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(54) FILLING A CAVITY OF A THERMAL BREAK PROFILE WITH THERMALLY INSULATING MATERIAL

(57) A method for filling with thermally insulating material a cavity of a thermal break profile is described. The method provides for forming a thermally expandable profile comprising a thermally expandable composition. The composition is suitable for expanding under the pressure exerted by an expansion gas produced within the composition itself at a first temperature T_E. The thermally expandable profile has a cross-section smaller than the cross-section of the cavity to be filled. The thermally expandable profile is inserted inside the cavity and subjected to a heat treatment at a second temperature T_V greater than or equal to T_E. In this way, the expansion gas is produced and exerts a pressure inducing the thermally expandable profile to expand and fill the cavity. Expansion under the action of the expansion gas allows completely filling the whole cavity, even if its cross-section shape is complex.

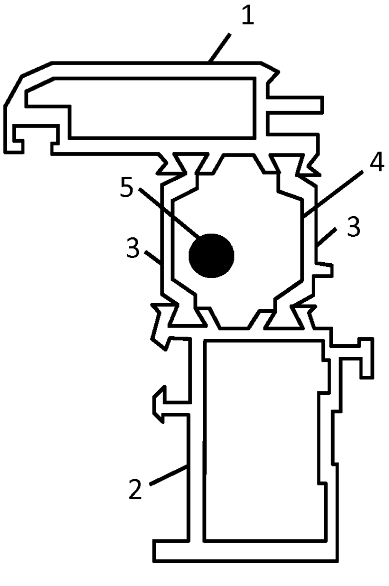

Fig. 1a

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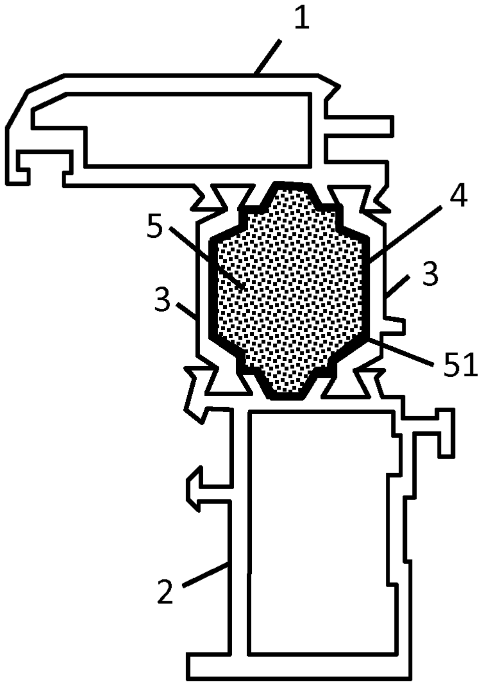

Fig. 1b

Description

Technical field

[0001] The present invention relates to the field of profiles, preferably metal profiles made of aluminium or aluminium alloy, for constructing window and door frames or the like. In particular, the present invention relates to a method for at least partially filling with thermally insulating material a cavity of a thermal break profile.

[0002] Although the present invention will be described with specific reference to door and window frames made of aluminium or aluminium alloy, the present invention is applicable also to door and window frames made of other materials such as wood, resin (optionally containing glass fibre or carbon fillers), PVC or any combination thereof (for example wood and aluminium).

Background art

[0003] Thermal break profiles have been known for many years. A thermal break profile reduces significantly the heat bridge, between inside and outside, of windows, doors or continuous facades. A thermal break profile typically comprises two half-shells and at least one thermally insulating element. Each half-shell essentially is a longitudinally elongated element with rectilinear axis, typically made of aluminium or aluminium alloy. The thermally insulating element is a body which is also longitudinally elongated and made of thermally insulating material, for example a plastic material. The thermally insulating element is typically arranged between the half-shells so as to define a thermal break chamber, which interrupts the transmission of heat due to conduction between outside and inside and provides the profile with a high thermal insulation power.

[0004] In the currently known thermal break profiles, the thermal break chamber is formed by inserting the end of two thermally insulating bars of plastic material (for example NY66, ABS, Noryl™, PET, PBT) inside special seats provided in the two half-shells of the profile. Alternatively, the thermal break chamber is formed by arranging between the two half-shells a thermally insulating element of tubular shape.

[0005] Even higher thermal insulation values are typically obtained by filling the thermal break cavity (and optionally the other cavities of the profile) with a thermally insulating material, generally a low-density material. The thermally insulating material may be in the form of suitably shaped thermally insulating profiles, which are inserted inside the thermal break chamber, or in the form of foams which are injected into the thermal break chamber.

[0006] EP 2 405 092 describes a frame profile comprising a foamed insert, wherein the foam is a shape memory polymer foam. The profile is assembled by inserting the foam, typically in the form of a strip of compressed shape memory foam having cross sectional dimensions smaller than the cross sectional dimensions of the profile inner chamber, in that inner chamber. Subsequently, the profile can be heated up to a temperature above the Tg (glass transition temperature) of the shape memory foam used, such that the foam strip will expand until it takes the shape of the inner chamber.

Summary of the invention

[0007] The Applicant has noted that the known methods for filling the thermal break chamber and/or the other cavities of the profile with a thermally insulating material have a number of drawbacks.

[0008] As regards the insertion of suitably shaped thermally insulating profiles, firstly an operation involving shaping of the thermally insulating material is required, this giving rise to significant costs. Furthermore, insertion inside thermal break chambers which are 6-7 metres long may be difficult and cause breakages of the thermally insulating material which, being low density, is typically not very resistant to mechanical stresses. For the same reason, the maximum length of the thermally insulating profiles which can be obtained is generally less than that of the metal half-shells. In order to fill, therefore, the thermal break chamber over the entire length of the half-shells, it is necessary to use several thermally insulating profiles. Moreover, in order to allow sliding of the thermally insulating profiles inside the thermal break chamber, it is necessary to ensure that there is play around the whole of the perimeter of the thermally insulating profile. This means that it is not possible to fill entirely the thermal break chamber. Besides, the insertion of the shaped thermally insulating profiles is generally performed after the profile has been assembled and painted, this involving additional costs.

[0009] As regards instead the injection of foams, these are methods which are very costly and technically very difficult to implement.

[0010] The technique described by EP 2 405 092 solves only a part of these drawbacks. Indeed, the shaping operation of the shape memory foam shall disadvantageously be still performed, before the shape memory foam is compressed and inserted in the profile. Such shaping operation is costly and, if the cavity to be filled has an articulated shape (e.g. with narrow recesses and/or protrusions), can not guarantee that, after re-expansion, the shape memory foam will be capable of completely filling the whole cavity, including all its recesses and/or protrusions.

[0011] The object of the present invention is to provide a method for at least partially filling with thermally insulating material a cavity of a thermal break profile which solves the aforementioned problems.

[0012] In particular, the Applicant has tackled the problem of providing an alternative and more efficient way of at least partially filling a cavity (for example, but not exclusively, the thermal break chamber) of a thermal break profile with thermally insulating material.

[0013] According to the present invention, the thermal break chamber is initially assembled by inserting in at least one of its cavities to be filled a thermally expandable profile in the form of an elongated element with a substantially rectilinear axis. The thermally expandable profile comprises a thermally expandable composition designed to expand under the pressure exerted by an expansion gas produced within the thermally expandable composition at a certain temperature T_E and has a cross-section with a smaller area than the cross-sectional area of the cavity inside which it is inserted. After assembly (for example during painting), the thermal break profile is subjected to a heat treatment at a temperature $T_V \geq T_E$. During this heat treatment, the expansion gas is produced within the thermally expandable composition and exerts a pressure inducing the thermally expandable composition to expand (namely its volume increases, with a corresponding reduction in its density), being transformed into a solid foam (namely into a thermally insulating material) which at least partially fills the cavity.

[0014] According to the present invention, therefore, the thermally expandable profile is inserted inside the cavity to be filled, while not yet in an expanded condition, and is expanded under the pressure exerted by an expansion gas produced within the thermally expandable composition itself subsequently, for example during painting. This offers various advantages.

[0015] Firstly, since the thermally expandable profile has - when it is not yet expanded - a cross-section with an area smaller than the cross-sectional area of the cavity to be filled, ample play is present between the thermally expandable profile and the inner walls of the cavity to be filled, this making the operation of inserting the thermally expandable profile inside the cavity very easy, without the risk of breakage thereof.

