The combustion characteristics of vehicle upholsteries

Hyung Ju Park, Young Goo Kang, Hong Kim
Division of Safety Engineering, Hoseo university, KOREA

ABSTRACT

Five parts of vehicle upholsteries were sampled to determine its combustion characteristics. Oxygen Indexer, Smoke chamber, Differential Scanning Calorimetry(DSC) are applied as the analysis apparatus.

All LOI values of samples appear less than 21. The combustion phenomena of vehicle upholster primarily depends on properties of each layer material. The amount of smoke generated is the experiment reached the maximum value within 30 – 90sec after ignition. The experimental results of combustion characteristics and DSC of H/Line also indicated that the layer of foam was melt first and it caused the propagation of flame through the sample.

The combustion characteristics of multi layer materials primarily depend on thermal characteristic of single layer material.

INTRODUCTION

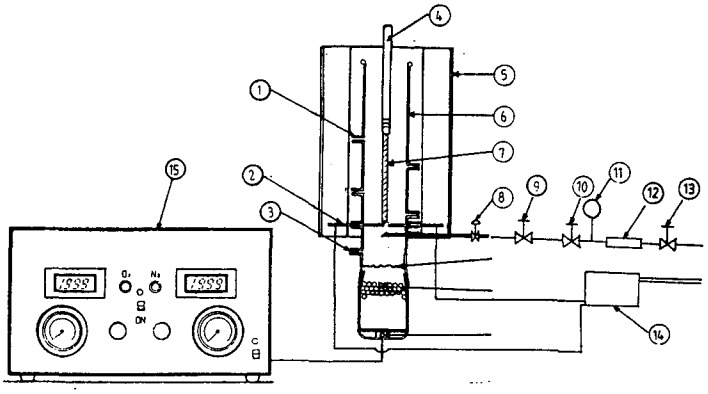
In recent years, the amount use of light-weighted materials in vehicle for increase of combustion efficiency has been increasing.[1][2] Vehicle's light-weighted materials was estimated that polypropylene, polypropylene, polyethylene and Nylon go on increasing in the amount used to 5 – 12%, but PVC is show a slight decrease.[3]

Most of the light-weighted materials are thermoplastics that have advantage for the lower specific gravity and simplexes manufacture. But its has weak point for thermal characteristics and combustion-proof, and generate much combustion gas, smoke and toxic gas during fires.[4] Vehicle upholsteries have complicate combustion phenomenon than single polymer because it's consisted of 2 – 4 layers different in polymer.

In the present work a study is conducted of LOI(Limit Oxygen Index), combustion velocity, combustion time and smoke evolution of vehicle upholsteries.[5][6] Smoke density measuring apparatus was used for measuring the smoke producing characteristics of vehicle upholsteries under controlled condition of combustion. The test method is the subject of ASTM D2843.[7]

This apparatus employs a chamber 300 by 300 by 790mm, in which a specimen 25.4mm(±3mm) long by 25.4mm(±0.3mm) wide by 6.2mm(±0.3mm) thick is placed on a stainless steel screen and burned using a propane burner at a specified gas pressure. The smoke density chamber is completely closed except for 25 by 230mm openings in the four sides of the bottom during the test. The smoke produced by burning is captured in the chamber. To measure light absorption, a photoelectric cell and a meter as a light source are used in the test. Percentage of light absorption is measuring every 15seconds for 4 minutes. The 15second interval measuring for the three samples in each group are averaged. The maximum smoke density is chose as the highest point on the curve, and the total smoke production is determined by measuring the area under the curve.

Differential Scanning Calorimetry(DSC) was used for measuring the thermal characteristics of Glass Transition Temperature(Tg), melting point, Heat of fusion, etc. for each part of vehicle upholsteries.



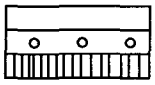
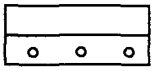
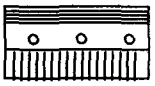
No	Item	No	Item
1	establishement place of thermocouple(Φ3.0mm)	9	flow valve
2	white gold electrode(Φ1.5mm)	10	regulator
3	establishement place of thermocouple(Φ3.0mm)	11	pressure gauge
4	holder	12	filter
5	screen	13	valve
6	glass column	14	step-up transformer
7	sample	15	N_2, O_2 mixing machine
8	valve		

Fig. 1 Schematic diagram of candle type flammability tester

EXPERIMENT

The vehicle upholsteries was produced in five company of Korea, it's consist of 2 – 4 layers different in polymer. Those used put each layer apart for research on difference in the combustion phenomenon and interaction of between each polymer.
Construction and type of samples used for the combustion characteristics are given in table 1.

