ELASTIC, ELECTRICALLY CONDUCTIVE TEXTILE STRUCTURES FOR INTELLIGENT TEXTILES

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ABSTRACT

The emerging of intelligent textiles in recent years has exposed the necessity of *e-textiles* (electronic textiles). These are textiles with electrically conductive properties, under the form of fibres, yarns or textile structures. The e-textiles developed and produced in the framework of this project have the additional property of being elastic. To obtain this property, metallic yarns are spun around an elastic core, applying a hollow spindle spinning machine. Mechanical and electrical properties of the obtained elastic, electrically conductive yarn are reported.

1. INTRODUCTION

In October 2007 the TETRA[1] project **'el2vint'** [1] (which stands for **'elastic, electrically conductive textile structures for intelligent textiles'**) started and continues for two years. It is a joint project between the textile departments of Ghent University and University College Ghent. Additionally, a selection of Flemish companies form a user committee in order to contribute to the project. The project results from a need for conductive elastic yarns to be applied into wearable textiles systems, where sensorized fabrics are part of the garment [2,3]. These systems commonly rely on electrical properties and can benefit from elastic properties when integrated into a garment, e.g. a heart rate sensor can be brought in close contact to the skin when integrated into a stretchable undershirt.

Conductive yarns can be produced in various ways such as spinning of metal fibres or metalizing polymeric yarns. Different properties in terms of conductivity or touch are obtained. This project focuses on manufacturing elastic yarns that are electro conductive, process them in textile structures and characterize them in terms of mechanical and electrical properties, processablity, durability. The yarns are developed applying the hollow spindle spinning process, where an elastic core yarn is combined with an electrically conductive yarn. A variety of yarns based on stainless steel and on copper have been produced and tested in the first project year. Textile structures are manufactured in collaboration with Flemish textile companies.

During the second project year, up scaling guidelines for the manufacturing of the yarn will be formulated. Furthermore, three prototypes in which the electrically conductive elastic yarns are applied, will be worked out.

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2. YARN MANUFACTURING

2.1 Yarn design

The elastic, electrically conductive yarn is produced in a mechanical way by combining an *elastic nonconductive yarn* with a *nonelastic conductive yarn* on the hollow spindle spinning machine ‘Elextraspinroc’ that is available at the Department of Textiles at University College Ghent. This spinning machine is commonly used to spin fancy yarns but was additionally equipped with a feed device for elastic yarns. The yarn design is based on an elastic, nonconductive core yarn with a metallic, nonelastic binder yarn wound around the core, as illustrated in Figure 1. The elasticity of the combined yarn (which will be referred to as ‘el2vint’ yarn) is maintained because of the spiral shape of the nonelastic yarn. This metallic binding yarn can be given a Z-twist or/and an S-twist. For all produced yarns, the core is covered with 2 identical metallic yarns, one in Z-direction, the other in S-direction. The number of times the yarn is twisted around one meter of elastic core yarn is expressed as ‘*twist*’.