[0016] It is therefore advantageously possible to insert inside the thermal break profile a thermally expandable profile with a length comparable to that of the metal half-shells and plastic thermally insulating elements (6-7 metres or more), such as to fill the cavity along its whole length using only one thermally expandable profile.

[0017] Besides, it is advantageously possible to choose with a certain degree of freedom the shape of the cross-section of the thermally expandable profile, substantially independently of the shape of the cross-section of the cavity to be filled. It is therefore possible to provide a thermally expandable profile with a section which facilitates expansion under the pressure of the expansion gas, for example a circular section.

[0018] Independently of the section shape chosen for the thermally expandable profile before expansion, it is advantageously guaranteed that the cavity is filled even when it has an articulated shape. During the expansion, indeed, the expansion gas under pressure advantageously pushes the thermally expandable composition in every point of the cavity, thereby allowing to fill every possible narrow recess and/or protrusion of the cavity.

[0019] Moreover, the thermally expandable profile may be advantageously used to fill with thermally insulating material not only the thermal break chamber, but also any other cavity present in the thermal break profile, including for example the cavities formed inside each half-shell or inside the thermally insulating element. For example, it is possible to envisage inserting during assembly a thermally expandable profile inside each cavity of the thermal break profile, so as not leave any cavity empty. This allows the thermal insulation to be increased significantly, for the same external dimensions of the thermal break profile.

[0020] According to one aspect of the present invention, it is provided a method for at least partially filling with thermally insulating material a cavity of a thermal break profile, the method comprising:

a) forming a thermally expandable profile comprising a thermally expandable composition suitable for expanding under the pressure exerted by an expansion gas produced within the thermally expandable composition at a first temperature T_E, the thermally expandable profile having a cross-section smaller than the cross-section of the cavity to be at least partially filled;

b) inserting the thermally expandable profile in the cavity to be at least partially filled; and

c) subjecting the thermal break profile to a heat treatment at a second temperature T_V higher than or equal to the first temperature T_E, so that the expansion gas is produced within the thermally expandable composition and exerts a pressure inducing the thermally expandable profile to expand and at least partially fill the cavity.

[0021] Preferably, step a) comprises providing the thermally expandable composition by mixing a base polymer material having a melting temperature T_M lower than or equal to the second temperature T_V and an expanding agent suitable for producing the expansion gas at the first temperature T_E.

[0022] Preferably, the base polymer material is an EVA (ethylene vinyl acetate) copolymer with melt flow index between 17 and 23 and percentage of VA (vinyl acetate) ranging between 19% and 21%.

[0023] Preferably, the expanding agent comprises a plurality of microspheres containing a physical blowing agent suitable for producing the expansion gas by passing from a liquid state to a gaseous state during the heat treatment, the microspheres being impermeable to the physical blowing agent.

[0024] Preferably, the physical blowing agent is a hydrocarbon.

[0025] Preferably, the concentration of the plurality of microspheres in the thermally expandable composition is between 1% and 40% by weight of the thermally expandable composition.

[0026] Preferably, the expanding agent also comprises a chemical blowing agent.

[0027] Preferably, the concentration of the chemical blowing agent in the thermally expandable composition is between 1% and 20 %wt relative to the weight of the microspheres with the physical blowing agent.

[0028] Preferably, the thermally expandable composition further comprises a crosslinking agent suitable for inducing a crosslinking of the base polymer material during the heat treatment.

[0029] Preferably, the base polymer material comprises nanofillers.

[0030] Preferably, step a) comprises providing the thermally expandable profile with a control layer surrounding the thermally expandable composition and suitable for controlling the expansion of the thermally expandable composition during the heat treatment.

[0031] Preferably, the control layer is an adhesive control layer comprising an adhesive polymer material suitable for carrying out its adhesive action at the second temperature T_V.

[0032] Preferably, the adhesive polymer material belongs to the category of hot melts.

[0033] Preferably, step a) comprises forming the thermally expandable profile so that the area Si of the cross-section of the thermally expandable profile is greater than Sf/15, Sf being the area of the cross-section of the cavity to be at least partially filled.

[0034] Preferably, step c) is performed during the painting of the thermal break profile.

Brief description of the drawings

[0035] A detailed description of the invention now follows, being provided purely by way of a non-limiting example, to be read with reference to attached sets of drawings in which:

- Figures 1a and 1b show an exemplary thermal break profile comprising a thermally expandable profile according to an embodiment of the present invention, before and after expansion, respectively;
- Figures 2a and 2b show portions of a thermal break profile comprising respectively two and three thermally expandable profiles for filling the same cavity;
- Figures 3a, 3b, 3c and 3d show four thermally expandable profiles according to a corresponding number of variants of the present invention;
- Figure 4 shows a flow chart of the method for filling with thermally insulating material a cavity of a thermally expandable profile according to two different embodiments of the present invention; and
- Figures 5a and 5b show an exemplary thermal break profile comprising two thermally expandable profiles inside respective cavities according to an embodiment of the present invention, before and after expansion, respectively.

Detailed description of preferred embodiments of the invention

[0036] Figures 1 a and 1b show, merely by way of a example, a thermal break profile with two half-shells 1 and 2 and two thermally insulating elements 3 in the form of bars made of ABS, NY66, Noryl™, PET, PBT or the like. The cross-section of the half-shells 1 and 2 must not in any way be regarded as limiting the present invention. Each of the half-shells 1, 2 has teeth which form seats for the ends of the bars 3. For example, the bars have solid sections. This is not limiting, since the bars 3 could be hollow. Instead of the pair of bars 3, the thermal break profile could comprise a single thermally insulating element with a tubular shape.

[0037] The half-shells 1, 2 and the bars 3 define a thermal break chamber 4 inside which a thermally expandable profile 5 is housed.

[0038] The thermally expandable profile 5 comprises a thermally expandable composition suitable for expanding under the pressure exerted by an expansion gas produced within the thermally expandable composition itself at a temperature T_E. The thermally expandable profile 5 also has a cross-sectional area smaller than the cross-sectional area of the thermal break chamber 4, so that ample play is present around the whole perimeter of the thermally expandable profile 5, this facilitating insertion thereof inside the thermal break chamber 4.

[0039] The thermally expandable profile 5 is inserted inside the chamber 4 when it is not yet expanded, for example during assembly of the thermal break profile (Fig. 1 a).

[0040] After assembly, the thermal break profile is subjected to a heat treatment at a temperature $T_V \geq T_E$. In this way, expansion of the thermally expandable composition of the profile 5 is activated, namely production of the expansion gas within the thermally expandable composition is activated, this continuing until the composition is transformed into a solid foam which at least partially fills the thermal break chamber 4 (Fig. 1 b).

[0041] Preferably, the heat treatment to which the thermal break profile is subjected and which activates expansion of the profile 5 is the painting of the thermal break profile. This generally consists of electrostatic painting with epoxy resins, the thermal break profile being heated to a painting temperature T_V of about 190°C for a period of about 20 minutes.

[0042] Preferably, the thermally expandable composition of the profile 5 is optimized to expand (namely, to start producing the expansion gas) during the course of the operation for painting the thermal break profile.

[0043] Therefore, the thermally expandable composition is firstly chosen so that its expansion temperature T_E is less than or equal to 190°C. In particular, the thermally expandable composition preferably comprises a base polymer material having a melting temperature T_M lower than or equal to the temperature T_V and an expanding agent suitable for activation (namely, to produce the expansion gas) at a temperature T_E lower than or equal to T_V.

[0044] Moreover, the thermally expandable composition is preferably chosen so as to give rise, at the end of the painting operation, to a solid foam with good thermal insulation properties. In particular, the thermally expandable composition is preferably chosen so as to give rise, at the end of the painting operation, to a solid foam with thermal conductivity λ preferably less than 0.05 W/mK, more preferably less than 0.04 W/mK.

[0045] The Applicant has noted that the thermal conductivity λ of a solid foam generally depends both on the thermal conductivity of the thermally expandable composition prior to expansion and on the final density of the solid foam and its morphology at the end of expansion.

