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The effects of ramie blended car seat covers on thermal comfort during road trials

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ABSTRACT

The main objective of this study was to investigate the thermal comfort effects of ramie blended seat cover (RBSC) material on drivers. In the experiment, polyester seat covers (PSC) were compared to RBSCs. Both quantitative (measured) and qualitative (perceived) thermal comfort data were collected under normal traffic conditions. Ten volunteer subjects (seven males and three females) who had at least 5 years driving experience and were between 30 and 35 years of age were selected to participate in the study. During trials, temperature was measured at four points that have direct contact between the driver and the seat. Skin wettedness was measured at the back of the subject's torso. During the trials, subjects provided qualitative data by responding to a five question survey administered at 5 min intervals. A significance level of 0.001 inferred that subjects preferred RBSC over PSC seat covers.

Relevance to industry: This study demonstrates the effects of ramie blended seat cover material (RBSC) and real traffic conditions in thermal comfort. Industries can use our findings to evaluate their ergonomic seat comfort in vehicles and the results of this study can be applied to related industrial applications.

1. Introduction

1.1. About ramie

Ramie (*Boehmeria nivea*) is one of the oldest fibre crops, and is principally used for fabric production. This fibre is known especially for its ability to hold shape and to introduce a silky lustre to the fabric appearance. Ramie fabrics are strong, smooth and durable. It is extremely absorbent and therefore comfortable to wear, especially in warm weather. Ramie is the most resistant to mildew and rotting of all plant fibres. It can be washed without any problems and dries quickly and it has a very high tear resistance. It is reported to have tensile strength eight times that of cotton and seven times that of silk (André, 2006; Liu et al., 2001; Lu et al., 2006).

The mechanical properties of ramie fibres have been widely studied and characterized by tensile tests of single filaments. Its tensile strength is about 870 MPa (Xu et al., 2001), the density is l.50 g/cm^3 (Wen et al., 2006), moisture content is 8 wt% (Mohanty et al., 2000), absorbed humidity is up to 31% (Paiva Junior et al., 2004). Nishino et al. (2004) reported a Young's modulus of 42 GPa (standard deviation: 9 GPa) and a tensile strength of 730 MPa (SD 190 MPa). Lodha and Netravali (2002) reported higher or lower values, but since the ramie fibres' mechanical properties also depend on the length and the diameter of the fibres, the differences cannot be considered significant.

Ramie is mostly blended (commonly 55% ramie and 45% cotton) with other fibres for its unique strength and absorbency, lustre and dye-affinity. When blended with high-quality cotton it offers increased lustre, strength and colour. When mixed with wool, ramie adds lightness and minimizes shrinkage. When polyester is included in the blend, ramie improves wrinkle resistance and helps provide easy care and shrinkage control. Ramie cloth is a good reinforcement material for UP resin (Wen et al., 2006). Pal et al. (2003) investigated the properties of ramie fibre reinforced polyester. The produced composite exhibits better flexural strength and less water uptake. According to Paiva Junior et al. (2004), composites with 45% ramie fibres showed an increase in tensile strength over the bare polyester resin of up to 338%.

1.2. Environmental considerations and use of ramie in autos

According to the European Guideline 2000/53/EC administered by the European Commission, 85% of the weight of a vehicle has to be recyclable by 2015 (EU Directions, 2000). The debate about the preservation of natural resources and recycling has led to renewed interest in biomaterials with the focus on renewable raw materials. The use or removal of traditional composite structures (such as

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structures made of glass, carbon fibres reinforced with epoxy, unsaturated polyester, or phenolics) are considered critical, because of increasing environmental consciousness and demands of legislative authorities (Mohanty et al., 2000). Natural fibres play an important role in developing high performing fully biodegradable 'green' composites, which will be key materials to solve the current ecological and environmental problems in societies where global warming issues have become almost uncontrollable (Goda et al., 2006). Green composites can replace man-made fibre applications due to their high values of stiffness and strength (Angelini et al., 2000). Natural fibres have low cost, low density, competitive specific mechanical properties. In automotive parts, compared to glass composites, composites made of natural fibres reduce the mass of the component and can lower the energy needed for production (Mohanty et al., 2004).

The use of vegetable fibres such as kenaf, ramie, jute, flax, hemp and cotton has a good potential for automotive applications. Vegetable fibres are used in the most recent Mercedes, BMW, Renault, Volvo vehicles, etc. to produce interior panels (headliner, wall panels, trunk liners, parcel shelves, and hood sound insulators, etc.) (André, 2006). By using these bio -based composites, mechanical strength and acoustic performance will be enhanced, and material weight and processing time will be reduced (Chen et al., 2005; Lodha and Netravali, 2005).

