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CATALYST FOR HYDROTREATING HYDROCARBON FEEDS IN A FIXED BED REACTOR

The present invention relates to a catalyst for hydrorefining and/or hydroconverting hydrocarbon feeds (also known as hydrotreatment), the catalyst comprising an essentially alumina-based support in the form of extrudates, optionally at least one catalytic metal or a compound of a catalytic metal from group VIB (group 6 in the new periodic table notation), preferably molybdenum or tungsten, more preferably molybdenum, and/or optionally at least one catalytic metal or a compound of a catalytic metal from group VIII (groups 8, 9 and 10 in the new periodic table notation), preferably iron, nickel or cobalt.

The present invention also relates to methods for preparing the catalyst, also to its use for hydrorefining and hydroconverting hydrocarbon feeds such as petroleum cuts, cuts originating from coal, or hydrocarbons produced from natural gas.

Hydrotreatment of hydrocarbon feeds, such as sulphur-containing petroleum cuts, is becoming more and more important in refining with the increasing need to reduce the quantity of sulphur in petroleum cuts and to convert heavy fractions into lighter fractions which can be upgraded as a fuel. Both to satisfy the specifications imposed in every country for commercial fuels and for economical reasons, imported crudes which are becoming richer and richer in heavy fractions and in heteroatoms and more and more depleted in hydrogen must be upgraded to the best possible extent. This upgrading implies a relatively large reduction in the average molecular weight of heavy constituents, which can be obtained, for example, by cracking or hydrocracking the pre-refined feeds, i.e., desulphurized and denitrogenated feeds. Van Kessel et al explained this subject in detail in an article published in the review "Oil & Gas Journal", 16th February 1987, pages 55 to 66.

The skilled person is aware that during hydrotreatment of petroleum fractions containing organometallic complexes, the majority of those complexes

are destroyed in the presence of hydrogen, hydrogen sulphide, and a hydrotreatment catalyst. The constituent metal of such complexes then precipitates out in the form of a solid sulphide which then becomes fixed on the internal surface of the pores. This is particularly the case for vanadium, nickel, iron, sodium, titanium, silicon, and copper complexes which are naturally present to a greater or lesser extent in crude oils depending on the origin of the crude and which, during distillation, tend to concentrate in the high boiling point fractions and in particular in the residues. This is also the case for liquefied coal products which also comprise metals, in particular iron and titanium. The general term hydrodemetallization (HDM) is used to designate those organometallic complex destruction reactions in hydrocarbons.

The accumulation of solid deposits in the catalyst pores can continue until a portion of the pores controlling access of reactants to a fraction of the interconnected pore network is completely blocked so that that fraction becomes inactive even if the pores of that fraction are only slightly blocked or even intact. That phenomenon can cause premature and very severe catalyst deactivation. It is particularly sensitive in hydrodemetallization reactions carried out in the present of a supported heterogeneous catalyst. The term "heterogeneous" means not soluble in the hydrocarbon feed. In that case, it has been shown that pores at the grain periphery are blocked more quickly than central pores. Similarly, the pore mouths block up more quickly than their other portions. Pore blocking is accompanied by a gradual reduction in their diameter which increasingly limits molecule diffusion and increases the concentration gradient, thus accentuating the heterogeneity of the deposit from the periphery to the interior of the porous particles to the point that the pores opening to the outside are very rapidly blocked: access to the practically intact internal pores of the particles is thus denied to the reactants and the catalyst is prematurely deactivated.

The phenomenon described above is known as pore mouth plugging. Proof of its existence and an analysis of its causes have been published a number of times in the international scientific literature, for example: "Catalyst deactivation through pore mouth plugging" presented at the 5th International Chemical Engineering Symposium at Houston, Texas, U. S. A., March 1978, or "Effects of feed metals on catalyst ageing in hydroprocessing residuum" in Industrial Engineering Chemistry Process Design and Development, volume 20, pages 262 to 273 published in 1981 by the American Chemical Society, or more recently in "Effect of catalyst pore structure on hydrotreating of heavy oil" presented at the National conference of the American Chemical Society at Las Vegas, U. S. A., 30th March 1982.

A catalyst for hydrotreatment of heavy hydrocarbon cuts containing metals must thus be composed of a catalytic support with a porosity profile which is particularly suitable for the specific diffusional constraints of hydrotreatment, in particular hydrodemetallization.

The catalysts usually used for hydrotreatment processes are composed of a support on which metal oxides such as cobalt, nickel or molybdenum oxides are deposited. The catalyst is then sulphurated to transformed all or part of the metal oxides into metal sulphide phases. The support is generally alumina-based, its role consisting of dispersing the active phase and providing a texture which can capture metal impurities, while avoiding the blocking problems mentioned above.

Catalysts with a particular pore distribution have been described in United States patent US-A-4 395 329. There are two types of prior art alumina-based supports. Firstly, alumina extrudates prepared from an alumina gel. Hydrotreatment catalysts prepared from such extrudates have a number of disadvantages. Firstly, the process for preparing the alumina gel is particularly polluting, in contrast to that of alumina originating from rapid dehydration of

hydrargillite, known as flash alumina. The pores of alumina gel based supports are particularly suitable for hydrodesulphuration and hydrotreatment of light hydrocarbons, and not for other types of hydrotreatment. Further, even though such extrudates are balanced in their hydrodemetallization/hydrodesulphuration ratio, their hydrometallization retention capacity is low, in general at most 30% by weight, so they are rapidly saturated and have to be replaced. Further, considering the high production cost of the alumina gel, the manufacture of such catalysts is very expensive.