[0046] In particular, the thermal conductivity λ increases both with an increase in the thermal conductivity of the thermally expandable composition before expansion and with an increase in the final density of the solid foam. The Applicant has estimated for example that solid foams with thermal conductivity values less than 0.04 W/mK may be obtained by initially using thermally expandable compositions with thermal conductivity values of between 0.2 and 0.35 W/mK and expanding them until solid foams with a density of less than 100 Kg/m^3 are obtained. For example, starting from thermally expandable compositions with thermal conductivity values of between 0.2 and 0.35 W/mK and with a density of between 30 Kg/m^3 and 80 Kg/m^3 it is possible to obtain solid foams with a thermal conductivity λ of between 0.025 W/mK and 0.038 W/mK.

[0047] As regards the morphology, at the end of expansion the solid foam has a plurality of cells. In order to provide a foam with low thermal conductivity, the cells to preferably have small dimensions and are uniform, closed, with thin walls and without coalescence. Preferably, the diameter of the cells at the end of expansion should be between 40 μm and 200 μm, while the thickness of the walls of the cells should be preferably less than 10 μm.

[0048] Preferably, the base polymer material of the thermally expandable composition is an EVA (ethylene vinyl acetate) copolymer, more preferably an EVA copolymer with MFI (Melt Flow Index) of between 17 and 23 and percentage of VA (vinyl acetate) ranging between 19% and 21%.

[0049] This EVA copolymer advantageously has a melting temperature T_M of between 80°C and 100°C, namely lower than the painting temperature Tv.

[0050] It also advantageously allows the formation of thermally expandable compositions having thermal conductivity values of between 0.2 - 0.35 W/mK and able to be converted into solid foams with a density of less than 100 kg/m^3 and optimum morphological characteristics, such as to obtain thermal conductivity values λ less than 0.04 W/mK, as will be described in greater detail hereinbelow.

[0051] The EVA copolymer also advantageously has a good adhesion both to the metal of the half-shells 1 (aluminium) and to the thermally insulating material of the bars 3 (nylon).

[0052] It also does not absorb moisture, is able to incorporate additives of different types, is not toxic and has a low cost.

[0053] The Applicant has for example obtained positive results using the product Evatane® 20-20 manufactured by the company Arkema (based in Nanterre, France) or the product Elvax® 3178 manufactured by the company DuPont (based in Italy at Cernusco sul Naviglio, Milan). These products had the following characteristics:

- VA content: 20% (measured using FTIR technique);
- MFI: 20 g/10’ (measured at 190°C according to the standard ISO1133);
- melting temperature: 80°C (measured in accordance with the standard ISO 11357-3);
- Vicat softening temperature 10N: 46°C (measured in accordance with the standard ISO 306); and
- density: 0.95 g/cc (measured in accordance with the standard ISO 1183).

[0054] As regards the expanding agent, it should be suitable for being activated (namely, to produce the expansion gas) "a posteriori", namely not at the moment when it is incorporated in the composition, but at a later time, in particular in response to subsequent application of heat which heats the composition to the temperature $T_V \geq T_E$.

[0055] The Applicant has noted that known expanding agents of the CBA (Chemical Blowing Agent) type, such as azodicarbonamides, tetrazoles, sulfo hydrazides or bicarbonates, would not per se be able to provide a solid foam having the low densities and, at the same time, the morphological characteristics described above. In particular, the Applicant has noted that the minimum density which can be obtained with an expanding agent of the CBA type would be limited by the maximum concentration of expanding agent which can be included in the thermally expandable composition without altering the physical characteristics thereof.

[0056] The Applicant has also noted that, in order to obtain lower densities, it would be preferable to use expanding agents of the PBA (Physical Blowing Agent) type, such as isopentane, CO2 or hydrofluorocarbons. The PBAs however, per se, are not suitable for expansion at a later time, in particular if the expansion has a prolonged duration (20 minutes) as occurs when it is performed during a painting cycle of the thermal break profile. In this case, in fact, the prolonged expansion time would induce the PBA converted into gaseous form (namely, the expansion gas) to migrate from the composition during expansion, something which would gradually reduce the expansion efficiency and not allow the required low densities to be obtained.

[0057] Besides, the Applicant has also noted that the expansion triggered by a CBA and/or PBA is difficult to control, in that the morphology of the solid foam produced by expansion (in particular the form, the size and the number of cells of the solid foam) is difficult to control. Moreover, as is known the PBAs per se do not allow expansion at a later time to be performed.

[0058] In order to overcome these problems, the thermally expandable composition preferably comprises a PBA encapsulated in special microspheres consisting of polymers impermeable thereto and mixed with the base polymer material of the composition. Preferably, the PBA is a liquid with an evaporation temperature T_E less than T_V. For example, the PBA may be a hydrocarbon (for example pentane or isopentane). The microspheres before expansion preferably have a diameter of between 20 μm and 40 μm. The concentration of the microspheres in the thermally expandable composition is preferably between 1 and 40% by weight of the thermally expandable composition, more preferably between 20 and 40% by weight and even more preferably between 30 and 40% by weight. The Applicant has obtained positive results using the microspheres Expancel 093 DU120 produced by the company Akzo Nobel (based in Sundsvall, Sweden), with a diameter of between 28 μm and 38 μm and expansion temperature T_E of between 120°C and 210°C.

[0059] Under the action of the heat, upon reaching the temperature T_E the base polymer material melts and, at the same time, the expanding agent in the microspheres passes from the liquid state to the gaseous state (production of the expansion gas), causing an increase in volume of the microspheres, which induces an expansion of the composition and therefore a reduction of its density. During expansion, the microspheres advantageously retain inside them the expanding agent in gaseous form (namely, the expansion gas), preventing it from migrating from the composition and keeping it therefore available for expansion for the entire duration of the heat treatment at the temperature T_V. It is thus possible to achieve at the end of expansion densities of less than 100 kg/m^3.

[0060] Moreover, the microspheres advantageously allow the morphology of the solid foam obtained at the end of expansion to be controlled. In particular, the morphology of the solid foam depends on the characteristics of the microspheres (concentration of the microspheres in the thermally expandable composition, their size, the material of their walls, properties of the PBA contained in them, etc.), which may therefore be chosen so as to obtain cells with optimum characteristics from the point of view of thermal insulation (small, uniform cells with thin walls and no coalescence).

[0061] Preferably, in addition to the microspheres with PBA, the thermally expandable composition of the profile 5 also comprises an expanding agent of the CBA (Chemical Blowing Agent) type, such as azodicarbonamides, tetrazoles, sulfo hydrazides or bicarbonates. The concentration of the CBA in the thermally expandable composition is preferably between 1 and 20 %wt relative to the weight of the microspheres with PBA. The Applicant has obtained positive results using for example as CBA an OBSH (4,4'-oxydibenzene sulfonyl hydrazide) with activation temperature T_E ranging between 140°C and 180°C. Once the temperature T_E is reached, the OBSH decomposes and produces further expansion gas (consisting mainly of nitrogen) which induces an expansion of the thermally expandable composition. The Applicant has obtained positive results, using for example as OBSH the product Neocellborn OBSH manufactured by the company Marubeni Europe plc (based in London, UK) or the product Ferrocell OBSH manufactured by the company Ferro-plast S.r.l. (based in Vimodrone, Italy) and as azodicarbonamide the product Ferrocell AZC-800 manufactured by the company Ferro-plast S.r.l. (based in Vimodrone, Italy).

[0062] The combination of microspheres with PBA and CBA in the thermally expandable composition is advantageous since the CBA compensates for any loss of expansion power of the microspheres which may occur owing to breakages of the microspheres during extrusion forming of the thermally expandable profile 5.

[0063] It also allows a solid foam to be obtained with density and morphology comparable to those which can be obtained with only PBAs, these requiring the use of very complex plants.

[0064] In order to improve further the morphological characteristics of the solid foam, the Applicant has noted that it is advantageous to use a number of mechanisms for controlling the expansion, which counteract the thrust or pressure of the expansion gas produced by the expanding agent (PBA in microspheres, and optionally CBA) during expansion.