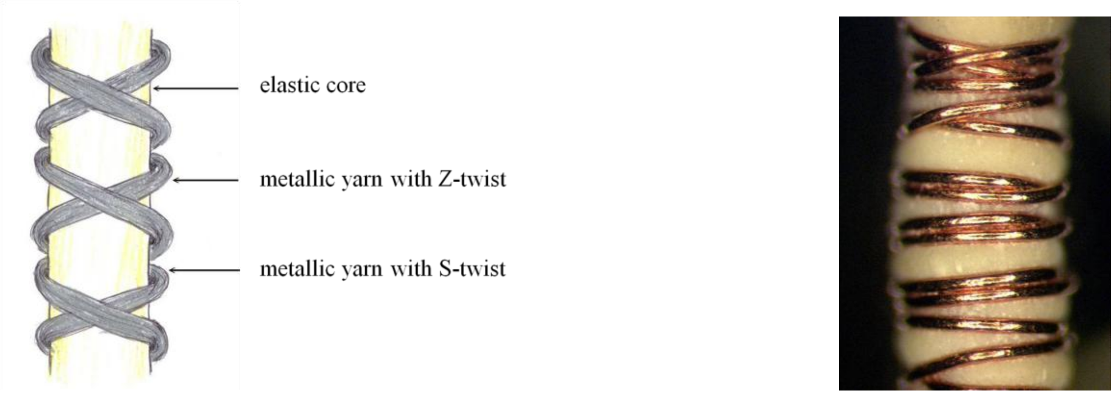

Figure 1 - Schematic representation of el2vint-yarn and el2vint yarn with copper

2.2 Basic yarns

Table 1 gives an overview of the yarns used as basic material. A selection of elastic core yarns was provided by members of the user committee. It should be noted that the rubber based yarns (K1-K4) have a significantly larger diameter than the elastane yarns (K5 – K6). Stainless steel-based [4] and copper-based metallic yarns are chosen as conductive material, of which copper is much more conductive than stainless steel (conductivity of stainless steel is 1.4 S/m and of copper 59.6×10^6 S/m) .

Table 1 – Overview of the basic yarns

Core yarn		Metallic yarn	
K1	Rubber	O1	Stainless steel staple fibre yarn
K2	Rubber covered with polyamide	O2	Stainless steel multifilament yarn (235 tex)
K3	Rubber covered with polyamide	O3	Stainless steel multifilament yarn (110 tex)
K4	Rubber covered with polyester	O4	Stainless steel multifilament yarn (505 tex)
K5	Elastane with polyamide	O5	Copper thread with silver coating (0.056 mm)
K6	Elastane with polyamide	O6	Copper thread (0.050 mm)
		O7	Stainless steel thread (0.035 mm)

2.3 Produced elastic, electrically conductive yarns

Several elastic and metallic yarns were combined. An overview is given in Table 2. For some combinations, yarns with a different twist were produced, they get the extention .a or .b in the name. Variation in twist results in other electrical properties but also in a different coverage of the core yarn. If an application requires that the core yarn is entirely covered, also upon stretching, a high twist will have to be applied.

Table 2 – Overview of the produced yarns

	O1	O2	O3	O4	O5	O6	O7
K1	K1O1		K1O3.a	K1O4	K1O5	K1O6.a	K1O7.a
			K1O3.b			K1O6.b	
			K1O3.c			K1O6.c	K1O7.b
			K1O3.d				
K2	K2O1		K2O3		K2O5	K2O6	
K3	K3O1				K3O5.a	K3O6.a	K3O7
					K3O5.b	K3O6.b	
K4					K4O5	K4O6	K4O7
K5						K5O6	K5O7

3. EL2VINT YARN PROPERTIES

Several mechanical and electrical properties of the el2vint-yarns were measured. The results of the copper based yarns are reported here. Results on the other yarns are also available.

According to the law of Pouillet, resistance in a wire is given by

$$R = \rho\, l/A$$

where ρ is the material's resistivity (inverse of conductivity and expressed in Ωm),
l is the length of the wire and A is its cross section. Thus, doubling the length l over which the resistance is measured, will result in a double resistance R. All of the following conclusions are based on this law.

The electrical properties of the el2vint-yarns are expressed as the *linear resistivity*, being the resistance measured over a certain length (in Ω/m). Since we are interested in how the el2vint-yarns behave upon stretching, the resistance is measured of the yarn in relaxed state (0 % elongation) and when stretched till 100 %.
From Table 3 we learn that this linear resistivity of a 100 % stretched yarn is about half of that

in relaxed state. This corresponds with an invariable resistance (in Ω) of the yarn when stretched from 1 to 2 meters, which was expected since the total length of conductive yarn does not change when the el2vint-yarn is stretched.

The change in resistivity was also measured after stretching the yarn a great number of times (e.g. 2150 times), up to 25 % of its original length. In all cases an increase in linear resistivity was observed. This could be explained by damage of the metallic yarns whereby electric current flow is obstructed and overall resistance increases.

