in the transport pipe 16 by the sectional area [m^2] of the transport pipe 16.

[0026] The content of the FCC catalyst in the gas in transporting the FCC catalyst through the transport pipe 16 (in other words, the concentration of the FCC catalyst) is specified as 5 g/l or more and 10 g/l or less, or 15 g/l or more and 20 g/l or less. When the

concentration of the FCC catalyst is less than 5 g/l, the amount of the FCC catalyst is low for the gas and thus transport efficiency tends to decrease. When the concentration of the FCC catalyst exceeds 10 g/l and less than 15 g/l, abrasion at the curved portion 18 of the transport pipe 16 caused by impingement of the FCC catalyst to the transport pipe tends to increase. When the concentration of the FCC catalyst exceeds 20 g/l, the minimum amount of gas required for transporting the FCC catalyst must be increased. The economic efficiency tends to decrease. [0027] In the embodiment of the invention as mentioned above, since the FCC catalyst is transported under the aforementioned specific conditions in the step of transporting an FCC catalyst through the transport pipe 16 made of metal material with the help of gas, the frictional force of the FCC catalyst applied to the transport pipe 16 can be reduced. As a result, abrasion at the curved portion 18 of the transport pipe 16 can be significantly reduced.

[0028] (Example)

In the example, a test was performed in order to confirm that the abrasion of a transport pipe is reduced by a method for transporting an FCC catalyst according to the present invention. As the test, the abrasion resistance of a test piece 20 was measured in accordance with ASTM-C 704 "Standard Test Method Abrasion Resistance of Refractory Materials at Room Temperature". Specifically, as shown in Figure 3, SiC particles were sprayed together with compressed dry air along the vertical direction from a nozzle 22 arranged above the test piece 20, toward the test piece 20, whose angle of inclination ϕ [°] relative to the vertical direction can be changed, and allowed to impinge

upon the test piece 20. In this way, the abrasion rate [%] of the test piece 20 was calculated. The test conditions were set as follows:

Materials of the test piece 20: two types of SUS-304BA and SUS-316BA

Size of the test piece 20: 100 mm x 100 mm x 2 mm

Spray pressure of compressed dry air: 0.01 MPa to 0.5 MPa

Spray amount of SiC particles: 500 g to 3 kg

Size of SiC particles: 0.3 mm to 0.85 mm

The diameter of the spray nozzle 20: 4.74mm

Direct distance between the spray nozzle 20 and the test piece 20: 203 mm.

Note that, the abrasion rate was calculated in accordance with the expression:

$$(W_0 - W_1)/W_0 \times 100$$

where the weight of the test piece 20 before the test was W_0 [g] and the weight of the test piece 20 after the test as W_1 [g].

[0029] First, the superficial velocity of compressed dry air was set to 55 m/s and the concentration of SiC particles was set to 11.5 g/l. The abrasion rate was measured individually in the cases where the angle of inclination ϕ of the test piece 20 was changed to 15°, 30°, 45°, 60°, 75° and 90°. As a result, the abrasion rates were 0.18%, 0.22%, 0.21%, 0.18%, 0.14% and 0.13%, respectively. Accordingly, as shown in Figure 4, the peak abrasion rate was obtained in the case where the angle of inclination ϕ as set to about 30°. It was confirmed that the abrasion rate decreased as the angle of inclination ϕ decreased from

about 30° and as the angle of inclination ϕ increased from about 30°.

[0030] Next, the concentration of SiC particles was set to 11.5 g/l and the angle of inclination ϕ of the test piece 20 was set to 90°. The abrasion rate was measured individually in the cases where the superficial velocity of compressed dry air was changed to 10 m/s, 15 m/s, 20 m/s, 30 m/s and 55 m/s. As a result, the abrasion rates were 0%, 0%, 0.01%, 0.04% and 0.13%, respectively. Accordingly, as shown in Figure 5, it was confirmed that as the superficial velocity of compressed dry air increased, the abrasion rate increased, and in particular, when the superficial velocity of compressed dry air was larger than 20 m/s, an increase rate of abrasion rate became significant.

