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[54] **ALIGNMENT AND ORIENTATION OF WHISKERS AND FIBERS**

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[58] **Field of Search**.....161/172, 173; 57/140 R; 264/108, 109, 111, 165, 176 F, 128, 164; 106/44, 50

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[57] **ABSTRACT**

Alignment of fibers or whiskers such as β-SiC and α-A$_2O_3$ is accomplished by suspending unoriented whiskers into an ethylene glycol solution and adding several drops of amyl acetate to the solution near the center to produce a rolling action at the interface due to the motion of the solutions as they mix with each other. The unoriented whiskers are caught up in the rolling interface and are aligned into a thread.

3 Claims, No Drawings

ALIGNMENT AND ORIENTATION OF WHISKERS AND FIBERS

BACKGROUND OF THE INVENTION

This invention relates to a process for producing aligned whiskers and more specifically to a process for aligning whiskers into threads.

The use of metal, crystal and ceramic fibers or whiskers as reinforcement material to produce high strength matrices is well known. Usually the reinforcing material is mixed into the matrix as randomly oriented fibers, or the fibers are aligned by extrusion through a die prior to mixing. However, the extrusion operation limits matrices or composites to a small size while unaligned whiskers, although not restricting the matrix size, do not achieve maximum reinforcing strength. Other processes which align whiskers involve expensive equipment or require a binder for the fibers. Commercially, the use of whiskers in the form of threads is not limited to producing high strength matrices but also finds use in textile materials.

With this background of the prior art in mind, it is an object of this invention to provide a process for aligning fibers and whiskers into threads.

Another object is to provide a process for aligning fibers and whiskers into threads on a continuous or semi-continuous basis.

Another object is to provide a process for aligning fibers and whiskers into threads without the necessity of employing a binder.

Another object is to provide a process for aligning fibers and whiskers into threads and employing a binder to improve the green strength of threads to facilitate handling.

Another object is to provide a novel thread structure employed by the process of the present invention.

Other objects of the invention will become apparent from the description to follow.

According to the invention, unoriented fibers or whiskers are suspended in a first solution, a second solution miscible with the first solution is then added to form a rolling type of action at the interface of the two solutions as they mix together, thereby causing the suspended whiskers to be drawn into the interface and aligned into a thread, and then withdrawing the thread.

The composition of the fibers or whiskers is not critical to the operation of the process. Thus, whisker compositions which were found suitable include α-Al_2O_3, β-SiC and Si_3N_4.

A preferred suspending solution is ethylene glycol; amyl acetate, which is miscible in the ethylene glycol, is employed to produce the spinning interface.

For an ethylene glycol depth of about ¼ inch, the mixing action will be most effective for whisker lengths of about ⅛ – ½ inches.

The mixing action can be brought about in a variety of ways. For example, a drop of amyl acetate can be placed in the center of a container containing the ethylene glycol (and suspended whiskers) in such a manner so as not to cover the entire surface of the ethylene glycol with the amyl acetate, but allowing a non-restricted interface (amyl acetate-ethylene glycol) to exist. In this case, the interfacial action will take place in a manner such that a continuous circular filament is formed. In an alternate method, a series of drops or a continuous stream or sheet of amyl acetate

can be brought together with the ethylene glycol (containing the whiskers), resulting in a free interface which is a straight line. In this case, a long single strand of whiskers or filaments will be formed. Obviously, many different mixing geometries can be employed in either batch or continuous processes. With the proper mixing geometry many filaments can be produced in parallel.

Other compounds which are miscible with ethylene glycol and produce a suitable interface include: benzene, chlorobenzene, cyclohexane and toluene.

Obviously, other systems comprising a suspending solution and a miscible, interface-reaction-producing material can be employed. The characteristics of the mixing action are dependent upon the nature of the liquid and its temperature which can result in different degrees of compaction and twisting.

The invention will become more apparent from the examples to follow.

EXAMPLE I

β-SiC whiskers were dispersed in an ethylene glycol solution in a petri dish. Several drops of amyl acetate were added to the solution near the center of the dish forming an advancing interface between the two solutions and air. The interface had a spinning motion due to the mixing action, which caused the unoriented whiskers to be drawn into and along the interface and become twisted into an aligned thread.

EXAMPLE II

The twisting effect of the advancing interface results in twisted consolidated segments of whiskers that appear as a loose envelope around the main portion of the thread. Here again, ethylene glycol and amyl acetate were employed.