Table 3 – Linear resistivity in Ω/m of copper based yarns

El2vint yarn	Relaxed state	Stretched until 100 %	After repeated stretching
K1O6.b	21	11	40
K1O6.c	36	19	58
K2O6	36	18	56
K3O6	36	18	60

When taking 1 cm of el2vint-yarn and unwrapping the metallic binding yarn, a length of several centimeters will be obtained. Accordingly, 1 cm of el2vint-yarn will measure a much higher resistance than 1 cm of pure metallic yarn. Figure 2 shows this increase in linear resistivity.

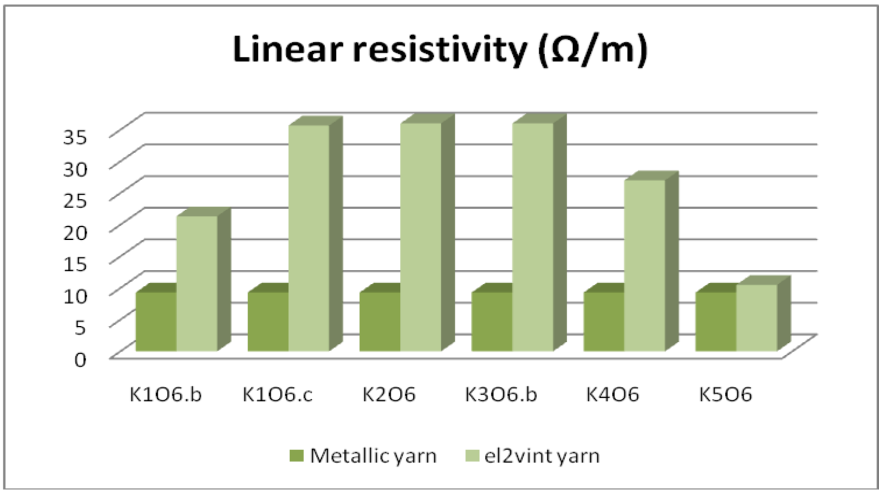

Figure 2 – The el2vint-yarn is less conductive then the basic metallic yarn

Variation in the linear resistivity can be achieved by changing the twist of the binder yarn around the core. In Figure 3, a copper yarn is twisted with 2 different twist levels (3200/2700 and 5000/5000) around the same core yarn. A higher twist requires a longer length of binder yarn and thus results in a higher resistance and linear resistivity.

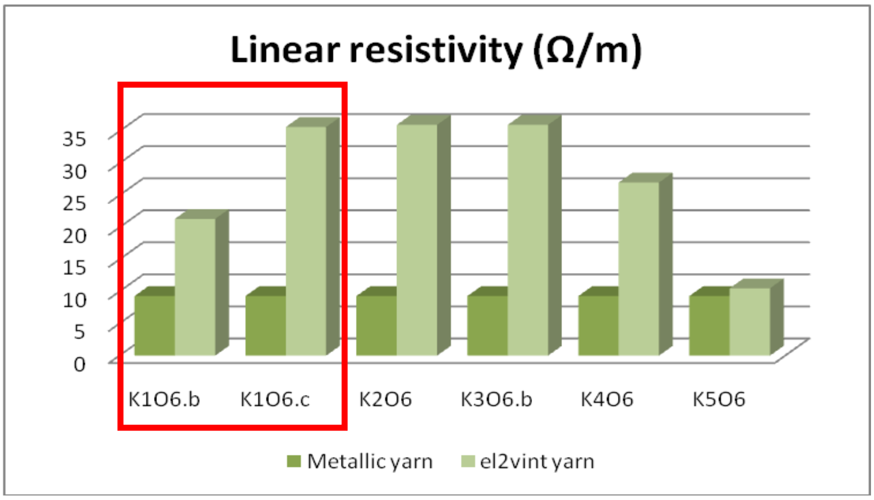

Figure 3 – A higher twist results in a yarn with a higher linear resistivity
K1O6.b 3200/2700 per meter
K1O6.c 5000/5000 per meter