Secondly, alumina beads prepared by rapid dehydration of hydrargillite then agglomerating the flash alumina powder obtained are used as a support for catalysts for hydrotreatment of hydrocarbon feeds containing metals. The cost of preparing these beads is lower, however, in order to maintain it at a satisfactory level, beads with a diameter of more than 2 mm have to be prepared. As a result, the metals cannot be introduced right into the core of the beads, and the catalytic phase located there is not used.

Hydrotreatment catalysts prepared from flash alumina extrudates which are smaller and which have a porosity which is suitable for hydrotreatment would not have all of those disadvantages, but there is currently no industrial process for preparing such catalysts.

The present invention concerns a catalyst for hydrotreating carbon-containing fractions, processes for preparing that catalyst, and its use in hydrotreatment reactions, in particular hydrogenation, hydrodenitrogenation, hydrodeoxygenation, hydrodearomatization, hydroisomerisation, hydrodealkylation, hydrodewaxing, hydrocracking, and hydrodesulphuration with a hydrodemetallization activity which is at least equivalent to that of catalysts currently known to the skilled person, to obtain particularly high hydrotreatment results with respect to prior art products.

The catalyst of the invention comprises an essentially alumina-based support in the form of extrudates, optionally at least one catalytic metal or a compound of a catalytic metal from group VIB (group 6 in the new periodic table notation), preferably molybdenum or tungsten, more preferably molybdenum, and/or optionally, at least one catalytic metal or a compound of a catalytic metal from group VIII (groups 8, 9 and 10 in the new periodic table notation), preferably iron, nickel or cobalt, more preferably nickel.

The extruded support used in the catalyst of the invention is generally and preferably essentially based on alumina agglomerates, the alumina agglomerates generally and preferably being obtained by forming a starting alumina originating from rapid dehydration of hydrargillite, and generally having a total pore volume of at least 0.6 cm^3/g, an average mesoporous diameter in the range 15 to 36 nm (manometers), and generally a quantity of alumina originating from boehmite decomposition in the range 5% to 70% by weight. The term "alumina originating from boehmite decomposition" means that during the extrudate preparation process, boehmite type alumina is produced to the point of representing 5% to 70% by weight of the total alumina, then decomposed. This quantity of alumina from boehmite decomposition is measured by X ray diffraction of the alumina before decomposing the boehmite.

The extruded support of the catalyst of the invention can also be obtained by extruding a mixture of varying proportions of an alumina powder from rapid dehydration of hydrargillite (flash alumina) and at least one alumina gel obtained, for example, by precipitating aluminium salts such as aluminium chloride, aluminium sulphate, aluminium nitrate, or aluminium acetate, or by hydrolysis of aluminium alkoxides such as aluminium triethoxide. Such mixtures of flash alumina and alumina gel contain less than 50% by weight of alumina gel, preferably 1% to 45% of alumina gel.

The catalyst of the invention can be prepared using any method which is known to the skilled person, more particularly using the methods described below.

The support is formed by alumina extrudates with a diameter generally in the range 0.5 to 10 mm, preferably 0.8 to 3.2 mm, when the catalyst is used in a fixed bed, the extrudates having the characteristics described above. Any known method can be used for the optional introduction of the catalytic metals, at any stage of the preparation, preferably by impregnation or co-mixing, onto the extrudates or prior to their forming by extrusion, the optional catalytic metals being at least one catalytic metal or a compound of a catalytic metal from group VIB (group 6 in the new periodic table notation), preferably molybdenum or tungsten, more preferably molybdenum, and/or optionally at least one catalytic metal or a compound of a catalytic metal from group VIII (groups 8, 9 and 10 in the new periodic table notation), preferably iron, nickel or cobalt, more preferably nickel. The metals can optionally be mixed with the support by co-mixing at any step of the support preparation process. When there are a plurality, at least part of the group VIB and VIII metals can optionally be introduced separately or simultaneously during impregnation or co-mixing with the support, at any stage of forming or preparation.

As an example, the catalyst of the invention can be prepared using a preparation process comprising the following steps:

a) co-mixing alumina powder originating from rapid dehydration of hydrargillite with at least one compound of a catalytic metal from group VIB and/or at least one compound of a catalytic metal from group VIII, optionally followed by ageing, and/or drying, then optional calcining;

b) forming by extruding the product obtained from step a).

The metals cited above are usually introduced into the catalyst in the form of precursors such as oxides, acids, salts, or organic complexes. The sum S of the

group VIB and VIII metals, expressed as the oxides introduced into the catalysts, is in the range 0 to 50% by weight, preferably 0.5% to 50% by weight, more preferably 0.5% to 40% by weight. It is thus possible to use the support as a catalyst without introducing a catalytic metal into the catalyst.

The preparation then generally comprises ageing and drying, then generally a heat treatment, for example calcining, at a temperature in the range 400°C to 800°C.

The support the use of which is one of the essentially elements of the invention is essentially alumina-based. The support used in the catalyst of the invention is generally and preferably obtained by forming a starting alumina originating from rapid dehydration of hydrargillite, forming preferably being carried out using one of the processes described below.

Processes for preparing the support of the invention are described below for a support constituted by alumina. When the support contains one or more other compounds, the compound or compounds or a precursor of the compound or compounds may be introduced at any stage in the process for preparing the support of the invention. It is also possible to introduce the compound or compounds by impregnating the formed alumina using the compound or compounds or any precursor of the compound or compounds.

A first process for forming a starting alumina originating from rapid dehydration of hydrargillite comprises the following steps:

a_1 starting with an alumina originating from rapid dehydration of hydrargillite;

b_1 rehydrating the starting alumina;

c_1 mixing the rehydrated alumina in the presence of an emulsion of at least one hydrocarbon in water;

d_1 extruding the alumina-based paste obtained from step c_1;

e_1 drying and calcining the extrudates;

f_1 carrying out a hydrothermal acid treatment in a confined atmosphere on the extrudates from step e_1;

g_1 drying and calcining the extrudates from step f_1.

