The invention describes making core structures for tooling panels air permeable and resistant to higher temperatures. Core structures may be a non-woven made from fibers that may be treated with an adhesion promoter. The fiber is then treated with an outer-coating. Proper choice of outer coating allows the tooling panel to function at higher temperatures. The non-woven core may be constructed in various dimensions. Air permeability allows tooling panels to show superior response to changing temperatures. The non-woven may be bonded with another to form a larger tooling panel. The outer surface of the tooling panel may be coated with a material such as rigid foam that can be machined to a pattern placed in contact with material in manufacture a part. The permeable core structure can be made from permeated plastic, wood, metal, ceramic and the like.
Fig. 1
LIGHT-WEIGHT MOLD MAKING MATERIAL AND PROCESS OF MANUFACTURE OF THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a utility application which claims benefit of U.S. Provisional Application No. 61/820,271, filed 7 May 2013. The entirety of the aforementioned application are incorporated herein by reference.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

BACKGROUND OF THE INVENTION

[0003] The present invention generally relates to apparatuses to make tooling panels (boards) capable of acting as a template to make prototypes as well as parts to be manufactured on an ongoing basis.

[0004] This invention relates to the field of machinable, synthetic tooling panels. More specifically, the invention comprises a medium for making machinable tooling panels by using air permeable core structures singly, stacking them in layers and/or side-by-side as well as methods for making the tooling panels. The individual air permeable components may have suitable coatings on selected outside surfaces as well as between segments.

[0005] The rapid production of prototypes by using tooling panels (boards) is a task frequently required in modern manufacturing. Furthermore, techniques to make prototypes using tooling panels can often be applied to the manufacturing process itself in various occasions.

[0006] Tooling panels are molds used to make parts from composites, thermo-formable sheets, resin infused fibers and the like. The top part of a tooling panel which will be in contact with the part to be manufactured is often formed into the shape required to make the prototype or part by machining it into the desired configuration. Tooling panels usually remain in intimate contact with the part to be made throughout the manufacturing process. Thus, they must undergo the same processing conditions such as thermal care that the part does.

[0007] Tooling panels have been made from a variety of substances such as wax, ceramic, wood and metal. In addition, polymers such as polyurethanes, epoxy resins and other polymeric substances have been used.

[0008] One provider of wax to make tooling panels is the Freeman Manufacturing & Supply Company. This wax can be readily machined to provide tooling panels from which parts can be formed. However, wax has a relatively low melting point and can only be used to make parts that do not require more than a moderate temperature cure cycle. In addition, the manufacturing process must not impose large forces on the wax tool panel or it will be destroyed.

[0009] Ceramic used to make tooling panels can be obtained from Advanced Ceramic manufacturing among other suppliers. Ceramic tooling panels overcome the low melt point associated with wax. However, ceramics tend to be brittle and dense. They are not readily responsive to dynamic temperature changes in ovens and autoclaves that are commonly used to make parts. Accommodation this sluggish temperature response by using slow temperature ramps may unnecessarily lengthen production time. Ceramic tooling panels are heavy and are difficult to use when large parts are to be made.

[0010] Wood has been used to make tooling panels and it can be shaped by various well-understood methods to make a tooling panel upon which to cure parts. However, wood is susceptible to dimensional changes when relative humidity changes. Its dimensions frequently change more in response to changing relative humidity than the part which will be formed from it. Wood is also relatively dense resulting in heavy tooling panels.

[0011] Metal can be used as to make tooling panels. Its dimensional stability is not affected by changes in relative humidity and can be readily machined. However, metal is dense and heavy tooling boards. In addition, metals have relatively large thermal expansion coefficients that will exceed those from plastic parts being made using metal tooling panels. This can cause the metal tooling panel to have different dimensions that a curing part during a thermal cure leading to detectable parts.

[0012] Plastics/resins can be used to make tooling panels. One such is described in U.S. Pat. No. 7,906,063 where by resin particles are formed layer-by-layer via selective melting and hardening to make tooling panels. Resins such as polyurethane foams and epoxy resins are available from Rampf Molds Canada. Polymeric tooling panels generally have slow responses to temperature changes. They can be dense resulting in heavy tooling panels.

[0013] All existing tooling panel materials have limits to their practical size resulting in compromises when large parts are required to be manufactured.

[0014] Response to temperature change is a key property of tooling panels. During the heat-up phase of a cure process used to make a part, the tooling panel has a higher temperature on the outside than on the inside. Matching the dimensional change of the part being manufactured and the tooling panel is a large factor determining part quality. When the tooling panel/part is cooled the interior part of the tooling panel as hotter than the outer surface. Dimensional changes are important even after the heating part of the cycle is completed. In addition, the cooling at different temperatures can cause the tooling panel to crack limiting its reusability.