[0065] According to preferred embodiments, at least one additive suitable for increasing the viscosity of the base polymer composition is included in the thermally expandable composition of the profile 5. Preferably, the additive is a crosslinking agent. Preferably the crosslinking agent is a bifunctional peroxide, for example the peroxide identified by the number CAS 78-63-7. The Applicant has obtained positive results using the product Trigonox® 101 manufactured by the company Akzo Nobel (based in Sundsvall, Sweden).

[0066] The increased viscosity induced by the crosslinking agent advantageously allows the pressure produced by the expansion gas to be controlled. The crosslinking agent in fact causes crosslinking of the base polymer material in the melted state, so as to form a cage-like structure which offers an increased resistance to the expansion gas. Moreover, the crosslinking agent has the effect of making the thermally expandable composition thermosetting so that it cannot be melted again once the heat treatment during which expansion takes place has been terminated.

[0067] As an alternative or in addition to control of the expansion by means of additives, a control layer, preferably an adhesive control layer, may be optionally provided, said layer externally coating the thermally expandable profile 5.

[0068] Preferably, the adhesive control layer comprises an adhesive polymer material. The adhesive polymer material is preferably highly compatible both with the base polymer material of the thermally expandable composition of the profile 5 and with the materials of the walls of the thermal break chamber 4 (namely the aluminium of the half-shells 1 and 2 and the thermally insulating material of the bars 3).

[0069] Preferably, the adhesive polymer material used for this purpose belongs to the category of hot melts, namely is solid and not sticky at room temperature and performs its bonding action only after being heated to the temperature T_V. In this way, the adhesive polymer material may be easily worked at temperatures lower than T_V (for example extruded, the extrusion temperature being typically lower than the painting temperature T_V). Preferably the hot melt used in the adhesive control layer is based on one of the following: EVA, amorphous polyolefins, polyolefins with a certain degree of acidity in the molecule such as copolymers of EA (ethylene acrylates), EBA (ethylene butyl acrylates), EAA (ethyl acetoacetate), ionomer copolymers such as Surlyn® (ethylene methacrylic acid), copolyamides such as Vestamelt®, copolyesters such as Griltex®, or styrene derivatives such as SBS, SEBS, etc., and optional mixtures thereof. These polymers may be modified/functionalized for specific adhesion with acrylic acids (for example hydrocarbon resins), maleic anhydrides, plasticizers, tackifiers (for example hydrocarbon resins), etc., i.e. with reactive end groups suitable for increasing/ensuring their adhesive power.

[0070] The adhesive polymer material of the control layer preferably also comprises an expanding agent, so that the control layer also expands under the pressure of an expansion gas produced within the control layer itself during expansion of the thermally expandable profile. Preferably, the expanding agent of the adhesive polymer layer comprises microspheres with a PBA and/or a CBA as described above. Preferably, the density of expanding agents in the control layer is less then or equal to the 15% by weight of the composition.

[0071] The control layer advantageously ensures physical/mechanical control of the expansion, controlling the thrust or pressure of the expansion gas produced by the microspheres with the PBA and, if present, the CBA.

[0072] Both the thickness of the control layer and the melting temperature of the adhesive polymer material included in it (and therefore its viscosity at the temperature T_V) have an effect on the control of expansion by the adhesive control layer. The greater the thickness and the viscosity, the greater the controlling action of the adhesive control layer on expansion. The Applicant has carried out a number of tests which have shown that a control layer with thickness 0.2 - 0.6 mm is able to control the expansion power of a thermally expandable composition containing up to 40% by weight of expanding agents (microspheres with PBA and optionally CBA).

[0073] The adhesive control layer has various other advantages.

[0074] Firstly, at the end of expansion, the adhesive control layer advantageously seals along its entire perimeter the thermal break chamber 4, as shown in schematic form in Figure 2a, where the adhesive control layer is indicated by the reference number 51. During expansion, indeed, the expansion gas produced within the thermally expandable composition of the thermally expandable profile 5 advantageously pushes the hot melt adhesive control layer 51 against the walls of the thermal break chamber 4 along its whole perimeter. The thermal break chamber 4 is thus completely isolated from the air movements. Therefore, advantageously, in the case where at the end of expansion one or more niches which are not filled with solid foam should remain inside the chamber 4 (something which could occur, for example, if the painting temperature were too high), the air present in these niches would constitute "immobile" air, with a thermal conductivity of 0.027 W/mK, since it is enclosed between surfaces which are impermeable thereto. The presence of any such niches therefore, owing to the sealing effect obtained with the adhesive control layer, advantageously would not result in a reduction in the thermal insulation capacity of the thermal break profile.

[0075] Moreover, the adhesive control layer advantageously allows optimum cohesion to be obtained between solid foam, bars 3 and metal half-shells 1, 2, thus increasing the shear strength of the thermal break profile as a whole. This facilitates assembly of the heat break profile since, for example, it allows the use of thermally insulating bars with a glue-free base (namely the bars 3 are not glued to the half-shells 1, 2), these being less costly and easier to assemble with the half-shells 1, 2.

[0076] As an alternative to the adhesive control layer, the thermally expandable composition itself may be provided with adhesive properties. In this case the same advantages, in terms of sealing of the thermal break chamber 4 and increased shear strength, would be obtained as those obtained with use of the adhesive control layer. The adhesives which can be used in the thermally expandable composition are substantially the same as those described above in connection with the adhesive control layer. It should be noted however that, since they may reduce the efficiency of the crosslinking agent, where adhesive is present it is preferable to increase the concentration of crosslinking agent. In any case, the thermally expandable composition itself, when based on an EVA copolymer, has an adhesive action both on the aluminium of the half-shells 1, 2 and on the nylon of the thermally insulating elements 3 of the thermal break profile.

[0077] Optionally, the thermally expandable composition of the profile 5 and, if present, the control layer may comprise nanofillers. By way of nanofillers, preferably montmorillonites obtained from bentonite and modified with end groups reactive with the base polymer material are used. The reactive end groups of the nanofillers thus bond with the base polymer material so as to form a continuous and homogeneous structure.

[0078] The nanofillers advantageously create a barrier effect preventing migration of the expansion gas from inside the profile 5 towards the outside and the moisture from outside the profile 5 towards the inside.

[0079] In particular, during expansion, the nanofillers advantageously prevent the expansion gas produced by the chemical reactions triggered by the CBA from leaving the composition during the entire expansion cycle. This expansion gas remains therefore available for the expansion mechanism substantially for the entire duration of the heat treatment, this helping achieve the low densities required. Besides, this barrier effect continues also after the end of expansion, thus allowing the expansion gas to be retained for a potentially indefinite period of time inside the solid foam. In the absence of this barrier effect, in fact, the expansion gas produced by the expansion, via a diffusion mechanism, would tend to migrate from the solid foam and be replaced by air. This process would disadvantageously give rise to an increase in the thermal conductivity of the solid foam, because in general air has a thermal conductivity greater than that of the expansion gas. The nanofillers therefore advantageously help preventing this undesirable phenomenon.

[0080] Moreover, the nanofillers also act as a barrier preventing any infiltration of air and moisture from outside of the thermal break profile. The barrier effect of the nanofillers against moisture may also be advantageously increased using hydrophobic polymers for the thermally expandable composition of the profile 5 and, if present, for the control layer. For this purpose, the base polymer material is preferably of the olefin type, for example an EVA copolymer with low percentage of VA or apolar polyolefins.

[0081] The Applicant has estimated that the permeability to the expansion gas and moisture of an adhesive control layer with a thickness of 100 micron may be increased up to 10-fold by adding nanofillers.

[0082] The nanofillers also advantageously improve the mechanical properties of the composition of the profile 5 when expanded, something which may be useful during the operations for cutting the thermal break profile performed using the ordinary tools used for cutting aluminium.

[0083] According to advantageous embodiments, the thermally expandable composition may be chosen so that the solid foam obtained from expansion thereof has a low Shore hardness, preferably less than 90 Shore A. For this purpose, the base polymer material may be an EVA copolymer with a greater percentage of VA so as to obtain a suitable Shore hardness (the greater the percentage of VA in the copolymer, the lower its Shore hardness). Alternatively, it is possible to use additives such as plasticizers or elastomeric modifiers which reduce the Shore hardness of the polymer material. In this way, since the sound absorption of a material is inversely proportional to its elastic modulus, a thermal break profile which also has good sound absorption properties is obtained.