A second process for forming the alumina from a starting alumina originating from rapid dehydration of hydrargillite comprises the following steps:

a_2 starting from a starting alumina originating from rapid dehydration of hydrargillite;

b_2 forming the alumina into beads in the presence of a pore-forming agent;

c_2 ageing the alumina beads obtained;

d_2 mixing the beads from step c_2 to obtain a paste which is extruded;

e_2 drying and calcining the extrudates obtained;

f_2 carrying out a hydrothermal acid treatment in a confined atmosphere on the extrudates obtained from step e_2;

g_2 drying and calcining the extrudates from step f_2.

A third process for forming an alumina from a starting alumina originating from rapid dehydration of hydrargillite comprises the following steps:

a_3 starting from a starting alumina originating from rapid dehydration of hydrargillite;

b_3 rehydrating the starting alumina;

c_3 mixing the rehydrated alumina with a pseudo-boehmite gel, the gel being present in an amount in the range 1% to 30% by weight with respect to the rehydrated alumina and the gel;

d_3 extruding the alumina-based paste obtained from step c_3;

e_3 drying and calcining the extrudates obtained;

f_3 carrying out a hydrothermal acid treatment in a confined atmosphere on the extrudates obtained from step e_3;

g_3 optionally drying then calcining the extrudates from step f_3.

This process uses identical steps to steps a_1, b_1, d_1, e_1, f_1 and g_1 of the first process described above.

However in step c_3, the rehydrated alumina from step b_3 is not mixed with a hydrocarbon emulsion but with a pseudo-boehmite gel in an amount in the range 1% to 30% by weight with respect to the rehydrated alumina and the gel, preferably in the range 5% to 20% by weight.

Such a pseudo-boehmite gel can be obtained by precipitating aluminium salts such as aluminium chloride, aluminium sulphate, aluminium nitrate, or aluminium acetate with a base or by hydrolysis of aluminium alkoxides such as aluminium triethoxide.

Mixing can be carried out using any method known to the skilled person, in particular using a Z blade mixer or a twin screw mixer.

Water can be added to adjust the viscosity of the paste to be extruded.

The alumina extrudates of the invention generally and preferably have a total pore volume (TPV) of at least 0.6 cm^3/g, preferably at least 0.65 cm^3/g.

The TPV is measured as follows: the grain density and absolute density are determined: the grain densities (Dg) and absolute densities (Da) are measured using a mercury and helium picnometry method respectively, then the TPV is given by the formula:

$$TPV = \frac{1}{D_g} - \frac{1}{D_a}$$

The average mesoporous diameter of the extrudates of the invention is also generally and preferably in the range 150 to 360 Å (Angström). The average mesoporous diameter for the given extrudates is measured using a graph of the

pore distribution of said extrudates. It is the diameter for which the associated volume Von the graph is:

$$V = V_{100nm} + \frac{V_{6nm} - V_{100nm}}{2}$$

where V_{100nm} represents the volume created by pores with a diameter of over 100 nm (macropores), or the macroporous volume;

V_{6nm} represents the volume created by pores with a diameter of over 6 nm;

$V_{6nm} - V_{100nm}$ represents the mesoporous volume, i.e., the volume created by pores with a diameter in the range 6 nm and 100 nm, i.e., the volume created by all the pores with a size in the range 6 nm to 100 nm (mesopores).

These volumes are measured using the mercury penetration technique in which the Kelvin law is applied which defines a relationship between the pressure, the diameter of the smallest pore into which the diameter penetrates at that pressure, the wetting angle and the surface tension in the following formula:

$$\varnothing = (4t\cos\theta).10/P$$

where

$\varnothing$ represents the pore diameter (in nm);

t represents the surface tension (48.5 Pa);

θ represents the angle of contact ($\theta = 140°$); and

P represents the pressure (MPa).

The extrudates of the invention preferably have a mesoporous volume ($V_{6nm} - V_{100nm}$) of at least 0.3 cm^3/g, more preferably at least 0.5 cm^3/g.

The extrudates of the invention preferably have a macroporous volume (V_{100nm}) of at most 0.5 cm^3/g. In a variation, the macroporous volume (V_{100nm}) is at most 0.3 cm^3/g, more preferably at most 0.1 cm^3/g and still more preferably at most 0.08 cm^3/g.

These extrudates normally have a microporous volume ($V_{0\text{-}6nm}$) of at most 0.55 cm^3/g, preferably at most 0.2 cm^3/g. The microporous volume represents the volume created by pores with a diameter of less than 6 nm.

Such a pore distribution which minimises the proportion of pores of less than 6 nm and those of more than 100 nm while increasing the proportion of mesopores (with a diameter in the range 6 nm and 100 nm) is particularly adapted to the diffusional constraints of hydrotreating heavy hydrocarbon cuts.

In a preferred variation, the pore distribution over the pore diameter range from 6 nm to 100 nm (mesopores) is extremely narrow at around 15 nm, i.e., in this range the diameter of the majority of pores is in the range 6 nm to 50 nm, preferably in the range 8 nm to 20 nm.

The specific surface area (SSA) of the extrudates of the is generally at least 120 m^2/g, preferably at least 150 m^2/g. This surface area is a BET surface area. The term "BET surface area" means the specific surface area determined by nitrogen adsorption in accordance with the standard ASTM D 3663-78 established using the BRUNAUER-EMMETT-TELLER method described in "The Journal of the American Society" 60, 309 (1938).

Preferably, the diameter of the extrudates of the invention is in the range 0.5 to 10 mm, preferably in the range 0.8 to 3.2 mm, and the length is in the range 1 mm to 20 mm, preferably in the range 1 to 10 mm, in particular when the catalyst is used in a fixed bed.

