Analysis of the Absorption Energy for NiTi Wires under Different Diameters and Loop Types

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Abstract

This paper presents the research undertaken at the University of Minho aiming to study the the behaviour of 3D weft-knitted structures using SMA wires and elastomers, in order to produce dynamic structures as a support to answer specific situations and applications. Several samples were produced using nitinol® wires in different diameters and loop types. The Tensile tests were carried out being based to NP EN ISO 2062:1993 standards, using a H100KS Hounsfield Universal Testing Instrument. The results showed that The 50µm wire showed to be too thin to this propose; moreover, The 210µm NiTi wire showed to be hard to process on the knitting machine due to its high stiffness; The 127µm NiTi wire showed to be the best among them, due to the process and energy absorption ratio. Finally, for both NiTi wires in different diameters studied, tuck loop showed to have the highest energy absorption capacity.

Keywords: Nininol® Wires; Knitted Structures; Energy absorption.

1. Introduction

This paper presents the research undertaken at the University of Minho aiming to study the behaviour of weft-knitted structures produced with SMA wires. It is widely acknowledged within the textile engineering community that Shape Memory Alloys (SMA), exhibit great potential for several applications.

Ultimately, fibers, yarns, fabrics and other fibrous structures with added-value features have been successfully developed for specific applications as technical and/or high performance end-uses. An excellent overview of smart technologies for clothing design and engineering was provided by Tang and Stylios, 2006**[1]**. Technical textiles have been promoted as alternative materials for an unlimited range of applications including medical, automotive, aerospace, civil and mechanical engineering, among others**[1, 2]**.

According to Tao, 2001**[3]**, shape memory materials have been considered as an ultra smart material, because they have the ability to sense stimuli and react according to the programmed way, by moving the internal molecular structure, leading the material for a pre-programmed shape. These physic factors stimulate the Shape Memory Effect (SME), making them to reach and transform as a specific shape, position, force or another pre-programmed characteristic**[4]**. Wherefore, when the stimulus is applied on a SMM, this must return to its memorized shape without deformations. However, the SME should be only performed if the stimuli achieve the glass transition temperature of SMM**[5]**. Shape memory materials (SMMs) can rapidly change their shapes from a temporary shape to their original (or permanent) shapes under appropriate stimulus such as temperature, light, electric field, magnetic field, or others**[6]**.

Shape memory alloy wires are widely used for permanent works in various applications such as on stents**[7]**, eyeglass frames, coffee pot thermostats, electrical connectors, heat pipes, clamps, and sculptures, medical apparatus, textiles applications, among others. Especially on clothing sector, high performance materials have attracted much interest for designs, sports and protective clothing**[1]**.

The SMAs have been used in textiles, due to their functional and aesthetical application. The processability of SMA in textile field is dependent upon a range of factors to be conducted in a positive manner, among which stands out the flexibility of the wire (required to being knitted) **[8]**. The SMA can be woven and knitted, both in their original wire form, and as bi-component yarns. Good aesthetic shape memory effects have been produced using SMAs in the clothing industry, with interesting "lively" effects on the garment. However, the incorporation of an excessive amount of alloy wires in the textile structure may lead to a detrimental effect on the handle and touch of the fabric**[9, 10]**. Challenges in the manufacturing and making-up processes, mostly caused by the lack of extensibility of the alloy during weaving or knitting, also need due consideration.

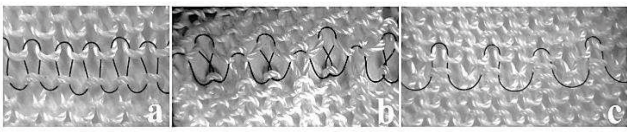
2. Experimental

For the current work, Nitinol® wires type B (which shows SME at body temperature) were used, with three different diameters: 50µm, 127µm and 210µm, in order to produce weft-knitted fabrics with three different loop types: stitch, tuck and miss. The samples were produced on a flat knitting machine, with 8 needle/inch, based on a single jersey structure. The structural parameters of the samples are listed in Table 1.

Table 1: Structural parameters of the samples

Parameters	Miss loop			Stitch loop			Tuck loop		
Wire diameter (µm)	50	127	210	50	127	210	50	127	210
Loop Length (mm)	3,7	4,9	4,2	4,9	6,7	6,1	5,4	7,2	6,9

A 70tex acrylic yarn was used as a basis for the formation of loops with the nitinol® wires in the samples. The stitch loop structure (single jersey), were made using stitch loop on the ground structure and for the NiTi wire course. The knitted structure with tuck loops, were produced by alternating stitch loops with tuck loops in adjacent needles in the same course and the knitted structure with miss loops, had been produced by alternating sticth loop with miss loop in adjacent needles in the same course, as shown on Figure 1 (a, b and c), respectively.



(a) (b) (c)

Figure 1: Knitted structures showing stitch loop (a), tuck loop (b) and miss loop (c).

After the sample production, the NiTi course had been removed from each sample, as can bee seen in Figure 2.