[0015] It was therefore an object of the present invention to provide a tooling panel that overcomes the disadvantages of current tooling panels. The disadvantages of current tooling panels are 1) poor temperature response, 2) difficulty of making tooling panels for large parts, 3) heavy weight to make tooling panels for large parts, 4) exaggerated susceptibility to changes in relative humidity; and 5) difficulty of operating at high temperatures.

BRIEF SUMMARY OF THE INVENTION

[0016] Surprisingly, it has now been found, as described in the claims, that the present invention comprises materials to make tooling panels and methods to make the tooling panels that overcome the disadvantages seen in current tooling panel materials. The disadvantages of existing products include 1) poor temperature response, 2) difficulty of making tooling panels for large parts, 3) heavy weight to make tooling panels for large parts, 4) exaggerated susceptibility to changes in relative humidity; and 5) difficulty of operating at high temperatures.

[0017] This invention provides a tooling panel that is light weight yet able to be formed into shapes of almost unlimited...
size. The invention can also make tooling panels that have superior temperature response and operating temperature and are virtually unaffected by changes in relative humidity.

[0018] Tooling panels described in the present invention can be based on a non-woven core structure. The non-woven core is made from fibers that are coated after the non-woven has been made. Suitable choice of the material used to coat the fibers can allow superior temperature workability. The coating also imparts strength to the material. The core structure can be coated with materials that are machinable thus converting the core material plus coating into a tooling panel that has a good response to temperature changes, is light-weight, insensitive to changes in relative humidity. Air permeable tooling panels can be based on materials other than non-wovens by puncturing a core material to make it air permeable. A core material can be made from a foam; however, foams commonly used as core panels are not air permeable. The foam would need to be perforated to provide necessary air permeability. A mold used to make the air permeable core material could be designed in a manner that the core is made containing perforations.

BRIEF DESCRIPTION OF THE VARIOUS VIEWS OF THE DRAWINGS

[0019] FIG. 1. Shows the construction of the various layers of a fiber incorporated into the non-woven.

[0020] FIG. 2. Shows the construction of the non-woven part.


[0022] FIG. 4. Shows several non-woven parts with coatings from an edge view.

[0023] FIG. 5. Shows a top view of an air permeable core structure with several holes to allow air passage.

[0024] FIG. 6. Shows the temperature response of tooling board material of the present invention compared to polymeric tooling boards. The plot is expressed in a percent change in temperature for a tooling board vs. oven temperature. Oven temperature is plotted on a second Y axis.

DETAILED DESCRIPTION OF THE INVENTION

[0025] The invention is based on improving tooling panels by making their core structure air permeable and able to function at higher temperatures. One aspect of the invention is a non-woven core structure. The non-woven can be made from fibers which can be made from synthetic polymers, natural polymers or inorganics such as glass or a combination of any of these fibers. The fiber may or may not be treated with an adhesion promoting material such as a latex. The fiber is then treated with an outer-coat to provide most of the physical properties of the non-woven construction. The outer-coat may be a curable system sued as a phenol-formaldehyde resin. After forming the nonwoven structure and curing the outer-coat, almost all of the physical properties of the non-woven core material such as compression and temperature stability likely come for the cured outer-coat resin. However, the invention does not depend on this mechanism being correct.

[0026] The non-woven core material may be constructed in various widths, lengths and thicknesses limited only by the capability of the machinery used to make the non-woven and the ability to transport the non-woven material. The tooling panel material produced in this manner may be bonded with another to form a larger tooling panel. In addition, an outer surface of the tooling panel may be coated with a material such as a rigid foam that can be machined to a pattern and used to make a part.

[0027] FIG. 1 shows a perspective view of one of the fibers comprising a segment of non-woven tooling board. The base fiber 3 provides the initial structure of the non-woven material. This fiber may be made from synthetic or natural materials. In addition, the fiber may be composed or organic polymers or inorganic materials. Representative examples of materials used to make synthetic fibers are polypropylene, various nylons and aromatic polyimides and polystyres. Representative examples of materials used to make natural fibers are cotton, wool, flax and wool. Hybrids of natural and synthetic fibers can be used seen as Rayon which is made by chemically modifying cellulose. Inorganic fibers could be made from glass or carbon among other materials. The individual fiber may be made from fibers of various thicknesses. In addition, the non-woven may be made from a mixture of fiber types and thicknesses.

[0028] The base fiber may be coated with an adhesive promoter. The adhesive promoter, if needed, will be selected on the basis of its performance with the fiber chosen and the outer layer 1. The adhesion promoter may be latex, solvent based or 100% solids materials. A latex adhesion promoter could be based on rubber latexes or various other materials. The same base monomers used to make latex or others could make a polymer that is dissolved in a solvent and used for the same function as the latex. Furthermore, one hundred percent solids materials such as hot melt adhesive could be used as the adhesion promoter. The adhesion promoter could be radiation cured for example with electron beam radiation.