The average crushing strength (ACS) of these extrudates is generally at least 0.68 daN/mm for 1.6 mm extrudates, preferably at least 1 mm, and the crush strength (CS) is at least 1 MPa.

The method of measuring the average crushing strength (ACS) consists of measuring the type of maximum compression which an extrudate can support

before it fails, when the product is placed between two planes being displaced at a constant speed of 5 cm/min.

Compression is applied perpendicular to one of the extrudate generatrices, and the average crushing strength is expressed as the ratio of the force to the length of the generatrix of the extrudate.

The method used to measure the crush strength (CS) consists of carrying out a certain quantity of extrudates to an increasing pressure over a sieve and recovering the fines resulting from crushing the extrudates. The crush strength corresponds to the force exerted to obtain fines representing 0.5% of the weight of the extrudates under test.

The alumina of the invention is essentially constituted by a plurality of juxtaposed agglomerates, each of these agglomerates generally and preferably being partially in the form of packs of flakes and partially in the form of needles, the needles being uniformly dispersed both around the packs of flakes and between the flakes.

In general, the length and breadth of the flakes varies between 1 and 5 μm with a thickness of the order of 10 nm. They can be packed in groups forming a thickness of the order of 0.1 to 0.5 μm, the groups possibly being separated from each other by a thickness of the order of 0.05 to 0.1 μm.

The needle length can be in the range 0.05 to 0.5 μm; their cross section is of the order of 10 to 20 nm. These dimensions are given by measuring the extrudates in electron microscope photographs. The alumina flakes principally comprise χ alumina and η alumina and the needles are γ alumina.

The flake structure is characteristic of the hydrargillite lineage of alumina, which means that before activation by calcining these extrudates have the same structure, the flakes being hydrargillite in nature. On calcining, this alumina in its hydrargillite form is principally transformed into dehydrated χ and η aluminas

In contrast, the needle structure is characteristic of a boehmite lineage, meaning that before activation by calcining, these extrudates have the same structure, this alumina being in the form of boehmite. Calcining transforms this boehmite alumina into dehydrated γ alumina.

The extrudates of the invention are thus obtained by calcining, the extrudates being constituted by hydrargillite alumina-based flakes prior to calcining, the flakes being surrounded at their periphery by boehmite alumina-based needles.

The forming process of the invention is more particularly suitable for a starting alumina originating from rapid dehydration of Bayer hydrate (hydrargillite) which is an industrially available aluminium hydroxide and extremely cheap.

Such an alumina is in particular obtained by rapid dehydration of hydrargillite using a hot gas stream, the temperature of the gas entering the apparatus generally being between about 400°C and 1200°C, the contact time between the alumina and the hot gases generally being in the range from a fraction of a second to 4-5 seconds; such a process for preparing an alumina powder has been described in French patent FR-A1-1 108 011.

The alumina obtained can be used as it is or before undergoing step b_1, it can be treated to eliminate the alkalis present: a Na_2O content of less than 0.5% by weight is preferable.

The starting alumina is preferably re-hydrated during step b_1 so that the boehmite type alumina content is at least 3% by weight, preferably at most 40% by weight.

The various steps of these processes for preparing alumina extrudates are described in more detail in a patent application entitled "Alumina extrudates,

processes for their preparation and their use as catalysts or catalyst supports" by Rhône-Poulenc Chimie.

The catalysts of the invention can thus be used in all processes for hydrorefining and hydroconverting hydrocarbon feeds such as petroleum cuts, cuts originating from coal, extracts from bituminous sands and bituminous schists, or hydrocarbons produced from natural gas, more particularly for hydrogenation, hydrodenitrogenation, hydrodeoxygenation, hydrodearomatisation, hydroisomerisation, hydrodealkylation, hydrodewaxing, dehydrogenation, hydrocracking, hydrodesulphuration and hydrodemetallization of carbon-containing feeds containing aromatic compounds and/or olefinic compounds and/or naphthenic compounds and/or paraffininc compounds, the feeds possibly containing metals and/or nitrogen and/or oxygen and/or sulphur. In particular, by modifying the parameters for preparing the essentially alumina-based support, it is possible to obtain different pore distributions and thus to modify the hydrodesulphuration (HDS) and hydrodemetallization (HDM) proportions.

Hydrorefining and hydroconversion of hydrocarbon feeds (hydrotreatment) can be carried out in a reactor containing the catalyst of the invention in a fixed bed. Such hydrotreatments can be applied, for example, to petroleum fractions such as crude oils with an API degree of less than 20, bituminous sand extracts and bituminous schists, atmospheric residues, vacuum residues, asphalts, deasphalted oils, deasphalted vacuum residues, deasphalted crudes, heavy fuels, atmospheric distillates and vacuum distillates, or other hydrocarbons such as liquefied coal products. In a fixed bed process, the hydrotreatments designed to eliminate impurities such as sulphur, nitrogen or metals, and to reduce the average boiling point of these hydrocarbons are normally carried out at a temperature of about 320°C to about 450°C, preferably about 350°C to 430°C, at a partial pressure of hydrogen of about 3 MPa (megapascals) to about 30 MPa, preferably 5

to 20 MPa, at a space velocity of about 0.1 to about 5 volumes of feed per volume of catalyst per hour, preferably 0.2 to 1 volume per volume of catalyst per hour, the ratio of gaseous hydrogen to the liquid hydrocarbon feed being in the range 200 to 5000 normal cubic metres per cubic metre (Nm^3/m^3), preferably between 500 and 1500 Nm^3/m^3.

The following examples illustrate the invention without limiting its scope.

