A Study on Quantifying the Emotional Quality Applied to a Materials Analysis Method for Genuine Automotive Leather

CHAN HO JEONG, KEUMHYANG LEE, MINCHUL SHIN, WONJU KIM and EUNCHUL SHIN[1]*

Hyundai Motors Company, Hwaseong-Si445-706, Korea

[1] Department of Natural Material Research Team, Korea Institute of Footwear & Leather Technology, Busan 614-100, Korea

Abstract

This study is concerned with the technique of quantifying and digitizing four kinds of emotions felt by customers with products, utilising the material quality control analysis methods to control leather materials for vehicles. Through the measurement of protein quantity and microscopic observation, this study conducted an authentication of natural leather and the discrimination of the grade of leather; customers' emotions, sensory characteristics, such as touch sensibility and flexibility were defined through an analysis of the fatliquoring agent contained in leather. As for visual characteristics, the luxury felt when we look at the leather surface composed of a dense structure was analysed in relation to the pore density of the leather surface, the phenomenon of loose grain or creases was investigated by an analysis of the pores between the fibrous layers of leather and the density. The developed comprehensive analysis technique can enable the development of the optimum material that reflects the customer's needs and be widely utilized in improving leather materials through investigating the causes for the problem of quality.

1 INTRODUCTION

An emotion is an important element that can enhance the value of a car brand and the customer's satisfaction with the quality, and so car manufacturers endeavor to manage this emotional quality. If the emotions which the customers feel with good natural leather can be quantified and digitised by a material analysis, then standards for the materials that reflect the customers' needs can be established. However; since natural leather is not a material consisting of a certain structure, unlike chemical products manufactured artificially, it is difficult to set standards and standardise it by certain numerical values.

The production of natural leather goods goes through many steps in the production process. Leather manufacturers sort out raw hides supplied by grade and make raw hides into leather through the processes of preparation, tanning, dyeing and finishing. The process of making raw hides into leather determines the quality of leather goods, and the leather produced like this is processed into vehicle parts, such as seats and interior component covering material *etc.*

Since currently, car manufacturers do not have a method for systematic analysis of the leather parts supplied, they cannot but rely on leather manufacturers. If they are supplied with low-quality leather, quality issues may be caused in terms of material properties and emotions, and this causes the depreciation of the product. In addition, to reflect the customers' emotions accurately for products in the step of product development, standards for the comparison of the quality of products and an accurate analysis method that can analyse the quality are required.

The structure of natural leather consists of the outermost layer of skin the grain layer, reticular stratum, and flesh layer from the outside to the inside, but the outermost layer of skin and the flesh layer are removed during the treatment of raw hides. Advanced specifications for aniline and semi-aniline exist from the grain layer; general specifications of the corrected grain exist from the boundary between the grain layer and the reticular stratum; and the lowest specifications of the split grade exist only on the reticular stratum.

The leather is graded by the structure, but since the chemical coating [finish] is applied on the natural leather surface during the treatment, it is not easy to find, with the naked eye, which grade of raw hides was used to produce the actual product.

There are few cases of research that connect the emotions of the customers with products through an analysis of raw hides. For example, methods of analysis, for such as the discrimination of natural leather are introduced,[1-3] but it is hard to find a case of research that digitised the emotions the customers felt according to the leather supplied and investigated the relationship with the results of an analysis of the leather materials. Studies of natural leather are conducted,[4-6] usually in the field of the development of luxurious leather.

The emotions the customers feel towards the parts to which leather was applied are classified broadly into four kinds: visual characteristics, sensory characteristics, chemical characteristics and physical characteristics, and of these, the biggest factor determining the visual characteristics is the problem of quality, such as the occurrence of loose grain or creases, and the sensory characteristics can be

* Corresponding author: E-mail: gunbaru@naver.com

divided into the touch sensibility that the customers feel. The chemical characteristics are evaluated by the smell of leather, while the physical characteristics are associated with durability. This study was conducted, aiming at the quantification of the emotions felt by the customers with products, the use of material analysis and the connection to the customers' emotions.

