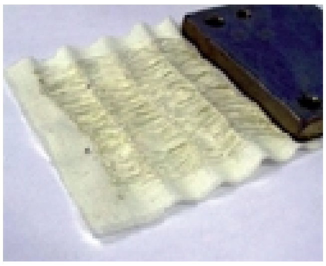
http://www.leapfrog-eu.org/LeapfrogIP/main.asp?pg=rma_results#Shape%20Memory%20Fabric

Shape Memory Fabric



Leapfrog Stimuli Sensitive Fabrics are hybrid textile structures able to modify their shape when exposed to a flow of hot air. They are composed by traditional yarns (Cotton and Nylon) and Stimuli Sensitive Polymers properly woven in a double weave structure. The potential use of these products, within Leapfrog project, regards the automatized assembly of garments: these easily deformable structures could facilitate the overlapping of different shaped fabrics by simply applying hot air, avoiding any manually arrangement. Besides their double weave structure could facilitate the laser welding process: the polymer side could be easily laser welded, avoiding delamination problems and maintaining the external surface complete with proper aesthetic and touch effects.

Three different Stimuli Sensitive Fabric (Sample 1, 2 and 3) were manufactured with three different Polymers, having Activation Temperatures of 40℃, 80℃ and 50℃.

After an evaluation of several textile structures, it was decided to use the double weave method, in order to improve comfort and maximize the Stimuli Sensitive Effect of the final product. In fact the upper surface of the fabric has a great density of Thermal Active Polymer, able to react to temperature change, while the lower side is composed by light and comfortable Cotton.

After setting up the process parameters, in terms of textile machinery, number of strokes and heddle, the obtained fabrics were exposed to hot air flow up to their Activation Temperature (Tg). The temporary shape of the Stimuli Sensitive Polymer was set by cold drawing, it was deformed during the weaving process into a new shape and then, when heated above their Tg, it immediately returns to its original shape, length and diameter, causing a 3D macro-deformation and quick shape change in the final fabric.

Sample 1 showed the strongest reaction to Temperature change with quick 3D macro-deformation also at low Temperature (40℃): it's enough the air flow of an hair dyer to activate the fabric movement.

Sample 2, instead, showed lower and slower 3D macro-deformation, because of the small count of the Stimuli Sensitive Filament and its higher Activation Temperature (80℃), but the deformation is at the end more stable and strong.

The PU based Leapfrog filament, finally, was not suitable to be inserted in any textile machine: it was manually sewn on a light cotton fabric, showing only wrinkle formations.

Other potential applications of these Stimuli Sensitive Fabrics, outside Leapfrog project, could regards the development of smart medical bendage, able to maintain its shape when applied to warm surfaces (human body), and activated flexible protective shielding able to close itself around its content in case of necessity.

Purpose and Scope

The smart polymer material processed into yarns, cured and stabilized, can be woven or knitted for the production of fabrics showing marked shape memory properties. SMFab was produced with the purpose of achieving a smart, stimuli sensitive active garment. It is expressly devoted to the cooperation with the reshapeable mould. SMFab capable of being shaped / sized by exploiting different operating temperatures, drastically reducing joining was the goal. These fabrics take into account the cooperation with a robotic end-effector in the automated (garment assembly) cell. They allow optimal control of the shape and size change phenomena. Through the prediction of the fabric behaviour it is possible to develop practical control strategies to guide the fabric handling and forming, including assembly processes as placing, folding and joining. Architecture for the production of the fabric was defined, taking into account the different specific behaviour of fabric employed. Candidate architectures included weaving, knitting, weft and warp knitting.

Characteristics and Features
The SMFab is characterized by the active reversible recovery of the initial shape. The required textile structure with a sharp and well-defined TN is obtained in textile factory with conventional weaving / knitting machines. Advanced concepts of co-spinning or fabric layered composites is introduced for the purpose of widening the potential fields of application of functional fabrics.

Position and Collaboration within the Value Creation Chain
Process Step: Fabric production
Collaboration: General collaboration is given with new product development and production management in all / most process stages regarding processing ability and quality aspects throughout the chain (behaviour of the fabrics in all subsequent processes).

R&D Approach
The intended two ways nematic shape memory polymer is characterized by the active recovery of the initial shape (set over the nematic transition TN) once this level of temperature is reached again, this effect is achieved reversibly. Characterisation of stress-strain and strain-temperature response in order to define constitutive laws was performed, to well define the behaviour of the material and to derive the basic properties of the fibre. Polymers of different chemical composition, varying the transition temperature of the meltelastomer (dynamic cross linking) transition, were tested with respect to their thermal and alignment properties.

Functionality/Mode of Operation
The two ways nematic polymer-based SMFab is characterized by the active recovery of the initial shape (set over the nematic transition temperature TN). Once this level of temperature is reached again, this effect is achieved reversibly. The required textile structure with a sharp and well-defined TN can be obtained in textile factory with conventional weaving / knitting machines. The stress-strain and strain-temperature response of the fabric was characterised. These abilities and rules were implemented in a constitutive model. The prototypes underwent thermal treatments to simulate thermo-mechanical stresses occurring in finishing operations.

Interoperability and Implementation Aspects
Application/production of SMFab in industrial scale requires appropriate production facilities. With respect to the production path identified, the different standard machines have to be modified in order to fulfil the needs of this specific product. Weaving, knitting, coating and/or sizing machines have to be properly adapted to the operating conditions. Interoperability: Physical interoperability occurs with a robotic end-effectors in the automated (garment assembly) cell, and with the adjustable mould, with the grasping device.

Pays and Pitfalls
No fabric currently exists made of yarns or filaments with the aimed at properties; the following risks and contingencies are highlighted:
Risks:

- Accuracy in the prediction of stress-strain curves of fabric with SM fibres to ensure virtual modelling and cooperation with the robotic end-effectors.

- Accurate characterisation due to the combination of properties for hybrid materials that could lead to a too great number, complex and time consuming identification and analysis of the variables; realistic or real time simulations due to the difficulty to develop efficient models based on these material characterisations.
- Effective stiffening that may lead to failure in handling.

Contingency:

- Constitutive modelling of the smart polymer, and fabric produced thereto, was based on uniaxial loading conditions to prove the general laws with extensive experimental activities to multiaxial loading.
- Different polymer solutions were considered. Trials and error approaches complemented by modelling and proper design of experiments minimised the risks.

Innovation Set

The smart polymer material can be processed to form yarns suitable for being used in weaving, knitting or sewing activities. The polymeric raw material filaments are transformed into yarns, which can be inserted in functional stimuli-responsive textiles in the following activities. Fibres of shape memory materials are expressly designed to perform reversible actuation in response to diverse energetic stimuli, such as thermal or light - UV rays. The most suitable process method to obtain yarns is through spinning. One of the main issues is related to the development of a mechanism that allows limitation of the amount of wasted raw material, and the achievement of enough mechanical resistance for the subsequent textile operations.

The smart polymer material processed into yarns, cured and stabilized, can then be woven or knitted for the production of fabrics showing marked shape memory properties.

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Video

http://www.youtube.com/watch?v=UmrrhNrVRwE

Images

http://www.leapfrog-eu.org/LeapfrogIP/download.asp?file=results_Documents/Shape_Memory_Fabric.pdf