EXAMPLE 1: Preparation of alumina support A forming part of the composition of catalysts A1 and A2 of the invention

Step a_1 - starting alumina: The starting material was alumina obtained by very rapid decomposition of hydrargillite in a hot air stream (T = 1000°C). The product obtained was constituted by a mixture of transition aluminas: (khi) and (rho) aluminas. The specific surface area of the product was 300 m^2/g and the loss on ignition (LOI) was 5%.

Step b_1 - rehydration: The alumina was rehydrated by taking it into suspension in water at a concentration of 500 g/l at a temperature of 90°C for a period of 48 h in the presence of 0.5% citric acid.

After filtering the suspension, a cake of alumina was recovered which was washed with water then dried at a temperature of 140°C for 24 h.

The alumina obtained was in the form of a powder, its loss on ignition (LOI), measured by calcining at 1000°C, and its amount of alumina in the form of boehmite, measured by X ray diffraction, are shown in Table 1.

Step c_1 - mixing: 10 kg of rehydrated and dried powder was introduced into a 25 l volume Z blade mixer and an emulsion of hydrocarbon in water stabilised by a surfactant, obtained using a stirred reactor, and 69% nitric acid, was gradually added. The characteristics are shown in Table 1.

Mixing was maintained until a consistent homogeneous paste was obtained. After mixing, a 20% ammonia solution was added to neutralise the excess nitric acid, continuing mixing for 3 to 5 min.

Step d_1 - extrusion: The paste obtained was introduced into a single screw extruder to obtain raw extrudates with a diameter of 1.6 mm.

Step e_1 - drying/calcining: The extrudates were then dried at 140°C for 15 h and calcined for 12 h at a temperature of 680°C. The calcined support had a specific surface area of 148 m^2/g.

Step f_1 - hydrothermal treatment: The extrudates obtained are impregnated with a solution of nitric and acetic acid in the following concentrations: 3.5% of nitric acid with respect to the weight of alumina and 6.5% of acetic acid with respect to the weight of alumina. They then underwent hydrothermal treatment in a rotating basket autoclave under the conditions defined in Table 1.

Step g_1 - drying/calcining: At the end of this treatment, the extrudates were calcined at a temperature of 550°C for 2 h. The amount of boehmite shown in Table 1 was measured for the extrudates prior to final calcining.

The characteristics of the extruded alumina support A obtained are shown in Table 1.

EXAMPLE 2: Preparation of catalyst A1 (in accordance with the invention)

We dry impregnated the extruded support A of Example 1 with an aqueous solution containing molybdenum and nickel salts. The molybdenum salt was ammonium heptamolybdate $Mo_7O_{24}(NH_4)_6.4H_2O$ and the nickel salt was nickel nitrate $Ni(NO_3)_2.6H_2O$.

After ageing at room temperature in a water-saturated atmosphere, the impregnated extrudates were dried overnight at 120°C then calcined at 550°C for 2 hours in air. The final molybdenum trioxide content was 6.5% by weight and that of nickel oxide NiO was 1.4% by weight.

EXAMPLE 3: Preparation of catalyst A2 (in accordance with the invention)

We dry impregnated the extruded support A of Example 1 with an aqueous solution containing nickel salts (nickel nitrate $Ni(NO_3)_2.6H_2O$).

After ageing at room temperature in a water-saturated atmosphere, the impregnated extrudates were dried overnight at 120°C then calcined at 550°C for 2 hours in air. The final nickel oxide NiO content was 5% by weight.

EXAMPLE 4: Preparation of alumina support B forming part of the composition of catalyst B of the invention.

The same steps of Example 1 were used except that mixing step c_1 was carried out as follows.

Step c_1 - mixing: This was a continuous process carried out in a co-rotating twin screw mixer.

Upstream of the mixer, the rehydrated and dried alumina was introduced at a rate of 90 kg/h. An emulsion of petroleum in water was prepared in a stirred reactor, by introducing:

- 5.46 kg of water;
- 10.04 kg of 69% nitric acid;
- 10.4 kg of petroleum;
- 1.56 kg of Soprophor SC138.

This emulsion was introduced into the primer of the twin screw machine at a rate of 27.46 kg/h immediately following introduction of the alumina powder. After machining, a 28% ammonia solution was introduced at a rate of 4.34 kg/h. The passage time for the powder in the machine was of the order of 50 to 60 s. A homogeneous paste which could be extruded was obtained from the machine outlet.

The boehmite content was measured for the extrudates prior to final calcining.

The extruded alumina support B obtained had the characteristics shown in Table 1.

TABLE 1

	Alumina A	Alumina B
Rehydrated alumina -end of step b1		
% boehmite	24	33
LOI (1000°C)	25	23
Mixing - step c1		
Hydrocarbon type	petroleum	petroleum
%HNO3/Al2O3*	10	10
% hydrocarbon/Al2O3*	15	15
water/hydrocarbon	3.7	2.6
Surfactant type	Galoryl EM 10	Soprophor SC138
% surfactant/hydrocarbon	17	15
Time (h)	2.15	
% neutralisation with respect to HNO3, equivalents	65	65
Drying/calcining - step e1		
Calcining temperature (°C)	680	600
Specific surface area (m^2/g)	148	177
Hydrothermal treatment - step f1		
Temperature (°C)	212	202
Pressure (bar)	19	16
Time (h)	2	2
% boehmite	40	43
Characteristics of calcined extrudates obtained		
TPV (cm^3/g)	0.80	0.66
V_{6nm}-V_{100nm} (cm^3/g)	0.60	0.66
V_{100nm} (cm^3/g)	0.19	< 0.02
av. mesopore diameter (nm)	28	24.5
$V_{0\text{-}6nm}$ (cm^3/g)	0.02	0.01
Specific surface area (m^2/g)	140	152
ACS (daN/mm)	1.2	1.1
CS (MPa)	1.58	1.58

EXAMPLE 5: Preparation of catalyst B (in accordance with the invention)

We dry impregnated the extruded support of Example 4 with an aqueous solution containing molybdenum and nickel salts. The molybdenum salt was

ammonium heptamolybdate $Mo_7O_{24}(NH_4)_6.4H_2O$ and the nickel salt was nickel nitrate $Ni(NO_3)_2.6H_2O$.

