博 士 論 文 の 内 容 の 要 旨

氏名	CHUANG, YU CHUN
学位名	博士（工学）
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論文題目	Research study on the reuse of textile waste selvage for high-performance mechanical properties: stab-proof and buffering applications （高力学特性的な応用を目指した繊維加工廃棄物の再利用に関する研究-防突き刺しおよび緩衝用途）

（博士論文の内容の要旨）

Fibrous and textile materials have a great diversity of applications, from domestic and industrial purposes to custom-made special functionality requests. Therefore, with the rapid development of the textile industry, a large amount of textile waste is produced. Textile waste includes waste from fiber processing (fiber flock and cotton linter), waste from spinning engineering (waste yarn), waste from textile processing (rag and selvage), and discarded textiles in people's lives (discarded clothing, textile decoration, bedsheets), and so on. Meanwhile, the textile wastes include those high performances, high strengths, and high modulus fibrous materials. According to statistics, more and more textile waste is produced every year around the world. If the recovery rate of these wastes can be improved, it can reduce wastes while creating new value and save the earth's resources.

This thesis investigating the recycle manufacture design which uses the high performance of m-aramid (Nomex®), ρ-aramid (Kevlar®), and polyester (PET) waste selvages. This thesis analyzes the structure of waste selvages and uses non-woven processing technology to recycle waste selvages. The principle and mechanism of nonwoven processing technology are used to destroy the structure of the waste selvages and evenly comb and disperse these fibers. These dispersed short fibers are then made into a recycled nonwoven fabric through a complete nonwoven manufacturing process. Because the fibers of the recycled short fiber bundles are smooth and have no crimp structure, the recycled fiber bundles are not easily dispersed during the non-woven fabric manufacturing process. Therefore, low-melting polyester fibers (LMPET) are added during the recycling process to increase the friction between the recycled short fibers and the nonwoven machine. The recycled fibers take up 50, 70, and 90 wt% of the hybrid composites and corresponding LMPET fibers account for 50, 30, and 10 wt%. When mass weight was excluded from consideration, the sample in which contents 90 wt% recycled Kevlar® had the optimal mechanical properties before hot-press treatment, and after hot-press treatment the sample in which contents 90 wt% recycled PET has the optimal mechanical properties.

Secondly, this thesis investigates the performance of hybrid-fiber-reinforced composite boards made of recycled aramid composite fabric, LMPET fabric, and aramid woven fabrics, which are laminated, needle punched and hot pressed. The test results show the tensile strength of hybrid-fiber-reinforced composite boards was 5 times greater than that of the control group, while it is tearing strength is 8.5 times greater than that of the control group. The employment of hot pressing had enhanced the properties even more. And the composite boards with hot-pressed containing 90 % recycle aramid fibers as the aramid fabric has the optimal static puncture resistance, and the major factor is the compact plain woven structure and LMPET fibers. Heat-pressing treatment creates thermal-bonds between the fibers, which can stop the slipping of aramid and LMPET fibers, fixed the structure, and increases the friction between fibers.

Then, in this thesis, I used the different reinforcing woven fabrics to combined with recycled fabrics (which made by recycled fibers) to form hybrid-fabric fibrous planks. Despite multiple combining and carding processes, the recycled PET staple fibers are proven to provide the fibrous planks with high tensile and tear strengths. The test results indicate that recycled PET fibers remain high strength and can be made into protective products. The combination of nonwoven and woven fabrics provides the benefits of their different stab behaviors, strengthening the puncture resistance of the hybrid-fabric fibrous planks. Most of all, an efficient recycling process and using textile and fiber waste to make protective fibrous planks decreases the production cost considerably, which makes the industrial and livelihood protective products more advantageous and acceptable.

In order to improve the stab resistance from the fabric structure, I study to develop sandwich-structured puncture-resistant fabric composites, and the optimal N/L/W/F/L/N has good puncture resistance at level 3 (N: Nylon/aramid recycled nonwoven fabrics；L: Low-melting PET fabrics；W: reinforced woven fabric；F: PET filament). The proposed fabric composites are characterized in terms of tearing strength, static puncture resistance, and dynamic puncture resistance. The test results indicate that thermally treated N/L/W/F/L/N has a 63.3 % greater tearing strength at CD orientation, 63.9 % greater static puncture resistance, and 32.5 % greater bursting strength than N/L/L/N. Compared to other studies, using the LPET adhesive layer had a positive influence, preventing the slide of the filaments, but the poor interfacial combination only contributes limited reinforcement. Hence, improving the interfacial affinity between laminates is suggested to be conducted in future studies.

At final, I investigate the properties of the PET/TPU buffering sandwiches in terms of the different basic weights and the number of nonwoven cover sheets on both middles, upper and lower sides which made by the needle-punching method. The results are compared with the properties of the control group (i.e. pure PET nonwoven fabrics). Similarly, so far as the PET/TPU buffering sandwiches are concerned, the residual impact stress is decreased when the number of the nonwoven cover sheets increases, and then reaches 3248 N when the buffering sandwiches are composed of 3-layered nonwoven cover sheets on both upper and lower sides. Moreover, the optimal bursting strength of the experimental group is 1336 N. To sum up, compared to the control group, the experimental group has 23.2 % lower residual impact force and 5.2 times the bursting strength. The proposed buffering sandwiches are composed of environmentally friendly TPU honeycomb grids and traditional nonwoven fabrics and are proven to have excellent buffering and protective properties.