[0029] The outer coat 1 likely provides much of the physical properties of the non-woven tooling board. Representative examples of the outer coat are phenol-formaldehyde resins, urea-formaldehyde resins and epoxy resins. Proper choice of the outer coating allows the core structure to perform for extended times up to 250° F and for brief periods at temperatures up to 300° F. These examples are one hundred percent solids, heat cured resins but other resins such as hot melt resins and solvent or water based resins may be used. The outer layer could be radiation cured for example with electron beam radiation.

[0030] It is likely that once the outer coat is applied and cured, if necessary, that this layer provides most of the structural properties of the non-woven structure. Furthermore, the coating process may leave some of the resin in interstitial spaces among the fibers. This model relegates the base fiber and adhesion promoter to relatively unimportant status once the outer coat is fully functional. The applicability or not applicability of this model does not influence the applicability of the invention.

[0031] FIG. 2 illustrates a element of the non-woven material. The arbitrary outer boundary 5 contains fibers 4. The arbitrary outer boundary does not necessarily define the contours of the non-woven since it may be configured into various shapes. An individual fiber 4 is intertwined amongst numerous other fibers to form a non-woven structure.

[0032] The non-woven elements may be various sizes limited only by constrains of the equipment used to manufacture and ship them. The size of the non-woven component may be altered, FIG. 3. Two individual elements 6 and 7 are stacked to form a thicker element. The individual components may be
stacked on top of one another as shown in FIG. 3 or may be placed beside each other or a combination of stacking and placing beside each other.

Individual non-woven components may be adhered to one another as well as coated. FIG. 4. The individual elements 10 may be adhered to each other by a layer 8. This layer may be continuous or non-continuous. Layer 8 may be applied by brush, spray, roller applicator or any other method that successfully applies it. Layer 8 may be composed of a two component polyurea or polyurethane sprayed onto one of both of the surfaces prior to placing them together. A hot melt adhesive, epoxy adhesive, silicone adhesive, water based adhesive are representative examples of other coatings that may be used to bond non-woven structures together. In addition, the non-woven structures may not need an adhesive to bond them together. The choice of the adhesive or whether to use an adhesive will depend on the structure of the non-woven and the application in which it will be used.

A coating, 9, may be applied to the outer surface or surfaces of the non-woven structure. The coating can be applied by the same processes used to apply 8. Components 8 and 9 may be applied by the same or by different methods and may be composed of the same or different materials. The coating on an outer surface may be formed into a configuration needed to manufacture a part. For example, the outer surface coating may be a rigid foam that can be machined. The improved, air permeable core structure can be based on non-fibrous materials. For example, the invention can be made from any materials or configuration of materials that make a high air permeability core structure. A material may be made permeable by perforating it multiple times with a drill or other suitable tool. Top surface of a non-fibrous core structure is shown in FIG. 5. The top surface is denoted by 11 and examples of holes by 12. The holes can be a variety of sizes and shapes. The number of holes and their size/shape depends on the amount of air permeability needed to maintain the temperature response needed to maintain good parts from the resultant tooling panel. The perforated material could be coated with a material that can be machined. However, depending on the material, size of the perforations and amount of perforations the core structure may serve without the need for a coating.

Although the preceding description contains significant detail, it should not be construed as limiting the scope of the invention but rather as providing illustrations of the preferred embodiments of the invention. As an example, sprayed polyurea coatings illustrated here to form the coating on an outer surface could be made from various other materials. One alternative is to use polyurethane coatings. Such a variation would not materially affect the nature of the invention.

The following examples are intended to describe the invention without restricting the invention to the examples.

EXAMPLE 1
Preparation of the Non-Woven Fabric

The nonwoven core material is a resin bonded, high loft nonwoven. It was produced by processing 200 denier polyester staple, 1.5" cut length (Welstrom PET, Poole Company, Greenville, S.C.), through a Rando Webber system (Rando Machine Corporation, Macedon, N.Y.) The airlaid webb was 84" wide.

The lofty airlaid web from the webber was sprayed on side one with a mixture of 95% styrene butadiene emulsion (Noveon Stycur 1177, Noveon, Inc, Cleveland, Ohio) and 5% melamine (Resiminede-7551, Ineos Melamines, LLC, Springfield, Mass.). The mixture contained black pigment. The web was processed through an oven set at 300°F to cure the mixture. The web was turned over upon exiting and the other side was sprayed with the same mixture and processed back through the same oven. The web was turned again upon exiting and passed a third time through the oven.