After ageing at room temperature in a water-saturated atmosphere, the impregnated extrudates were dried overnight at 120°C then calcined at 550°C for 2 hours in air. The final molybdenum trioxide content was 12.5% by weight and that of nickel oxide NiO was 3.0% by weight.

EXAMPLE 6: Preparation of alumina support C forming part of the composition of catalysts C1 and C2 of the invention.

Step a_2 - starting alumina: The sulphide of Example 1 was used.

Step b_2 - bead formation: The alumina was mixed with wood dust as a pore-forming agent (20% by weight with respect to the alumina), then formed in a rotating bowl granulator. Water was added to aid forming. The diameter of the alumina beads obtained was in the range 1.5 to 4 mm.

Step c_2 - ageing of beads: These beads were aged by passing steam, the bead temperature being 90°C for 20 h. The loss on ignition of the beads obtained was 47.5% and they contained 25% by weight of boehmite.

Step d_2 - mixing/extrusion: The mixing process used was a continuous process carried out in a corotating twin screw mixer.

Upstream of the mixer, alumina beads were introduced at a rate of 90 kg/h. A solution of 2.42% nitric acid was introduced into the primer immediately following introduction of the aged beads at a rate of 10.9 kg/h.

At the end of the machine, a 2.1% ammonia solution was introduced at a rate of 4.2%. The passage time in the machine was of the order of 50 to 60 s.

A homogeneous alumina powder which could be extruded was obtained from the mixer outlet.

The paste obtained was extruded through a die with 1.6 mm diameter orifices.

Step e_2 - drying/calcining: The extrudates were then dried at 140°C for 2 h and calcined for 2 h at the calcining temperature shown in Table 3. The specific surface area of the calcined extrudates was between 120 and 200 m^2/g.

Step f_2 - hydrothermal treatment: The extrudates obtained were impregnated with a solution of nitric and acetic acid in the following concentrations: 3.5% of nitric acid with respect to the weight of alumina and 6.5% of acetic acid with respect to the weight of alumina. They then underwent hydrothermal treatment in a rotating basket autoclave under the conditions defined in Table 2.

Step g_2 - drying/calcining: At the end of this treatment, the extrudates were calcined at a temperature of 550°C for 2 h.

The amount of boehmite was measured for the extrudates prior to final calcining.

The characteristics of the extruded alumina support C obtained are shown in Table 2.

	Alumina C
Drying/calcining - step e2	
Calcining temperature (°C)	700
Specific surface area (m^2/g)	140
Hydrothermal treatment - step f2	
Temperature (°C)	204
Pressure (bar)	16
Time (h)	2
% boehmite	30
Characteristics of calcined extrudates obtained	
TPV (cm^3/g)	0.81
V_{6nm}-V_{100nm} (cm^3/g)	0.66
V_{100nm} (cm^3/g)	0.15
av. mesopore diameter (nm)	25
$V_{0\text{-}6nm}$ (cm^3/g)	0
Specific surface area (m^2/g)	141
ACS (daN/mm)	0.90
CS (MPa)	1.24

EXAMPLE 7: Preparation of catalyst C1 (in accordance with the invention)

We dry impregnated the extruded support of Example 6 with an aqueous solution containing molybdenum and nickel salts. The molybdenum salt was ammonium heptamolybdate $Mo_7O_{24}(NH_4)_6.4H_2O$ and the nickel salt was nickel nitrate $Ni(NO_3)_2.6H_2O$.

After ageing at room temperature in a water-saturated atmosphere, the impregnated extrudates were dried overnight at 120°C then calcined at 550°C for 2 hours in air. The final molybdenum trioxide content was 11.8% by weight and that of nickel oxide NiO was 2.5% by weight.

EXAMPLE 8: Preparation of catalyst C2 (in accordance with the invention)

We dry impregnated the extruded support of Example 6 with an aqueous solution containing molybdenum salts (ammonium heptamolybdate $Mo_7O_{24}(NH_4)_6.4H_2O$).

After ageing at room temperature in a water-saturated atmosphere, the impregnated extrudates were dried overnight at 120°C then calcined at 550°C for 2 hours in air. The final molybdenum trioxide content was 12.2% by weight.

EXAMPLE 9: Preparation of support D (comparative)

Alumina beads were prepared from the starting alumina of Example 1. The alumina was ground with a ball mill to obtain a powder with an average particle diameter of 7 μm.

This alumina was mixed with wood dust as a pore-forming agent (15% wood) then formed in a bowl granulator. Water was added to aid forming.

The beads obtained were dried and calcined, then aged by passing steam at 100°C for 24 hours.

These beads were immersed in a 50 g/l acetic acid solution for about 5 hours.

They were then removed from the solution, drained then introduced into an autoclave for about 2 hours, at a temperature of 210°C at a pressure of 20.5 bars.

After leaving the autoclave, the beads were dried for 4 hours at 100°C then calcined for 2 hours at 650°C.

Beads with a granulometry in the range 1.2 to 2.8 mm were selected.

EXAMPLE 10: Preparation of catalyst D (comparative)

Support D from Example 9 in the form of beads was dry impregnated with an aqueous solution containing molybdenum and nickel salts. The molybdenum salt was ammonium heptamolybdate $Mo_7O_{24}(NH_4)_6.4H_2O$ and the nickel salt was nickel nitrate $Ni(NO_3)_2.6H_2O$.