2 EXPERIMENTAL PROCEDURES

Preparation of specimens. This study used commercialised leather materials for cars, and leather products, including three domestic leather processing companies, including Samyang Tongsang, Chokwang Leather and Unichem and three German leather processing companies, including Valcona, Merino and Prima. The leathers were used without treatment. Specimens in DMF were soaked in DMF for 5 minutes, and an analysis was conducted after removing the surface coating.

Organic elementary analysis. For the authentication of natural leather, the specimens were cut in a size of 100mg and burned at 950°C, using Leco Truspec Micro equipment to measure the nitrogen content.

Optical microscopic measurement. For an analysis of the pores of the leather surface and the coating on the cross section, the specimens were observed at room temperature at magnifications from 50 to 100 times, utilising a Nikon LV100 microscope.

SEM measurement. Using the leather products with the coating removed, as prepared above, the surface and the shape of the cross section were observed in a low vacuum (10 to 130Pa) mode at room temperature at 15KV at magnifications from 50 to 100, using FEI Quanta 450 equipment.

BET measurement. Six samples of the leather sized 1cm in width and length were placed simultaneously in liquid nitrogen at a temperature of -196°C, and the specific surface area of the specimens was measured, using Micromeritics ASAP2020 equipment.

FTIR measurement. For chemical coating [finish] analysis of the leather surface, measurement was by the ATR method, using Bruker Vertex 80V equipment. The samples were scanned 32 times at room temperature at the resolution of 4cm^{-1} at the frequency range from 650 to 4,000cm^{-1}.

3 RESULTS AND DISCUSSION

Method of grading natural leather. Table I is the result of an elemental analysis for the authentication of natural leather. Through an analysis of nitrogen content, quantification of proteins contained in leather was conducted, and it is noted that leather can be judged to be natural if the total amount of proteins is at least over 50%. The nitrogen content in artificial leather is measured for urethane, one of its raw materials, or appears in its urethane coating.

Protein content can be calculated by substituting the measured nitrogen content in Kjeldahl's formula of nitrogen determination as follows:[7-8]

Protein contents (%) = Nitrogen contents (%) X 6.25

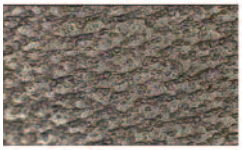
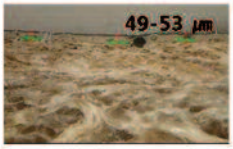
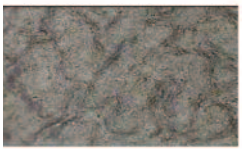
TABLE I
Protein contents of a variety of leather by elemental analysis

Grade	Nitrogen(%)	Protein(%)
Aniline	8.96	56.0
Semi-aniline	8.67	54.2
Corrected grain	8.65	54.1
Split leather	8.47	52.9
PU synthetic leather	1.56	–
PVC synthetic leather	1.35	–

If it has been confirmed that natural leather has been used it is necessary to determine what grade of leather was used.The higher the raw hide grade, the higher the unit price of the product, and the higher the customer's satisfaction with the leather product becomes. For the thickness of the surface coating, one of the most important factors through which the leather grade is judged, is to measure and observe the cross section of the leather and to compare the pore density of the leather surface, the leather surface was measured after removing the urethane surface coating. After cutting the analysis specimen to 1cm in width and length, it was soaked in organic solvent, DMF for 5 minutes. to separate the coating film from the leather. The separated leather is dried at 80°C for 30 minutes. and the surface is observed with an optical microscope to check the pore density.

Up to semi-aniline grade, the surface pores can be observed, while it is difficult to observe them in corrected grain and split leather since the grain layer has been removed. A product with a coating layers thickness of over 40μm is judged to be corrected grain grade. This result is summarised in Table II.