[0084] As regards the dimensions of the thermally expandable profile 5 before expansion, the Applicant has noted that, in order to obtain optimum expansion both in quantative terms (final density of the solid foam) and qualitative terms (morphology of the solid foam cells) preferably the expansion ratio, defined as being the ratio between the cross-sectional area Sf of the cavity to be filled and cross-sectional area Si of the thermally expandable profile 5 before expansion, lies between a minimum value (below which the thermally expandable profile 5, once expanded, may be subject to compression factors which may cause an undesirable increase in the final density) and a maximum value (above which the thermally expandable profile might not manage to fill the entire cavity). Preferably the expansion ratio has a minimum value of 15, more preferably between 5 and 8, and even more preferably substantially equal to 7. The Applicant has carried out tests and found that these preferred values of the expansion ratio allow a solid foam with a density of the order of 30-50 kg/m^3 to be obtained.

[0085] The cross-sectional area Si of the thermally expandable profile 5 is therefore preferably greater than Sf/15, more preferably between Sf/8 and Sf/5 and even more preferably substantially equal to Sf/7. For example, using thermally expandable profiles having a circular section of 4-8 mm diameter thermal break chambers (or other cavities of the thermal break profile) with dimensions of up to 15x12 - 20x12 cm may be filled with suitable densities.

[0086] For larger-size cavities, thermally expandable profiles with larger cross-sectional areas may be used. Alternatively, two or more thermally expandable profiles with a smaller size may be inserted inside the same cavity, as shown schematically in Figures 2a and 2b. Figure 2a shows a cavity 4a inside which two thermally expandable profiles 5a, 5b have been inserted, while Figure 2b shows the same cavity 4a inside which three thermally expandable profiles 5a, 5b, 5c have been inserted. According to these alternative variants, the cross-sectional areas of the thermally expandable profiles are chosen so that the expansion ratio calculated as the ratio between the cross-sectional area of the cavity 4a and the sum of their cross-sectional areas has a value in the preferred ranges indicated above.

[0087] Figures 3a, 3b, 3c and 3d show four thermally expandable profiles according to four variants of the present invention.

[0088] According to a first variant shown in Figure 3a, the thermally expandable profile 5 is an elongated body with a solid circular section. It does not have any adhesive control layer. Its thermally expandable composition comprises a base polymer material and one or more expanding agents of the type described above. Optionally it may comprise a crosslinking agent and/or an adhesive and/or nanofillers, as described above.

[0089] According to a second variant shown in Figure 3b, the thermally expandable profile 5 also comprises an adhesive control layer 51, as described above. The adhesive control layer 51 may be thermally expandable and may comprise nanofillers, as described above.

[0090] According to a third variant shown in Figure 3c, the thermally expandable profile 5 comprises, in addition to the control layer 51, also a central hole 52. The central hole 52 advantageously acts as a relief valve for excessive compaction pressure of the cells upon variation in the conditions of the painting cycle and the cavity sections to be filled. In this way the uniformity of shape and size of the cells in the central zones and peripheral zones of the solid foam is improved, this having a positive impact on the thermal insulation capacity of the foam. For example, if the thermal break chamber 4 has a substantially rectangular cross-section with dimensions 6x3 cm, a substantially circular cross-section with diameter of 10.6 mm and a central hole with diameter of 1.8 mm may be used for the thermally expandable profile 5.

[0091] According to a fourth embodiment shown in Figure 3d, the thermally expandable profile 5 comprises a thermally insulating core 53 and a thermally expandable cladding 54. The thermally insulating core 53 preferably comprises an expanded material (for example a synthetic foam, a phenolic or melamine foam, etc.) or a non thermally expandable material (for example an aerogel). The thermally expandable cladding 54 comprises instead the thermally expandable composition present in the preceding variants. Optionally, according to this variant, the adhesive control layer 51 may also be present.

[0092] According to this fourth variant, therefore, the thermal insulation of the thermally expandable profile 5 depends mainly on the nature of the material from which the thermally insulating core 53 is made, while the thermally expandable composition of the cladding 54, together with any adhesive control layer 51, basically performs the function of adapting the shape of the core 53 to the shape of the cavity to be filled and a cavity sealing function once filled.

[0093] As mentioned above, the expansion of the thermally expandable profile 5 is activated by heating the thermal break profile which contains it to a temperature $T_V \geq T_E$, preferably during painting of the thermal break profile. The parameters of the painting process (in particular its temperature and duration) therefore influence the characteristics of the solid foam which is obtained at the end of expansion. In particular, too short a duration does not allow optimum expansion of the composition, such that at the end of painting the solid foam obtained would have a density greater than that desired and also a non-uniform expansion of the cells. Besides, too long a duration would facilitate escaping of the expansion gas necessary for obtaining densities of less than 100 kg/m^3 and low thermal conductivity.

[0094] However, the use of suitable expanding agents and/or a suitable expansion ratio and/or suitable crosslinking agents in the thermally expandable composition and/or the control layer as described above advantageously allow expansion to be controlled in the desired manner so as to obtain - in the conditions determined by painting of the thermal break profile - a solid foam with density values less than 100 kg/m^3, an optimum morphology and, therefore, optimum thermal insulation.

[0095] In particular, it is known that the thermal conductivity of a solid foam is defined by the sum of a thermal conductivity λ_S of the solid phase, a thermal conductivity of the gaseous phase X_G, a convection component λ_C and a radiant component λ_R, i.e.

$$\lambda=\lambda_S+\lambda_G+\lambda_C+\lambda_R.$$

[0096] The solid foam of the thermally expandable profile 5 advantageously has an optimum thermal insulation since each component λ_S, λ_G, λ_C and λ_R is minimized.

[0097] As regards the thermal conductivity λ_S of the solid phase, it plays a less important part than other components, both because the base polymer material has an intrinsically low thermal conductivity (typically 0.12 - 0.35 W/mk) and because the solid phase occupies only a small fraction of the solid foam. For example, if the density of the solid foam is 32 Kg/m^3, only 3% of the volume is occupied by the solid phase.

[0098] As regards the thermal conductivity of the gaseous phase λ_G, the expansion gas produced during expansion by the PBA in the microspheres (hydrocarbon) and by the CBA (nitrogen) is responsible for most of the heat transfer since it occupies about 90% of the volume of the solid foam. Therefore, in order to obtain a low λ_G value it is preferable to use an expansion gas with a high molecular weight, which is not difficult to process and which does not pollute the atmosphere. For example, a hydrocarbon such as the aforementioned pentane has λ_G=0.014 W/mK.

[0099] As mentioned above, however, at the end of expansion the aforementioned expansion gas in general tends to be diffused and thus migrates from the solid foam, where it is replaced by the air which has a greater thermal conductivity λ_G. The speed of this diffusion mechanism depends on different characteristics of the solid foam, for example:

(i) chemical nature of the base polymer material of the composition and of the expansion gas, in particular permeability

of the walls of the cells to the expansion gas and the air;
(ii) size of the cells, since in general small-size cells withstand the diffusion of expansion gas longer than large-size cells; and
(ii) number of closed cells present.

[0100] Advantageously, in the thermally expandable composition according to embodiments of the present invention, this diffusion effect (with a consequent increase in the thermal conductivity of the gaseous phase) is hindered by the fact that the solid foam - obtained with the controlled expansion process as described above - has mainly closed cells which create a barrier effect as regards diffusion of the expansion gas. This barrier effect is further reinforced by the adhesive control layer 51, in particular when it contains the aforementioned nanofillers which, as result of their layered arrangement, help prevent both the diffusion of the expansion gas towards the outside of the expanded profile 5 and the infiltration of moisture from the outside towards the inside of the expanded profile 5.

[0101] As regards the convection component λ_C, in gas-containing cells the convection flows occur generally when the size of the cells exceeds a threshold value of between 2 mm and 5 mm. Since the solid foam obtained according to the present invention has smaller-size cells (typically from 20 μm to 150 μm), the convection component λ_C is advantageously negligible.