After ageing at room temperature in a water-saturated atmosphere, the impregnated extrudates were dried overnight at 120°C then calcined at 550°C for 2 hours in air. The final molybdenum trioxide content was 11.0% by weight and that of nickel oxide NiO was 2.6% by weight. The characteristics of the catalyst beads D obtained are shown in Table 3.

	Catalyst D
Characteristics of beads	
TPV (cm^3/g)	0.97
V_{6nm}-V_{100nm} (cm^3/g)	0.66
V_{100nm} (cm^3/g)	0.31
av. mesopore diameter (nm)	25
V_{0-6nm} (cm^3/g)	0
Specific surface area (m^2/g)	119
CS (MPa)	1.48

EXAMPLE 11: Hydroconversion tests using catalysts A1, A2, B, C1, C2, D for petroleum residues

Catalysts A1, A2, B, C1, C2 and D described above were compared in a hydrotreatment test for different petroleum residues. They were an atmospheric residue (AR) of Middle Eastern origin (Arabian Light) and an atmospheric residue from an extra heavy Venezuelan crude (Boscan). These two residues were

characterized by high viscosities, high Conradson carbon numbers and high asphaltene contents. The Boscan AR also contained very high amounts of nickel and vanadium.

The characteristics of these residues are shown in the following table:

		Arabian Light AR S4658	Boscan AR S3345
Density 15/4		0.959	1.023
Viscosity at 100°C	mm^2/s	25.6	1380
Viscosity at 150°C	mm^2/s	7.66	120
Sulphur	% by wt	3.34	5.5
Nitrogen	ppm	2075	5800
Nickel	ppm	9	125
Vanadium	ppm	35	1290
Iron	ppm	1	8
Carbon	% by wt	84.7	83.40
Hydrogen	% by wt	11.2	10.02
Aromatic carbon	%	26	29.0
Molecular weight	g/mol	460	730
Conradson carbon	% by wt	9.5	16.9
Asphaltenes C5	% by wt	5.6	24.1
Asphaltenes C7	% by wt	3.1	14.9
SARA	% by wt		
Saturates	% by wt	30.7	8.7
Aromatics	% by wt	47.5	35.0
Resins	% by wt	17.6	34.0
Asphaltenes	% by wt	3.0	14.6
Simulated distillation			
IP	°C	229	224
5%	°C	325	335
10%	°C	358	402
20%	°C	404	474
30%	°C	436	523
40%	°C	468	566
50%	°C	503	
60%	°C	543	
70%	°C	590	
80%	°C	642	

The tests were carried out in a pilot hydrotreatment plant for petroleum residues comprising a fixed bed tube reactor. The reactor was filled with one litre of catalyst. The fluid flow (petroleum residue + hydrogen recycle) was an upflow in the reactor. This type of pilot unit represents the operation of an IFP HYVAHL unit reactor for fixed bed hydroconversion of residues.

After a sulphuration step by circulating a gas oil cut with added DMDS at a final temperature of 350°C in the reactor, the unit was operated with the petroleum residues described above under the following operating conditions:

Total pressure	15 MPa
Temperature	380°C
Hourly space velocity of residue	0.5 h^{-1}
Hydrogen recycle	1000 std l. H_2/l. feed
Cycle start temperature	370°C

Arabian light AR was injected first. After a 250 hour stabilisation period, the hydrodesulphuration (HDS) and hydrodemetallization (HDM) performances were as follows:

Catalyst	HDS (% wt)	HDM (% wt)
Catalyst A1	66	78
Catalyst A2	58	72
Catalyst B	68	75
Catalyst C1	65	77
Catalyst C2	61	75
Catalyst D	60	75

The HDS ratio is defined as follows:

HDS (wt %) = ((wt % S)feed - (wt % S)test)/(wt % S)feed * 100

The HDM ratio is defined as follows:

HDM (wt %) = ((ppm wt Ni+V)feed - (ppm wt Ni+V)test)/ (ppm wt Ni+V)feed * 100

The feed was then changed by moving to the Boscan atmospheric residue. The test conditions aimed to maintain the HDM ratio constant at about 80% by weight throughout the cycle. To this end, catalyst deactivation was compensated for by a gradual increase in the reaction temperature. The test was stopped when the reaction temperature reached 420°C, a temperature considered to be representative of the temperature at the end of a cycle in an industrial residue hydroconversion unit.

The following table compares the quantities of nickel + vanadium from the Boscan AR deposited on the 6 catalysts and the HDS level at the middle of the cycle

Catalyst	Ni+V deposited (% of weight of fresh catalyst)	Mid cycle HDS (wt %)
Catalyst A1	80	52
Catalyst A2	82	50
Catalyst B	35	58
Catalyst C1	82	54
Catalyst C2	85	52
Catalyst D	80	50

It thus appears that the HDM catalysts in the form of extrudates of the present invention can lead to HDS performances which are higher than those of catalyst D (comparative example) while achieving identical performances both for HDS and for retention of nickel + vanadium metals. Higher HDS performances were observed both for the Arabian Light and the Boscan atmospheric residue. Adjusting the alumina preparation parameters enables different pore distributions to be obtained and thus enables the HDS and HDM ratios to be modified.

