Method for fiber alignament, local concentration and production in short fiber reinforced composites

1) Short fiber reinforced composites involve a wide range of materials, depending on combinations of fiber and matrix. The majority has polymer matrix.
Thermoplastic matrix are ideal for applications for which toughness is of critical importance, high volume production is involved, and long shelf life and scrap recycling are important issues. With all of these performance capabilities, one of the greatest advantages to using short fiber reinforced thermoplastics is their ease of processing and reprocessability. Effective processing techniques and the ability to recycle scrap offer significant cost reductions in comparison with those of thermoset compounds and metals. Because of this, short fiber reinforced thermoplastics are desired in the electrical and electronic, automotive, oilfield, chemical process, and defense industries.
Thermoset polymer are also use as matrix, more attractive for highly stressed parts, including lower processing viscosities for RTM, infusion or prepreg manufacture (which permit high fiber volumes), superior adhesion to fibers (especially true of epoxies), featuring higher thermal resistance, especially to compressive creep.
Is it possible to find a wide range of applications in automotive, aviation, as well in renewable energy like in wind turbine.
Fiber types are wide, the most used are glass fiber.
Material strength can vary widely depending on fiber orientation: the load is carried by the fiber, so if these are oriented in a direction this will be the higher in resistance and module.
As well properties change depending on the percentage of fiber contained in the material, having higher resistance and module increasing the fiber, up to a certain limit when the matrix cannot transmitt the stress properly.

2) Short fiber reinforced composites final products are produced nowadays using various methods, most common for fiber reinforced polymer are :
   - Compression molding
   - Transfer molding
   - Injection molding
   - Spray method

   Compression Molding is a method in which the molding material (fiber and matrix already together) is first placed in an open, heated mold cavity. The mold is closed with a top force or plug member, pressure is applied to force the material into contact with all mold areas,
while heat and pressure are maintained until the molding material has cured.
Transfer molding (resin transfer molding RTM) allowed to place first the fiber, with possibility to overlook fiber direction. Then the matrix is forced into the mold which contains the dry fiber.
Injection molding force the composite (fiber and matrix already together) into the closed mold by injecting the material.

When considering the raw material (matrix + fiber), this can produce and stocked as grains or prepreg layers.

3) An important issue faced when using fiber reinforced composites is the fiber direction. Considering that the resistance and module is optimize in the fiber direction is crucial to have these fibers aligned with load direction. With long fiber reinforced composites this is easier since the fiber are normally easy to align, placed by machine or by hand, but then I have some limit in big figures production.
   In case of short fiber reinforced composite, fiber direction is out of control in many application, leading to a material with isotropic characteristic in general, or with uncontrolled fiber direction due to the process (e.g. material flow in injection molding).
   Nowadays fiber orientation is predictable by specific software, but still not possible to fully control.
   The concentration change also depends on the production method and raw material, the distribution can be affected also by the matrix flow in some production methods.

4) The method for fiber alignment, concentration and production in short fiber reinforced composites proposed in this paper allowed to choose what will be the final fiber orientation, concentration and presence optimizing it to the load that the final component will be submitted.
   Moreover, the method is fully automatic, feasible for an industrial production.

5) The method proposed consist in a system to control fiber orientation, concentration or production using magnetic fields. The magnetic field can generate a force to an electric charged component, therefore having the fiber aligned with an orientation or concentrate in the area where major strees is submitted, or stick to the base component when the fiber are too big to be injected.

   The system basic components are:
   a) An electrostatic charger bar to charge the fiber
   b) A movimentation system to position the charged fiber
   c) A base where fiber are positioned, it can have different carachteristics depending on the production method, in some case can be the components itself
   d) Matrix distributor

   Additonal system components, depending on production method can be:

   e) Bar to opposite charge in comparison with the fiber
   f)

Example 1:
If fiber were not present in the initial component, will be possibile to charge the solid matrix to meet the charged fiber. The difference in charge will led the fiber to stick to the solid matrix. Then a liquid matrix can be applied over the fiber to obtain a unique composite component. This method is

particulary suitable for the high production simple shape parts, like pipes or compomponents produced via filament winding, or when fiber are too big to be injected together with matrix.
Is also suitable for component with a complex internal shape and simple external shape, when fiber are too big.

6) The advantage of using magnetic field and electrostaic is the control of the fiber positioning, moreover the possibility of an automatic system that nowaday may required human work in many passages. The possibility to have the fiber to stick on a base component allowed also to have higher productivity replacing some process.
The fiber used can be longer therefore increase the distance from the critical length and have a behaviour closer to the long fiber reinforced composite.
The system has also the advantage to do not cause fiber breakage.

7)

Example 2: the fiber are moved using for example a conveyor, passing under an electrostatic charger bar, then the conveyor lay the fiber over the base. The base is a thin, flexible, non conductive layer. Under the base a magnetic field create with the opposite charge will move the fiber in the desired direction. Once the position of the fiber is defined, the matrix is poured over the fiber to consolidate the position, then the layer wil be positioned in the mold to be compressed.

Example 3: the base is covered by matrix, then a moving head distribute the fiber over the matrix giving the orientation to the charged fiber via an opposite charged bar. Then a second layer of matrix is poured and fiber distributed again in order to obtain a stack-type multilayer prepreg.