[0102] Finally, as regards the radiant component λ_R, the contribution of the radiation processes to the heat exchange in solid foams depends on the radiative capacity of the starting material and therefore of the base polymer material used in the thermally expandable composition. Typically, in low-density solid foams, the component λ_R may represent up to 30% of the total thermal conductivity λ. The contribution of the radiative processes depends both on the size of the cells and on the thickness of their walls. Since the transfer of radiative heat occurs through the walls which separate adjacent cells, a solid foam with a greater number of smaller cells generally transfers less heat by means of radiation than a solid foam with a smaller number of larger cells. Advantageously, in the thermally expandable composition according to the present invention, the radiative phenomena are limited owing to the control of the expansion mechanism described above, this allowing the formation of a large number of small-size cells. The radiant component λ_R is therefore advantageously minimized, as is also the total thermal conductivity λ.

[0103] As described above, the thermally expandable composition preferably comprises as a base polymer material an EVA copolymer, more preferably an EVA copolymer with MFI (Melt Flow Index) of between 17 and 23 and percentage of VA (vinyl acetate) ranging between 19% and 21%.

[0104] The Applicant has tested various thermally expandable compositions based on an EVA copolymer. In particular, the thermal conductivity at different densities was measured for various thermally expandable compositions based on an EVA copolymer.

[0105] More particularly, a respective thermally expandable profile with circular section of about 8 mm diameter was formed for each thermally expandable composition. The thermal break profiles were inserted inside respective cavities with a substantially rectangular section and size 27 mm x 17 mm. The profiles were then subjected to a heat treatment in an oven at 190°C for a time period of 20 minutes (conditions similar to those used for painting the thermal break profile) so as to activate expansion of the thermally expandable profile and obtain substantially complete filling of the respective cavity. Finally, a sample of the expanded foam was taken from each profile.

[0106] Each profile was then subjected to measurement of the density and the thermal conductivity. The density values were measured using a Mettler Toledo AG 204 Delta Range balance, while the thermal conductivity values were measured using an apparatus of the "TCi Thermal Conductivity Analyzer" type made by C-Therm Technologies Ltd based in Fredericton (Canada).

[0107] The solid foam samples also underwent SEM ("Scanning Electron Microscopy") in order to perform a morphological analysis of the cellular structure, with the aim of checking the size of the cells, the presence of closed or open cells, the presence of any coalescence and the thickness of the cell walls.

[0108] Finally, the shear strength was measured according to the standard UNI EN 14024 and finally the adhesion to the walls of the filled cavity after expansion was measured.

[0109] Table I below shows the EVA copolymer thermally expandable compositions tested by the Applicant:

Table I

	composition codes			
	R	**0068**	**A1**	**A1xox310Pes**
components	**percentages by weight (% wt)**			
EVA	92.6 (%VA =18, MFI=2)	74 (%VA=20, MFI=20)	55,25 (%VA=20, MFI=20)	49 (%VA=20, MFI=20)
azodicarbonamide (Ferrocel ADC)	5	-	-	-
OBSH (Ferrocel OBSH)	-	10	7.5	7.5
microspheres (Expancel 093 DU120)	-	13	35	35,5
peroxide (Trigonox101)	2.4	3	2.25	3
polyester (Griltex® 1582)	-	-	-	5

[0110] As regards the profile obtained with the composition A1, it also had an adhesive control layer containing EVA-OREVAC 9304 produced by the company Arkema based in Colombes (France). As regards the profile obtained with the composition A1xox310Pes, it also had an adhesive control layer containing EVA-OREVAC 9304 and Expancel 093 DU120 in amount of 15%.

[0111] Table II below shows the results of the density measurements, morphological analyses and thermal conductivity measurements carried out by the Applicant on the solid foams obtained by expansion of the compositions shown in Table I:

Table II

composition code	density (Kg/m^3)	cell diameter (μm)	thermal conductivity (W/mK)
R	≈ 250	150-300	0.066
0068	≈ 150	>250	0.041
A1	50-80	50-200	0.035
A1xox310Pes	20-60	21-150	0.025-0.032

[0112] The results in Table II show that the lower densities and the smaller cell dimensions were obtained for the compositions A1 and A1xox310Pes, which used high concentrations of expanding agent (higher than 35%wt) in the form of microspheres with PBA together with a CBA in a smaller concentration (7.5%wt). With these compositions, in particular solid foams with densities less than 100 kg/m^3, cell sizes smaller than 200 μm and consequently thermal conductivity values less than 0.04 W/mK are obtained.

[0113] With the other thermally expanded compositions which were tested, R and 0068, which did not comprise microspheres with PBA or which comprised a much smaller amount thereof, it was not possible to obtain expanded foams with the same performance characteristics.

[0114] It should be noted that, for lower density values (i.e. less than 100 kg/m^3, of the compositions A1 and A1xoxPes), variable density values were recorded in the filled cavities owing to the compression factors affecting the expanded profile 5 as described above.

[0115] Table III below shows the results of the shear strength measurements and tests for adhesion to the walls of the cavity carried out by the Applicant on the solid foams obtained by expansion of the compositions shown in Table I:

Table III

composition code	pre-painting load (kg)	post-painting load (kg)	adhesion
R	490	310	+
0068	520	340	=
A1	480	350	+
A1xox310Pes	530	485	+

(continued)

composition code	pre-painting load (kg)	post-painting load (kg)	adhesion
empty cavity	500	300	

[0116] With regard to the shear strength values, for comparative purposes Table III also shows the results of the measurements carried out for a thermal break profile with empty cavity.

[0117] As can be seen from the results shown in Table III, all the thermal break profiles, before painting, had load values of between 480 kg and 530 kg. Following painting, as expected, all the shear strength values worsened, i.e. were lower. However, it may be commented that the presence of the solid foam inside the cavity in general mitigated such worsening, in the case of all the thermally expandable compositions considered. The reason being that all the solid foams, since they were obtained from thermally expandable compositions based on EVA, had the characteristic of adhering to the walls of the cavity, and therefore improved the shear strength of the thermal break profile.

[0118] In particular, the profiles obtained from the compositions A1 and A1xox310Pes helped offset more the reduction of the shear strength values following painting, since they had a greater adhesion to the cavity walls owing to the presence of the adhesive control layer.

[0119] The adhesion was assessed by means of a visual examination of the amount of solid foam left on the aluminium surface of the half-shell following shearing of the solid-foam profile from the cavity. In Table III the symbol "+" indicates a large amount, "=" indicates a medium amount, while "-" (not present) would indicate that there was no trace of foam left.

[0120] It may be commented that the compositions R, A1 and A1xox310Pes are those compositions where a greater amount of solid foam was left, thus indicating better adhesion properties.

[0121] With reference to the flow diagram shown in Figure 4, the process for obtaining the thermally expandable profile 5 for filling a cavity of a thermal break profile according to embodiments of the present invention will now be described in greater detail.

[0122] Firstly, the various components of the thermally expandable composition (base polymer material, PBA in microspheres, optional CBA, optional nanofillers, optional adhesives, optional crosslinking agents, etc.) are mixed together (step 400).

[0123] Then, according to first embodiments, the composition is subjected to granulation (step 401), i.e. is extruded in the form of granules. Then, the granules are used to form the thermally expandable profile in the desired form (step 402). This forming step may be performed by re-extrusion of granules or using a mould. The thermally expandable profile 5 obtained at the end of step 402 may have any desired shape, for example round, round with hole, or square or rectangular. The cross-sectional shape of the profile 5 may also be concave and comprise recesses which allow the engagement thereof with corresponding projections present on the surface of the half-shells 1, 2 or on the surface of the thermally insulating bars 3. The step 402 optionally may comprise also the application of the adhesive control layer 51, where envisaged. For example, if the profile 5 is obtained by means of extrusion, the control layer 51 may be co-extruded.

[0124] According to other embodiments, once mixing of the components in step 401 has been performed, the composition may be provided in powder form (step 403). Then, the thermally expandable profile 5 is obtained by filling, with this powder, the central cavity of a tubular body, which corresponds to the control layer 51 (step 404).

[0125] These second embodiments are advantageous since they avoid the granulation step 401 and re-extrusion step 402, which may cause a slight deterioration in the properties of the thermally expandable composition (in particular, a breakage of the microspheres comprising the PBA).