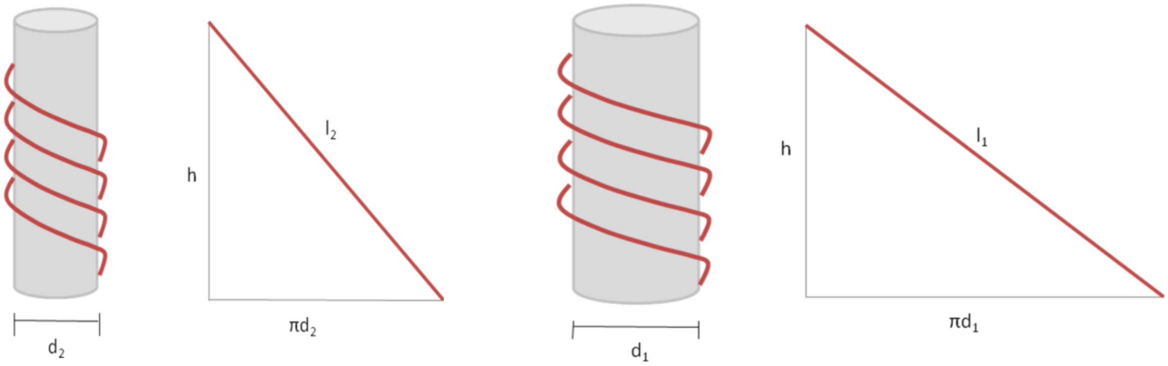

Figure 4 – The length of the binder yarns increases when an equal twist is applied on a core yarn with a larger diameter

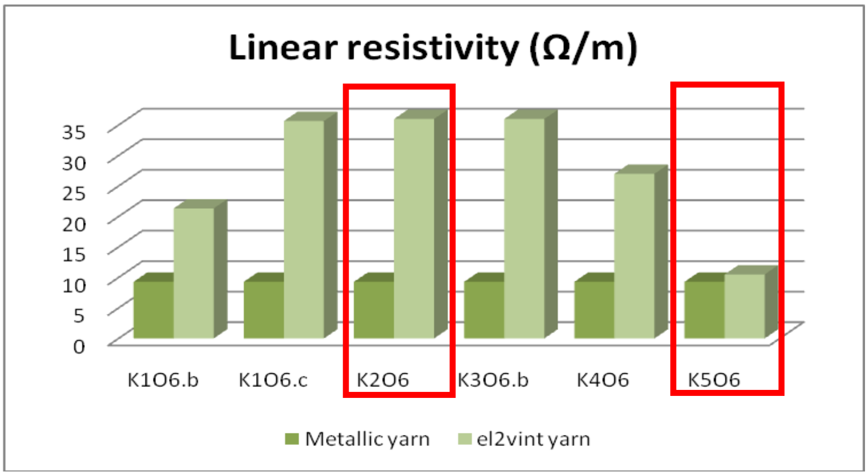

Figure 5- The same twist (5000/5000) but with a thicker core yarn (K2 is rubber, K5 is elastane) results in a higher linear resistivity

Figure 5 demonstrates that a thicker core yarn leads to a yarn with a higher linear resistivity when an equal twist is applied. K2 is a rubber core with a much higher cross section than the elastane yarn K5, leading to a larger length of conductive binding yarns and consequently to el2vint yarns with a higher resistivity In Figure 4 the relation between the diameter of the core yarn and the length of the binding yarn is illustrated.

4. CONCLUSIONS

The results till now proof the feasibility of producing elastic, electrically conductive yarns based on the hollow spindle spinning technology, commonly used to produce fancy yarns. The yarns combine an elastic core yarn with a metallic binder yarn. The linear resistivity of the resulting yarn depends on various parameters, such as the resistance of the metallic binder yarn, the applied twist, the thickness of the elastic core yarn.
In a second stage of the project these yarns will be integrated in elastic textile structures.

5. REFERENCES

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