[0031] Next, the superficial velocity of compressed dry air was set to 55 m/s and the angle of inclination ϕ of the test piece 20 was set to 90°. The abrasion rate was measured individually in the cases where the concentration of SiC particles was changed to 0 g/l, 7 g/l, 10 g/l, 11.5 g/l, 15 g/l, 20 g/l and 32.5 g/l. As a result, the abrasion rates were 0%, 0.05%, 0.07%, 0.08%, 0.07%, 0.02% and 0.01. Accordingly, as shown in Figure 6, the peak abrasion rate was obtained in the case where the concentration of SiC particles was set to about 12 g/l to 13 g/l. It was confirmed that the abrasion rate decreased as the concentration of SiC particles decreased from about 12 g/l to 13 g/l and as the concentration of SiC particles increased from about 12 g/l to 13 g/l.

[0032] Note that, in the test described above, not an FCC catalyst but SiC particles were used. However, when the same test was performed using an FCC catalyst (the maximum particle size: 0.15 mm), it was

confirmed that even if an FCC catalyst was used, the similar relationship was shown between the angle of inclination and abrasion rate and between superficial velocity and abrasion rate.

[0033] Specifically, first, the superficial velocity of compressed dry air was set to 55 m/s and the concentration of the FCC catalyst was set to 6 g/L. The abrasion rate was measured individually in the cases where the angle of inclination ϕ of the test piece 20 was changed to 0°, 15°, 30°, 45° and 90°. As a result, the abrasion rates were 0%, 0.015%, 0.018%, 0.01% and 0%, respectively. Accordingly, as shown in Figure 7, the peak abrasion rate was obtained in the case where the angle of inclination ϕ was set to about 30°. It was confirmed that as the abrasion rate decreased as the angle of inclination ϕ decreased from about 30° and as the angle of inclination ϕ increased from about 30°.

[0034] Next, the concentration of the FCC catalyst was set to 6 g/L and the angle of inclination ϕ of the test piece 20 was set to 90°. The abrasion rate was measured individually in the cases where the superficial velocity of compressed dry air was changed to 0 m/s, 10 m/s, 15 m/s and 25 m/s. As a result, the abrasion rates were 0%, 0.002%, 0.005% and 0.018%, respectively. Accordingly, as shown in Figure 8, it was confirmed that as the superficial velocity of compressed dry air increased, the abrasion rate increases, and in particular, when the superficial velocity of compressed dry air was larger than 20 m/s, an increase rate of abrasion rate became significant.

[0035] Accordingly, in consideration that the SiC particles are harder than the FCC catalyst, if the superficial velocity of gas is set to 5 m/s or more and 20 m/s or less, the angle θ is set to 45° or more and 90° or less,

and the concentration of the FCC catalyst is set to 5 g/L or more and 10 g/L or less, or 15 g/L or more and 20 g/L or less, based on the aforementioned test results, it is possible to reduce the abrasion at the curved portion 18 of the transport pipe 16, even if the FCC catalyst is used.

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CLAIMS

1. A method for transporting a fluid catalytic cracking catalyst comprising a step of transporting the fluid catalytic cracking catalyst with the help of gas by flowing the gas into a transport pipe having a curved portion, wherein the transport pipe is formed of a metal material, the curved portion is constituted of a first portion in the form of a linear pipe and a second portion in the form of a linear pipe communicating with the first portion, in the transport step, the superficial velocity of the gas is set to 5 m/s or more and 20 m/s or less, the angle of a flow direction of the gas flowing in the second portion with respect to a flow direction of the gas flowing in the first portion is set to 45° or more and 90° or less, and the content of the fluid catalytic cracking catalyst in the gas is set to 5 g/l or more and 10 g/l or less, or 15 g/l or more and 20 g/l or less.
2. A magnetic separation apparatus to selectively separate a fluid catalytic cracking catalyst reduced in activity and selectivity, including a fluid catalytic cracking catalyst transport pipe for transporting a fluid catalytic cracking catalyst under a flow of a gas into and out of the magnetic separation apparatus, the pipe being connected to the apparatus and formed of a metal material and having a curved portion is constituted of a first linear pipe portion and a second linear pipe portion communicating with the first portion; and a gas supply connected to the transport pipe; wherein the angle of a flow direction of the gas when flowing in the second linear pipe portion with respect to a flow direction of the gas when

flowing in the first linear pipe portion is set to 45° or more and 90° or less, and wherein in use, the content of the fluid catalytic cracking catalyst in the gas is set to 5g/l or more and 10g/l or less, or 15g/l or more and 20g/l or less and the superficial velocity of the gas is set to 5m/s or more and 20m/s or less.