[0126] Preferably, in step 404 the tubular body which is filled with thermally expandable composition in powder form is corrugated. This facilitates the subsequent introduction of the thermally expandable profile 5 into the cavity to be filled, since the profile 5 offers a smaller contact area (and therefore less friction) with the walls of the cavity. Moreover, the insertion inside the cavity is also facilitated by the fact that the corrugation of the tubular body ensures a greater rigidity of the thermally expandable profile 5.

[0127] Although in the above description reference has been made to only filling of the thermal break chamber, this is not limiting. Thermally expandable profiles of the type described above may in fact be advantageously used to fill any cavity of the thermal break profile, for example the cavities formed inside each half-shell or inside the bars.

[0128] In this connection, by way of example, Figures 5a and 5b show a thermal break profile in which two thermally expandable profiles 5 and 5a with respective adhesive control layers 51 and 52a are inserted respectively inside the thermal break chamber 4 and inside the internal chamber 4a of the half-shell 2 (Fig. 5a). Following the heat treatment at the temperature T_V, both the thermally expandable profiles 5 and 5a expand, such that each of them fills substantially entirely the respective chamber 4 and 4a with solid foam, while the adhesive control layers 51 and 51 a seal the respective chambers substantially along their entire perimeter (Fig. 5b).

[0129] This advantageously allows the thermal insulation of the thermal break profile to be increased significantly compared to a known thermal break profile, which has the same dimensions and empty chamber 4a.

[0130] According to the present invention, therefore, the thermally expandable profile is inserted inside the cavity to be filled, while not yet in an expanded condition, and is expanded under the pressure exerted by an expansion gas produced within the thermally expandable composition itself subsequently, for example during painting. This offers various advantages.

[0131] Firstly, since the thermally expandable profile has - when it is not yet expanded - a cross-section with an area smaller than the cross-sectional area of the cavity to be filled, ample play is present between the thermally expandable profile and the inner walls of the cavity to be filled, this making the operation of inserting the thermally expandable section inside the cavity very easy, without the risk of breakage thereof.

[0132] It is therefore advantageously possible to insert inside the thermal break profile a thermally expandable profile with a length comparable to that of the metal half-shells and plastic thermally insulating elements (6-7 metres or more), such as to fill the cavity along its whole length using only one thermally expandable profile.

[0133] Besides, it is advantageously possible to choose with a certain degree of freedom the shape of the cross-section of the thermally expandable profile, substantially independently of the shape of the cross-section of the cavity to be filled. It is therefore possible to provide a thermally expandable profile with a section which facilitates expansion under the pressure of the expansion gas, for example a circular section.

[0134] Independently of the section shape chosen for the thermally expandable profile before expansion, it is advantageously guaranteed that the cavity is filled even when it has an articulated shape. During the expansion, indeed, the expansion gas under pressure advantageously pushes the thermally expandable composition in every point of the cavity, thereby allowing to fill every possible narrow recess and/or protrusion of the cavity.

[0135] Moreover, the thermally expandable profile may be advantageously used to fill with thermally insulating material not only the thermal break chamber, but also any other cavity present in the thermal break profile, including for example the cavities formed inside each half-shell or inside the thermally insulating element. For example, it is possible to envisage inserting during assembly a thermally expandable profile inside each cavity of the thermal break profile, so as not leave any cavity empty. This allows the thermal insulation to be increased significantly, for the same external dimensions of the thermal break profile.

Claims

1. A method for at least partially filling with thermally insulating material a cavity (4) of a thermal break profile, said method comprising:

   a) forming a thermally expandable profile (5) comprising a thermally expandable composition suitable for expanding under the pressure exerted by an expansion gas produced within said thermally expandable composition at a first temperature T_E, said thermally expandable profile (5) having a cross-section smaller than the cross-section of said cavity (4) to be at least partially filled;
   b) inserting said thermally expandable profile (5) in said cavity (4) to be at least partially filled; and
   c) subjecting said thermal break profile to a heat treatment at a second temperature T_V higher than or equal to said first temperature T_E, so that said expansion gas is produced within said thermally expandable composition and exerts a pressure inducing said thermally expandable profile (5) to expand and at least partially fill said cavity (4).

2. The method according to claim 1, wherein said step a) comprises providing said thermally expandable composition by mixing a base polymer material having a melting temperature T_M lower than or equal to said second temperature T_V and an expanding agent suitable for producing said expansion gas at said first temperature T_E.

3. The method according to claim 2, wherein said base polymer material is an EVA (ethylene vinyl acetate) copolymer with melt flow index between 17 and 23 and percentage of VA (vinyl acetate) ranging between 19% and 21%.

4. The method according to claim 2 or 3, wherein said expanding agent comprises a plurality of microspheres containing a physical blowing agent suitable for producing said expansion gas by passing from a liquid state to a gaseous state during said heat treatment, said microspheres being impermeable to said physical blowing agent.

5. The method according to claim 4, wherein said physical blowing agent is a hydrocarbon.

6. The method according to claim 4 or 5, wherein the concentration of said plurality of microspheres in said thermally expandable composition is between 1% and 40% by weight of said thermally expandable composition.

7. The method according to any of claims 4 to 6, wherein said expanding agent also comprises a chemical blowing agent.

8. The method according to claim 7, wherein the concentration of said chemical blowing agent in said thermally expandable composition is between 1 % and 20 %wt relative to the weight of said microspheres with said physical blowing agent.

9. The method according to any one of claims 2 to 8, wherein said thermally expandable composition further comprises a crosslinking agent suitable for inducing a crosslinking of said base polymer material during said heat treatment.

10. The method according to any one of claims 2 to 9, wherein said base polymer material comprises nanofillers.

11. The method according to any one of the preceding claims, wherein said step a) comprises providing said thermally expandable profile (5) with a control layer (51) surrounding said thermally expandable composition and suitable for controlling the expansion of said thermally expandable composition during said heat treatment.

12. The method according to claim 11, wherein said control layer (51) is an adhesive control layer comprising an adhesive polymer material suitable for carrying out its adhesive action at said second temperature T_V.

13. The method according to claim 12, wherein said adhesive polymer material comprises a holt melt adhesive.

14. The method according to any one of the preceding claims, wherein said step a) comprises forming said thermally expandable profile (5) so that the area Si of said cross-section of said thermally expandable profile (5) is greater than Sf/15, Sf being the area of said cross-section of said cavity (4) to be at least partially filled.

15. The method according to any one of the preceding claims, wherein said step c) is performed during the painting of said thermal break profile.