CLAIMS

1. A catalyst comprising an essentially alumina-based extruded support, essentially constituted by a plurality of juxtaposed agglomerates, optionally at least one catalytic metal or a compound of a catalytic metal from group VIB (group 6 of the new periodic table notation) and/or optionally, at least one catalytic metal or a compound of a catalytic metal from group VIII (group 8 of the new periodic table notation), in which the sum S of the group VIB and VIII metals, expressed as the oxides, is in the range 0% to 50% by weight, and characterized in that each of these agglomerates is partly in the form of packs of flakes and partly in the form of needles, said needles being uniformly dispersed both about the packs of flakes and between the flakes.
2. A catalyst according to claim 1, containing no metals (S = 0% by weight).
3. A catalyst according to claim 1, in which the sum S is in the range 0.5% to 50% by weight.
4. A catalyst according to any one of claims 1 to 3, in which the alumina agglomerates are obtained by forming a starting alumina originating from rapid dehydration of hydrargillite, and in which the amount of alumina from boehmite decomposition is in the range 5% to 70% by weight.
5. A catalyst according to any one of claims 1 to 4, in which the total pore volume is at least 0.6 cm^3/g, and the average diameter of the mesopores is in the range 15 to 36 nm.
6. A catalyst according to any one of claims 1 to 5, in which the mesoporous volume $V_{6nm} - V_{100nm}$ is at least 0.3 cm^3/g, the macroporous volume V_{100nm} is at most 0.5 cm^3/g and the microporous volume V_{0-6nm} is at most 0.55 cm^3/g.

7. A catalyst according to any one of claims 1 and 3 to 6, in which the catalytic metal or the compound of a catalytic metal from group VIB is molybdenum or tungsten, and the catalytic metal or the compound of a catalytic metal from group VIII is iron, nickel or cobalt.

8. A catalyst according to any one of claims 1 and 3 to 7, in which the catalytic metal or the compound of a catalytic metal from group VIB is molybdenum, and the catalytic metal or the compound of a catalytic metal from group VIII is nickel.

9. A catalyst according to any one of claims 1 to 8, in which the diameter of the alumina extrudates is in the range 0.5 to 10 mm.

10. A process for preparing a catalyst according to any one of claims 1 to 9, characterized in that it comprises the following steps:

a) forming an essentially alumina-based support to obtain extrudates;

b) impregnating the extrudates with a solution comprising at least one compound of a group VIB catalytic metal, optionally followed by ageing, and/or drying, then followed by calcining;

c) impregnating the extrudates with a solution comprising at least one compound of a group VIII catalytic metal, optionally followed by ageing and/or drying, then followed by calcining.

11. A process for preparing a catalyst according to any one of claims 1 to 9, characterized in that it comprises the following steps:

a) forming an essentially alumina-based support to obtain extrudates;

b) impregnating the extrudates with a solution comprising at least one compound of a group VIB catalytic metal, and at least one compound of a group VIII catalytic metal, optionally followed by ageing and/or drying, then optional calcining.

* C L M S *

12. A process for preparing a catalyst according to any one of claims 1 to 9, characterized in that it comprises the following steps:

a) co-mixing the alumina powder originating from rapid dehydration of hydrargillite with at least one compound of a group VIB catalytic metal, and/or at least one compound of a group VIII catalytic metal, optionally followed by ageing and/or drying, then optional calcining;

b) forming by extruding the product obtained from step a).

13. A process for preparing a catalyst according to any one of claims 10 to 12, characterized in that the process for forming the starting alumina comprises the following steps:

a_1 starting with an alumina originating from rapid dehydration of hydrargillite;

b_1 rehydrating the starting alumina;

c_1 mixing the rehydrated alumina in the presence of an emulsion of at least one hydrocarbon in water;

d_1 extruding the alumina-based paste obtained from step c_1;

e_1 drying and calcining the extrudates;

f_1 carrying out a hydrothermal acid treatment in a confined atmosphere on the extrudates from step e_1;

g_1 drying and calcining the extrudates from step f_1.

14. A process for preparing a catalyst according to any one of claims 10 to 12, characterized in that the process for forming the starting alumina comprises the following steps:

a_2 starting from a starting alumina originating from rapid dehydration of hydrargillite;

b_2 forming the alumina into beads in the presence of a pore-forming agent;

c_2 ageing the alumina beads obtained;

d_2 mixing the beads from step c_2 to obtain a paste which is extruded;

e_2 drying and calcining the extrudates obtained;

f_2 carrying out a hydrothermal acid treatment in a confined atmosphere on the extrudates obtained from step e_2;

g_2 drying and calcining the extrudates from step f_2.

15. A process for preparing a catalyst according to any one of claims 10 to 12, characterized in that the process for forming the starting alumina comprises the following steps:

a_3 starting from a starting alumina originating from rapid dehydration of hydrargillite;

b_3 rehydrating the starting alumina;

c_3 mixing the rehydrated alumina with a pseudo-boehmite gel, said gel being present in an amount in the range 1% to 30% by weight with respect to the rehydrated alumina and the gel;

d_3 extruding the alumina-based paste obtained from step c_3;

e_3 drying and calcining the extrudates obtained;

f_3 carrying out a hydrothermal acid treatment in a confined atmosphere on the extrudates obtained from step e_3;

g_3 optionally drying, then calcining the extrudates from step f_3.

16. Use of a catalyst according to any one of claims 1 to 9, or prepared according to any one of claims 10 to 15, in a process for hydrotreating a hydrocarbon feed, in which the catalyst is used in a fixed bed.

17. Use according to claim 16, in which the hydrocarbon feed includes vanadium and/or nickel and/or iron and/or sodium and/or titanium and/or silica and/or copper.

18. Use according to claim 16 or claim 17, in which the hydrocarbon feed includes sulphur and/or nitrogen and/or oxygen.

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19. Use according to any one of claims 16 to 18, in which the hydrotreatment process is carried out at a temperature of 320°C to about 450°C, at a partial pressure of hydrogen of about 3 MPa to about 30 MPa, at a space velocity of about 0.1 to about 5 volumes of feed per volume of catalyst per hour, the ratio of gaseous hydrogen over the liquid hydrocarbon feed being in the range 200 to 5000 normal cubic metres per cubic metre (Nm^3/m^3).