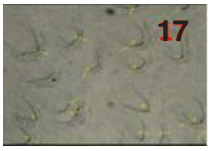
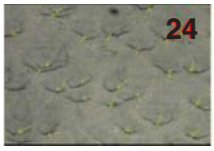
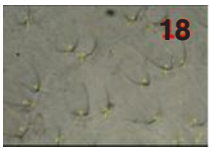
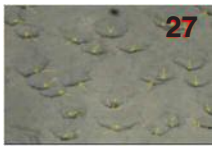
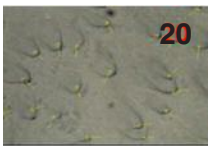
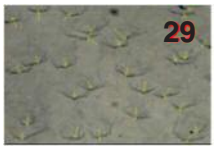
TABLE II
Leather classification by optical microscope

Grade	Surface	Section
Aniline		
Semi aniline		
Corrected grain		
Split leather		

Method of analysing visual characteristics. The softness of quality leather felt on the surface of leather goods and the occurrence of quality issues, such as loose grain and creases, are the biggest factors determining the emotional quality felt by the customer.

Even in the same specimen, more pores are observed in the dorsal region than in the abdominal region, where the tissues are densely distributed, so it feels luxurious. For example, in measuring the distribution of pores in the same leather product, by region, the number of pores is 18.3 on average in the abdominal region, while it is 27, which are much more densely distributed in the dorsal region.

TABLE III
Comparison of pore density by microscopy

Grade	Belly	Back
Image 1		
Image 2		
Image 3		
Average	18.3	27

The problem of quality, which can be a chronic issue such as loose grain and creases in leather goods, is a very important element that may directly lead to the customer's emotions, and the pores existing in the tissue of fibrous layers of reticular stratum leather is the main cause for the occurrence of the phenomenon of loose grain. The density of tissue is affected by the region from which the leather was taken, and the amount of the physical impact given during the manufacturing process, and during the vibration [staking] process, one of the processes of manufacturing leather. If excessive physical impact was given in order to soften the leather, the tissue would be destroyed and the pores in the tissue would increase. Thus, even if the final product is made, using the same leather, it is better to arrange the leather so that the dorsal region is used in the product surface that the customer looks at and to strengthen the management of the vibration [staking] process in terms of emotions they feel with the leather.

The quality, such as loose grain or crease is evaluated by placing the leather on a hemispherical jig and comparing the degree of the occurrence of loose grains and creases with that of the sample. For the judgment, the grade is judged from Grade 1 to Grade 5 by the naked eye, and the closer to Grade 1, the more frequent the occurrence of loose grain or crease in the leather becomes.

In Table IV and Figure 1, as a result of a BET analysis[9-10] of a specimen with loose grain and a reasonable product, it was found that the pore size was relatively bigger in the specimen with loose grain, and accordingly, the pore volume was larger. In other words, the density of the tissue is the main factor affecting the grade according to whether the problems of quality, such as loose grain or crease occur.

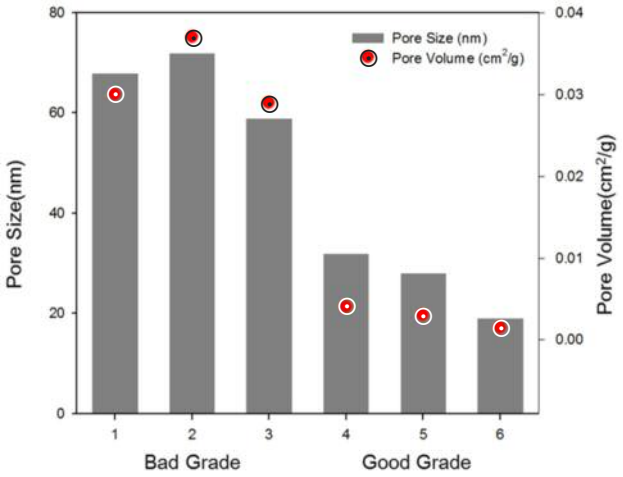


Figure 1. BET result of bad and good grades.

TABLE IV
Analysis of shape according to wrinkling (by microscopy)

Bad grade			
Good grade			

Method of analysing sensory characteristics. Touch sense and the sense of flexibility of leather goods as judged as felt by hand can be analysed. The touch sense refers to the degree of the soft touch of the surface, which can be analysed by the ATR method of FTIR equipment. Of the materials mixed in the leather surface coating, the material most widely used as an additive that gives slipperiness is poly dimethyl siloxane (PDMS).[11-12] As a result of an analysis of slippery additives, domestic products were composed of materials that emphasized softness more while, the foreign products were composed of those that emphasized roughness more. As a result of a panel test to compare the feel of the surface, the touch in a soft grade was expressed as Grade 1 and the rough grade as Grade 4, and the panel found softness with the domestic products to which PDMS was applied and felt the roughness with products when their surface was coated with polyurethane (PU) or acrylic material.