EXAMPLE III

An 8 inch diameter watch glass was filled to about an inch of the edge with ethylene glycol containing suspended β-SiC whiskers. Amyl acetate was introduced around the entire circumference of the watch glass into the ethylene glycol. An interface formed 1.5–2 inches from the edge of the ethylene glycol and migrated back out to the edge as the amyl acetate was consumed. The spinning action was faster near the edge of the watch glass where the depth of the solution was decreasing. This produced a single thread of aligned whiskers, 18 inch in length and able to hold its own weight (and that of the adhering ethylene glycol) in a vertical position when lifted out of the container.

EXAMPLE IV

The process of Example III can be adopted to continuous production by allowing a few inches of the thread produced in Example III to remain in the solution. After the initial amyl acetate had been consumed in Example III, additional amyl acetate is added, and as the new thread is formed, it is connected to the original thread, thus producing a three foot long thread in a semi-continuous manner.

The physical characteristics of the whiskers which appear important are: diameter/stiffness ratio, whisker length and whisker configuration.

Thus, when considering the diameter/stiffness ratio, small diameter, flexible whiskers such as Si_3N_4 tend to exhibit threadlike properties. The thread structure is unique in that it comprises inner, long pitch, spirals and outer spirals having a much shorter pitch. This thread structure is, of course, independent of the whisker composition and is much more stable to unravelling, etc. than the usual non-spiral type of thread. On the other hand, αAl_2O_3 whiskers of approximately the same diameter as the Si_3N_4, but which are stiffer, tend to be less threadlike and twisted.

When considering whisker length, if the whiskers are too short, they can be aligned, but cannot be lifted from the solution without breaking; they lack what is termed "green strength." This occurred in the case of α-SiC whiskers whose average lengths were in the order of 200 microns; use of a binder is necessary to impart the necessary "green strength." It is considered that the minimum satisfactory length necessary to give adequate green strength without a binder is 1,000 microns.

If the whiskers exceed the diameter of the interaction region of the two liquids, they will be pulled into but will not necessarily remain in the interaction area.

Whisker configuration can affect the usefulness of the whiskers as a strengthening agent. The whiskers should be straight and of uniform diameter; whiskers which are not straight, e.g., zigzag, not only are useless for strengthening purposes, but also can deter effective alignment of other whiskers within the vicinity.

Surface uniformity of the whiskers is also important. Whiskers having bumpy or rough surfaces such as α-SiC interfere with the alignment process because they prevent the free movement of whiskers over each other. Also, the rough surfaces may not allow the maximum whisker loading per unit volume. However, a rough surface whisker yields a higher green strength for the threads and thus enables easier handling and fabricating techniques to be employed.

On the other hand, relatively smooth surfaces such as β-SiC may be desirable for higher whisker loadings.

The process of this invention provides an orientation and alignment of fibers or whiskers in a uniform threadlike manner with a variety of controlled density of the whiskers in the thread. Furthermore, this process is accomplished without the use of a binder or expensive equipment. The process, which is inherently inexpensive, may be adapted to a continuous operation.

We claim:

1. A process for aligning unoriented whiskers which comprises:
   a. suspending the said unoriented whiskers in a first solution of ethylene glycol;
   b. adding a second solution selected from the class consisting of amyl acetate, benzene, chlorobenzene, cyclohexane, and toluene to form a rolling type of action at the interface of the two solutions as they mix together;
   c. thereby causing the suspended whiskers to be drawn into the interface and aligned into a thread; and
   d. then withdrawing the thread.

2. A process for aligning unoriented whiskers selected from the class consisting of metal, crystal, and ceramics which comprises;
   a. suspending the said unoriented whiskers in a first solution of ethylene glycol;
   b. adding a second solution selected from the class consisting of amyl acetate, benzene, chlorobenzene, cyclohexane, and toluene to form a rolling type of action at the interface of the two solutions as they mix together;
   c. thereby causing the suspended whiskers to be drawn into the interface and aligned into a thread; and
   d. then withdrawing the thread.

3. A process for aligning unoriented whiskers selected from the class consisting of αAl_2O_3, β-SiC, Si_3N_4, and α-SiC which comprises:
   a. suspending the said unoriented whiskers in a first solution of ethylene glycol:
   b. adding a second solution selected from the class consisting of amyl acetate, benzene, chlorobenzene, cyclohexane, and toluene to form a rolling type of action at the interface of the two solutions as they mix together;
   c. thereby causing the suspended whiskers to be drawn into the interface and aligned into a thread; and
   d. then withdrawing the thread.

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