Vegetable fibres also keep the car interior warmer in the winter and cooler in the summer and the thermal insulation properties of these materials vary significantly, depending on the type of vegetable fibre (Yachmenev et al., 2006). For ramie composites, thermal diffusivity and thermal conductivity values are high and vary with the direction of the heat flux (Alsina et al., 2005). Natural fibres are good humidity regulators, insulate well against heat and noise and reduce component weight due to their hollow structure.

1.3. Aim

Thermal comfort is considered an important factor in the ergonomic evaluation of driver seats. One of the main determinants of thermal comfort in seats is cover material. A car seat cover material should be resistant to ultraviolet degradation and abrasion, durable, and also be breathable and transport moisture. Fabric blended with vegetable fibres such as ramie are adequate as seat cover materials because of their properties. There is a gap in the literature concerning systematic studies on ramie blended car seat fabric for thermal comfort. An experimental study is therefore needed on the thermal behaviour of drivers in real traffic conditions.

Human thermal comfort in automobiles is a complex task. Climate is far from uniform and considerable local thermal effects must be visualized and evaluated (Nilsson, 2006). Comfort analyses are based on several evaluation methods. These methods can be theoretical or simulation by computer, in a laboratory using human subjects, in a laboratory using a thermal manikin, or on the road with participants. According to Rosendahl and Olesen (2006), thermal manikins are not always directly comparable due to differences between the various manikin types. Testing on the road is difficult but real traffic conditions affect comfort level directly. In a previous study by Cengiz and Babalık (2007), polyester seat covers were evaluated for thermal comfort in road trials.

In this study, RBSC, which is a new material for seat covers, was compared with polyester seat covers. The aim of this study is to show how RBSC influences seat comfort. The experimental evidence will provide a better understanding of existing relationships between RBSC and thermal comfort. The results of this study can be considered a suggestion for car manufacturers.

2. Experimental study

2.1. Participants and clothing

The participants consisted of 10 healthy Turkish volunteer drivers (seven males and three females) and they were the same ones as in the previous study (Cengiz and Babalık, 2007). This same sample of participants was used for two experiments on two different days. The body mass indexes (BMI) of participants were between 18.5 and 27.05. Other characteristics of participants are given in Table 1. They fulfilled the following three criteria: resident in the Bursa municipality; possessing a valid driving license for at least 5 years; between 30 and 35 years of age.

Clothing was provided for the participants during the trials except underwear, socks and shoes. The provided clothes consisted of a white shirt and trousers. The approximate insulation value of the entire clothing ensemble was 1.5 clo (ISO 9920, 1995).

2.2. Seat cover materials

Two seat cover materials were used in this study: 100% polyester (PSC) and ramie blended fabric. In general, polyester is used as seat cover material because of its cost and strength. The outstanding characteristics of this material are its ability to resist wrinkling and to spring back into shape when creased. In addition, polyester has good dimensional stability, washes and dries easily and quickly, and has excellent wash-and-use or minimum-care characteristics. In this study, PSC was obtained from Martur Ltd, Turkey.

RBSC fabric was supplied from Climatex, Rohner Textile AG. This fabric is a mixture of pure wool, polyester and ramie:

- *Polyester* with its high resistance to chafing, minimal creasing, good absorption transport;
- *Pure wool* with its high elasticity, good heat conservation, great moisture absorption;
- *Ramie* with its great absorbency, cooling effect and strong moisture transport that acts as a middleman between pure wool and polyester.

The ratio of components was 20% polyester, 60% pure wool and 20% ramie. These materials assure an optimal environment through vertical and horizontal moisture transport.

2.3. Road trials

Objective and subjective data collected on the road were compared .This study is a continuation of a previous study conducted by Cengiz and Babalık (2007) and the same methodology and participants were used for thermal comfort evaluation .

All experiments were performed on sunny days at the same time of the day, at 11:00 am and 02:00 pm considering the variability of thermal conditions both in the car and outside. Drivers were requested to keep their driving activities as similar as possible prior to driving on each of the trial days. These standardizations

Table 1
The characteristics of the 10 participants (seven males, three females).

	Mean	Minimum	Maximum
Age (years)	31.8	30	34
Height (cm)	174.77	155	189
Weight (kg)	70.13	51	87
Body mass index (kg/m^2)	22.95	19.87	27.05
Driving experience (years)	7	5	12