As another sensory characteristic, the flexibility which the customers feel is closely related to the stiffness of the material and the stiffness is affected the most by the process of fatliquoring during the process of manufacturing leather. As fatliquoring and stuffing agents, various natural oils and fats are used, generally, vegetable oil extracted from corn or castor is used. As compared to vegetable oil, neat's foot oil or wool oil extracted from an animal has very excellent flexibility but has a demerit in that the product may have a strong smell.

TABLE V
ATR result of coating material

Product	Coating material
Samyang	PDMS
Chokwang	PDMS
Unichem	PDMS
Valcona	PU
Merino	Acryl
Prima	PU

TABLE VI
Type and contents of softener oil [fatliquor]

Product	Oil (%)	Ingredient	Source
Samyang	13.0	Castor oil	Vegetable
Chokwang	9.5	Castor oil	Vegetable
Unichem	8.8	Castor oil	Vegetable
Valcona	14.6	Castor oil	Vegetable
Merino	11.5	Palmitic acid	Animal
Prima	12.3	Palmitic acid	Animal

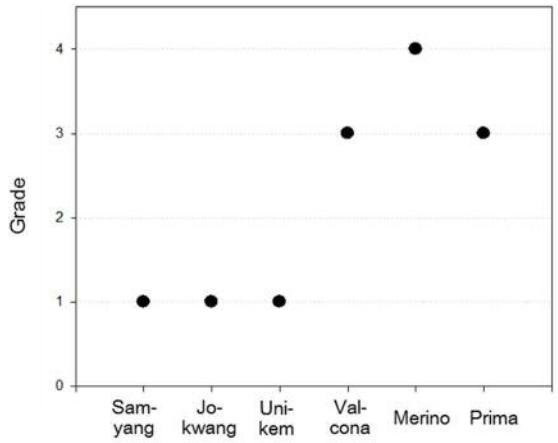


Figure 2. Panel test of surface feel.

To extract fatliquoring agent and oil only, not melting [damaging] the leather, ether was used as a solvent, and leather samples size 3cm in width and length were put in a filter thimble, and the initial weight was measured to perform Soxhlet extraction[13-14] for 24 hours. By measuring the weight of leather remaining after the completion of the extraction, the fat liquoring agent content can be calculated, and by analysing the extract by ATR,[15] a qualitative analysis is conducted on what fatliquoring agent was used. In general, it has been known that the flexibility of leather would be affected the most by fatliquoring agent content, but it is also affected by the vibration [staking] process and the density of the fibrous layers, so the flexibility the customers feel can be predicted only if all factors are checked comprehensively.[16]

Method of analysing physical characteristics. Customers want to preserve the properties of a product for them to remain the same for a long time as when they first purchased it. This is associated with the wear resistance of the material properties and, since the leather material is processed from the skin of an organism, when it is worn out, its properties decrease as time passes, despite it being mineralised through the tanning process. Thus, the surface chemical coating has a great impact on the prevention of the deterioration of the material and the thicker the coating, the more protected the properties become and the better the wear resistance becomes. To check the impact of the coating on leather properties, a test of abrasion was conducted 2000 times, according to the grade of leather and the surface was checked by the naked eye. According to the degree of abrasion, it was divided into 5 grades, classifying a specimen with very severe abrasion into Grade 1 and a specimen in which it would be hard to find any abrasion damage by the naked eye into Grade 5. As a result of an analysis, an aniline grade leather with almost no coating was Grade 1, which had very weak wear resistance and a split leather with coating thickness more than about 100μm was Grade 4, characterised by very excellent wear resistance. However, for the enhancement of durability, it was also found that the thicker the manufactured surface chemical coating layer, the more artificial the feel of the leather surface became, and the more difficult it became to achieve the feeling of luxury too.

4 CONCLUSIONS

Various material analyses were conducted with leather goods to find out how the emotions felt by customers with the products could be quantified.