The cured web was passed through a dip and squeeze pad where phenolic resin (resole, Fenolica de Monterrey) was saturated into the web with the excess squeezed away. The wet web was sprayed on side one with the phenolic resin and passed through another oven at 400°F to cure the resin. The web was turned over upon exiting the oven and sprayed on the other side with the phenolic resin. The web passed through the oven a second time, was turned over upon exiting and passed back through the oven a third time. The cured web was cut into sheets (78x49 inches) after exiting the second oven. The final thickness was approximately 1.5 inches.

EXAMPLE 2

A material that can be applied to the surface of the tooling board and can be machined is given below. The materials in the curing are blended together and then mixed in a spraying apparatus in a 1:1 by volume ratio with the isocyanate and deposited on the surface of the tooling board. The thickness of the sprayed layer is dependent on the needs of the tooling board. The sprayed layer may be machined to accommodate contours needed for the part to be prototyped or manufactured. The material can be sprayed using a E-XP-2 Reactor manufactured by Graco.

<table>
<thead>
<tr>
<th>Material</th>
<th>CAS Number</th>
<th>Weight</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyol 30-240</td>
<td>25791-96-2</td>
<td>75.7</td>
<td>Monument Chemical</td>
</tr>
<tr>
<td>1,4-Butanediol</td>
<td>110-63-4</td>
<td>17.6</td>
<td>Sigma Aldrich</td>
</tr>
<tr>
<td>Water</td>
<td>3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terephthylene diamine</td>
<td>281-57-9</td>
<td>1.7</td>
<td>Grubeck</td>
</tr>
<tr>
<td>Bis-(2-dimethylaminoethyl)ether</td>
<td>3033-62-3</td>
<td>1.0</td>
<td>Huntsman</td>
</tr>
<tr>
<td>Silstab 2100</td>
<td>0.5</td>
<td></td>
<td>Siltech Corp.</td>
</tr>
<tr>
<td>Isocyanate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM 200</td>
<td>9016-87-9</td>
<td>135</td>
<td>Hanson Group</td>
</tr>
<tr>
<td></td>
<td>101-68-8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXAMPLE 3

A material that can be used to adhere the layers together is given below. The D 2000 and DETDA are blended and then sprayed in a 1:1 volume ration with the PM 200.

<table>
<thead>
<tr>
<th>Material</th>
<th>CAS Number</th>
<th>Weight</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 2000</td>
<td>9046-10-0</td>
<td>25</td>
<td>Hanson Group</td>
</tr>
<tr>
<td>DETDA</td>
<td>68479-98-1</td>
<td>60</td>
<td>Hanson Group</td>
</tr>
<tr>
<td>PM 200</td>
<td>9016-870-9</td>
<td>100</td>
<td>Hanson Group</td>
</tr>
<tr>
<td></td>
<td>101-68-8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXAMPLE 4

The temperature response of the material in this invention is compared to responses for commercial tooling.
board materials, FIG. 6. The density of the commercial samples is listed on the plot legend. The commercial tooling boards are made from rigid polyurethane foam. All samples were 4 inches long x 2 inches wide x 1.5 inches thick. A thermocouple was placed 1.5 inches inside each sample into the length dimension and the half point for the height dimension.

The second Y axis of the plot shows the oven temperature for the test. The first Y axis shows the percent difference between the oven temperature and the thermocouple in each sample of tooling board. It can be seen that the difference between the oven temperature and the interior of a tooling board is always much smaller for the tooling board of the invention.

Definitions

[0045] Tooling panel (board) are molds or shapes used to manufacture parts.

[0046] Highlofts are low-density fibrous structures with a high ratio of thickness to mass per unit area. This is done by bonding or interlocking fibers using mechanical, chemical, thermal and/or solvent means.

[0047] Denier is a unit of measurement that describes the linear mass density of the material, calculated by the mass in grams of a single 9,000 meter strand.

[0048] Staples is a fiber of standardized length and may be of any composition.

[0049] Staple length is a property of staple fibers. It refers to the average length of a group of fibers of any composition. Staple length depends on the fiber. For example, the staple length of natural fibers such as cotton or wool has a range of lengths in each sample and is an average value. Staple length for synthetic fibers which have been cut to a certain length is essentially the same for every fiber in the group.

[0050] Air laid refers to manufacturing technology that produces a web of fibers. In this specific case, the process used staple fibers that are coated with bonding agents such as latex emulsions, thermoplastics or some combination of both.

[0051] Web is a continuous sheet of material.

What is claimed is:

1. A product comprising:
   (a) a non-woven material containing fibers that have been coated with a resin; and
   (b) a coating on an outer surface of the non-woven structure with a material that can be formed into desired contours.