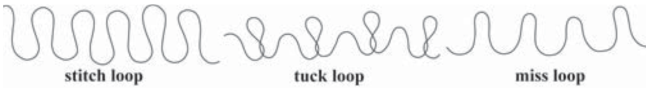


Figure 2: Knitted courses produced with NiTi wires

The NiTi course samples were then placed into an oven with a temperature of 550°C, during 30 minutes, in order to memorize the shape of the wires, according to the deformed loop types[11].

The samples of NiTi knitted courses were used to analyse the deformation force energy. The Tensile tests were carried out being based to NP EN ISO 2062:1993 standards, using a H100KS Hounsfield Universal Testing Instrument, using an initial gauge length of 95mm and crosshead speed of 10mm/min, as shown in Figure 3. Three tests were carried out for each sample, to calculate the influence of the loop type on the performance of the weft-knitted fabrics, in terms of energy absorption.

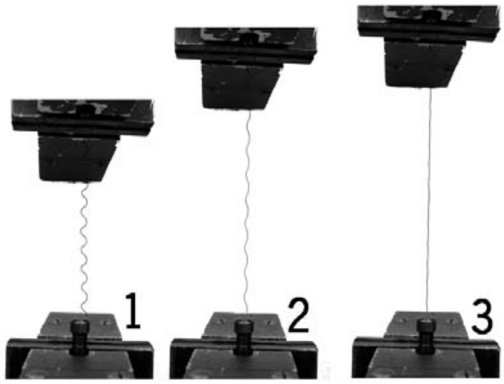


Figure 3: Test Method at initial position (1), medium deformation (2), linearity of the wire (3)

The values were generated for each experiment and were treated using the software OriginPro®8. The results are shown on table 2.

3. Results and comments

The energy absorption for the different loop types was calculated using the software OriginPro® 8. The energy absorption was calculated using the mechanical deformation data. For this calculation the area corresponding to the initial part of the curves to the point where the loop deformation stops and begins the elastic zone of the material, has been considered. The results are shown in Figs. 10, 11 and 12, respectively and the resume is shown in Table 2.

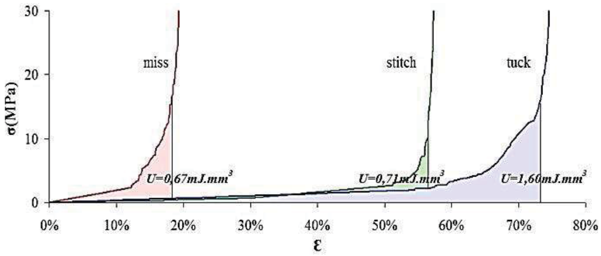


Figure 4: Deformation energy of 50µm NiTi wire for different type of loop structure

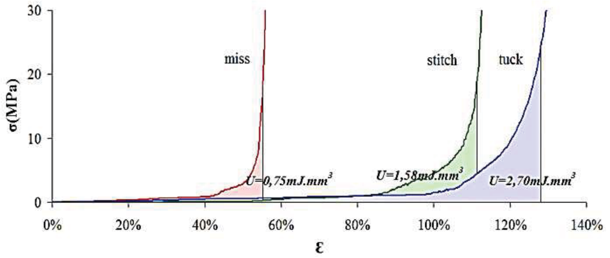


Figure 5: Deformation energy of 127µm NiTi wire for different type of loop structure

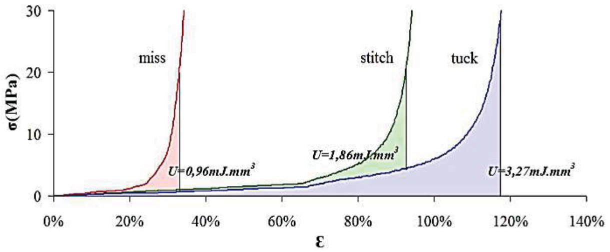


Figure 6: Deformation energy of 210µm NiTi wire for different type of loop structure

Table 2. Energy absorption for different loop types

Energy		NiTi wire diameter		
		50µm	**127µm**	**210µm**
Loop type	**Miss**	$0{,}67 mJ.mm^3$	$0{,}75 mJ.mm^3$	$0{,}96 mJ.mm^3$
	Stitch	$0{,}71 mJ.mm^3$	$1{,}58 mJ.mm^3$	$1{,}86 mJ.mm^3$
	Tuck	$1{,}60 mJ.mm^3$	$2{,}70 mJ.mm^3$	$3{,}27 mJ.mm^3$

4. Conclusions

Different types of weft-knitted loops using NiTi wires have been studied. Several conclusions could be taken considering the processability of the NiTi wires:

- the 50µm wire does not represent great percentage of SMA in the knitted structure, which can avoid its smart effect.
- - The 127µm NiTi wire shown to be the best among the analysed ones, due to the process and energy absorption ratio.
- the 210µm NiTi wire shown to be hard to process on the knitting machine due to its high stiffness. In Table 2, are shown the resume for the energy absorption for different loop types[10].

Finally, for the same NiTi wire diameter, tuck loop presents the highest energy absorption capacity. Moreover, larger energy absorption capacity has been obtained for higher NiTi wire diameters. The results obtained may be a good contribution to design weft-knitted structures with shape memory ability.

Acknowledgement: The authors acknowledge to the Capes Grant – Proc. nº BEX 0547/09-3

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