The grade of leather could be judged by the density of pores and the thickness of the surface coating. As for visual characteristics, through an observation of the number of pores on the leather surface and an analysis of the density of fibrous layers, it was found that customers would feel the leather surface soft when the leather had a dense structure. Through the result of the analysis of the density of the fibrous layers, this study could find the main causes for the occurrence of quality issues, such as leather lifting and loose grain.

The sensory characteristics felt by the customers differ depending on the coating ingredients, and the kind and content of the fat liquoring agent contained in a leather and it was noted that the durability and the properties of the leather material are associated with the thickness of the coating on the leather surface.

The process of making raw hides into leather is very important for the quality of leather goods, which determines most of the emotions felt by customers. Car manufacturers should standardise the kind and content

of chemicals according to the type of raw hides used in the process of manufacturing leather; enhance the emotional quality; perform a lot of research; and endeavor to produce the leather goods that maintain material properties above the required standards.

(Received 16 April 2018)

References

1. Hole, L. G. and Whittaker, R. E., Structure and properties of natural and artificial leathers. *J. Materials Science,* 1971, **6**(1), 1.
2. Zhang, Y. Q., Applications of natural silk protein sericin in biomaterials. *Biotechnology Advances,* 2002, **20**(2), 91.
3. Sano, T. and Suzuki, S., Basic forensic identification of artificial leather for hit and run cases. *Forensic Science International,* 2009, **192**(1), 27.
4. Sudha, T. B. and Thanikaivelan, P., Comfort, chemical, mechanical, and structural properties of natural and synthetic leathers used for apparel. *J. Applied Polymer Science*, 2009, **114**(3), 1761.
5. Ionita, I. and Dragne, A. M., Collagen fluorescence measurements on nanosilver treated leather. *Romanian Reports in Physics*, 2010, **62**(3), 634.
6. Francis, J. A. and Chan, W., Winter Northern Hemisphere weather patterns remember summer Arctic sea-ice extent. *Geophysical Res. Letters*, 2009, **36**(7), 16.
7. Mariotti, F. and Tomé, D., Converting nitrogen into protein – Beyond 6.25 and Jones' factors. *Critical Reviews in Food Science and Nutrition*, 2008, **48**(2), 177.
8. Kyriazakis, I. and Oldham, J. D., Diet selection in sheep: the ability of growing lambs to select a diet that meets their crude protein requirements. *Brit. J. Nutrition,* 1993, **69**(3), 617.
9. Kruk. M. and Jaroniec, M., Application of large pore MCM-41 molecular sieves to improve pore size analysis using nitrogen adsorption measurements. *Langmuir*, 1997, **13**(23), 6267.
10. Walton, K. S. and Snurr, R. Q., Applicability of the BET method for determining surface areas of microporous metal- organic frameworks. *J. Amer. Chem. Soc.,* 2007, **129**(27), 8552.
11. Xue, L., and Pham, J. T., Comparison of the slip of a PDMS melt on weakly Adsorbing surfaces measured by a new photobleaching-based technique. *Macromolecules*, 2017, **50**(14), 5592.
12. Honig, C. D. F. and Ducker, W. A., Squeeze film lubrication in Silicone Oil: Experimental test of the no-slip boundary condition at solid- liquid interfaces. *J. Phys. Chem. C,* 200, **112**(44), 17324.
13. De Castro, M. D. L. and Garcıa-Ayuso, L. E., Soxhlet extraction of solid materials: an outdated technique with a promising innovative future. *Analytica chimica acta*, 1998, **369**(1), 1.
14. Hawthorne S. B. and Grabanski, C., Comparisons of Soxhlet extraction, pressurized liquid extraction, supercritical fluid extraction and subcritical water extraction for environmental solids: recovery, selectivity and effects on sample matrix. *J. Chromat. A,* 2000, **892**(1), 421.
15. Chittur, K. K., FTIR/ATR for protein adsorption to biomaterial surfaces. *Biomaterials*,1998, **19**(4), 357.
16. Holbery, J. and Houston. D., Natural-fiber-reinforced polymer composites in automotive applications. *JOM J. Minerals, Metals and Materials,* 2006, **58**(11), 80.