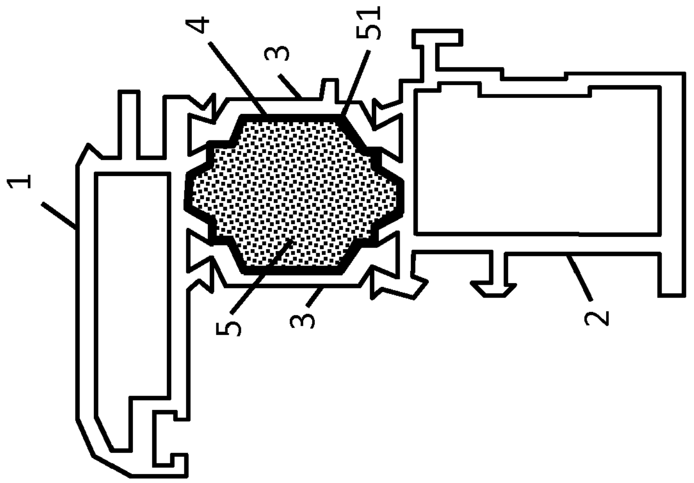

Fig. 1b

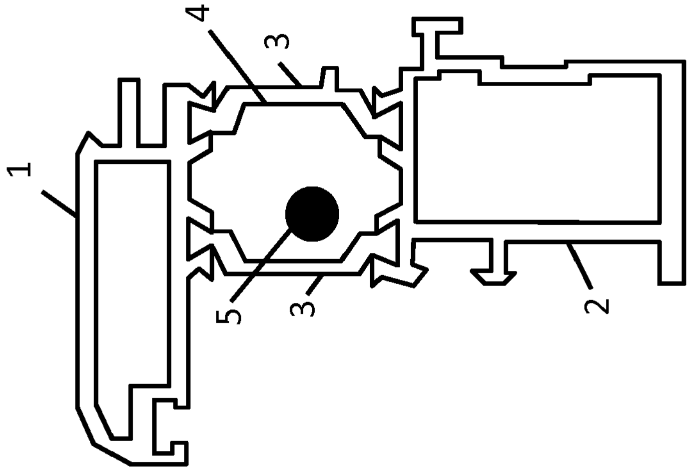

Fig. 1a

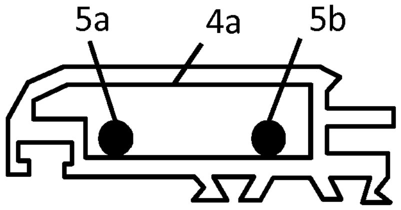

Fig. 2a

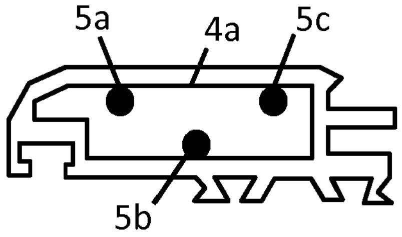

Fig. 2b

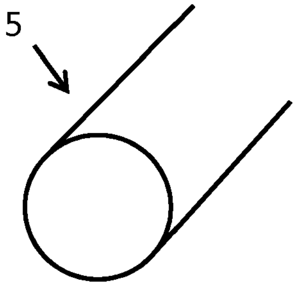

Fig. 3a

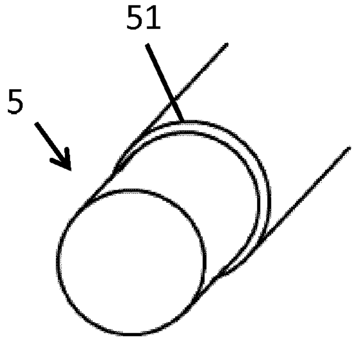

Fig. 3b

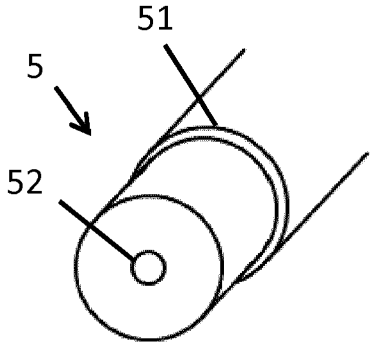

Fig. 3c

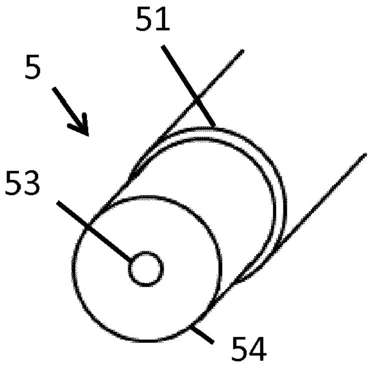

Fig. 3d

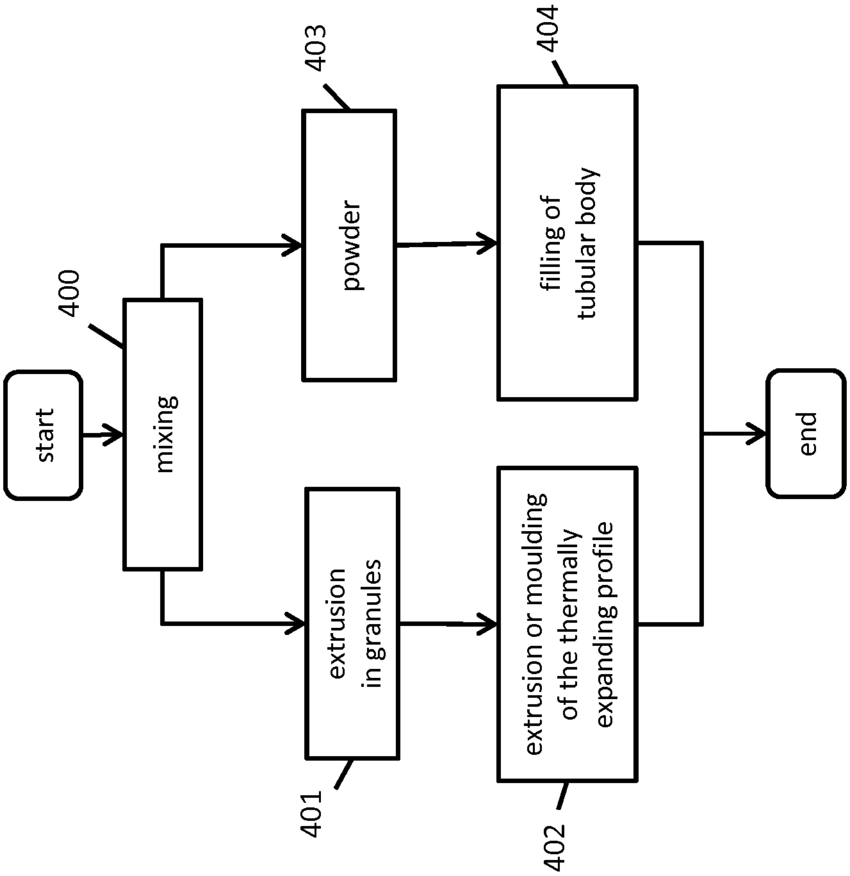
start
mixing
400
extrusion in granules
401
powder
403
extrusion or moulding of the thermally expanding profile
402
filling of tubular body
404
end

Fig. 4

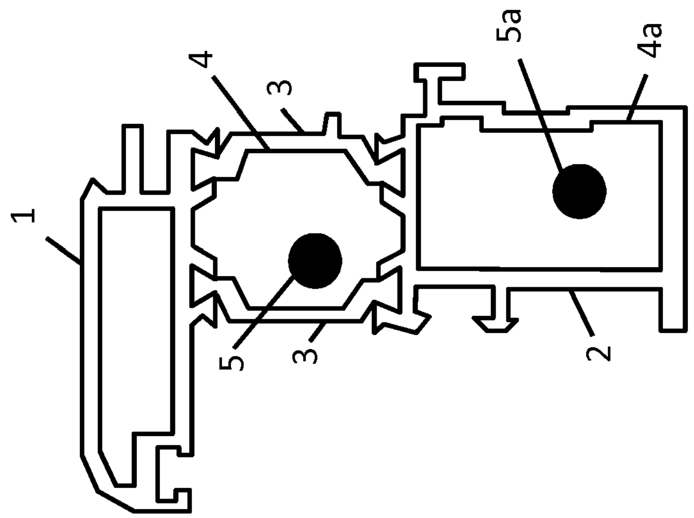

Fig. 5a

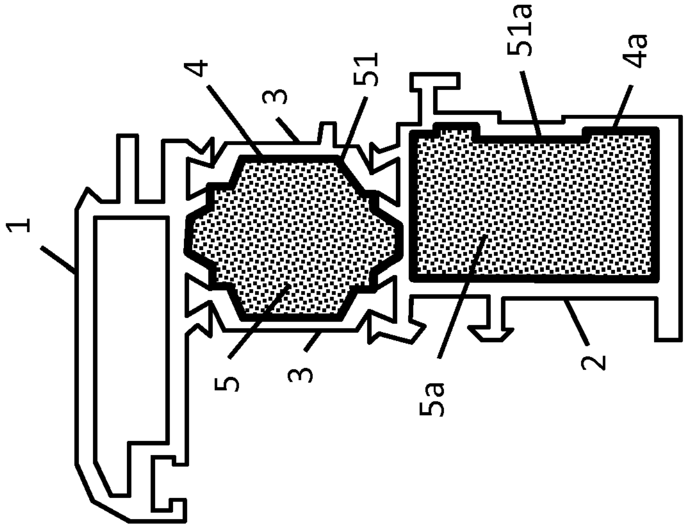

Fig. 5b

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EUROPEAN SEARCH REPORT

Application Number
EP 17 18 9624

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 2 405 092 A1 (RECTICEL NV [BE]) 11 January 2012 (2012-01-11) * paragraph [0022] - paragraph [0026]; figures 1, 2 * -----	1-15	INV. E06B3/263
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E06B
C08J

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	21 November 2017	Cobusneanu, D

CATEGORY OF CITED DOCUMENTS

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& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 18 9624

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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