Table 1. Layer structure of samples

Section	Outer layer	Base	Structure
D/Trim	PVC sheet + PP foam	Resin felt	
P/Tray	wall paper	Wood stock	
I/Panel	PVC	Polyurethane	
F/Carpet	Nylon	1st, 2nd foam layer PE	
H/Line	non-woven fabric + PP foam	Resin felt	

A schematic diagram of the Candle type flammability tester is shown in Fig. 1 that was used for measurement of Lower Oxygen Index, combustion velocity and combustion time. It consists of the Oxygen-Nitrogen mixing machine, heat-resistant glass column and ignition section. Vertical heat-resistant glass column provided 75mm in diameter and 450mm high, in which a specimen 150mm long, 30mm wide, and 3mm thick is hold vertically by a clamp. A mixture of Oxygen and Nitrogen of known composition is metered into the bottom of the column, passing through a bed of glass beads 3 to 5mm in diameter.

The Mixing gas flow rate in the glass column is 4 ± 1 cm/sec. The specimen is ignited during 10sec at its upper and downer end with an igniting flame. The Oxygen Index is the minimum concentration of Oxygen in an Oxygen-Nitrogen mixture, which will just permit the sample to burning during 30sec. Direction of combustion propagation was taken the downward and upward burning. The downward burning is the opposite direction to mixture gas of Oxygen-Nitrogen, and the upward burning is same direction to mixture gas.

RESULTS AND DISCUSSION

1. Limit Oxygen Index

The LOI values of samples are tabulated in Table 2. All LOI values appear less than 21. It indicated that all samples do not have an ability of fire resistance in air.

The rank of fireproof ability in Atmosphere shows D/Trim > P/Tray > I/Panel > H/Line > F/Carpet.

Table 2. Determinated LOI values of part of vehicle upholsteries
(Flow velocity : 4cm/sec, ignition : 5sec)

Combustion / Type Materiel	Upward Flame	Downward Flame
D/Trim	16.4	18.5
H/Line	12.7	16.4
Instrument Panel	14.8	16.6
F/Carpet	12.6	16.0
P/Tray	14.9	17.2

2. Combustion velocity and combustion time

The combustion velocities of various layer of D/Trim at 20% Oxygen concentration showed in Fig. 2. The values of PVC + PP foam (Surface material) higher than other's. Because of Resin felt the combustion velocity of whole D/Trim layer (PVC + PP foam + Resin felt) shows less than 0.1 cm/sec. The combustion time of various layer of D/Trim according to the variation of oxygen concentration showed in Fig. 3. The combustion time of layers decreases with increasing Oxygen concentration. The value of resin has longer than others.

Therefore, the combustion velocity and time of vehicle upholsteries that in, combustion phenomena strongly depends on properties of each layer material of vehicle upholsteries.

3. Smoke evolution

The smoke densities of samples are tabulated in Table 3. The smoke density of I/Panel and surface layer of D/Trim are respectively 73% and 67%. This layer consists of PVC. Therefore, PVC is main material in smoke evolution of vehicle upholsteries.

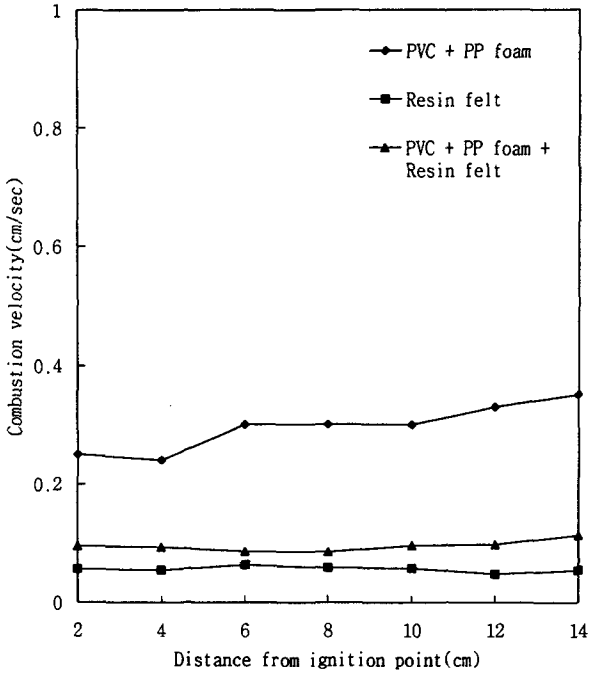


Fig. 2 Comparison of combustion velocity in various samples
[Ignition time : 5sec, downward flame, sample : layer of D/Trim]

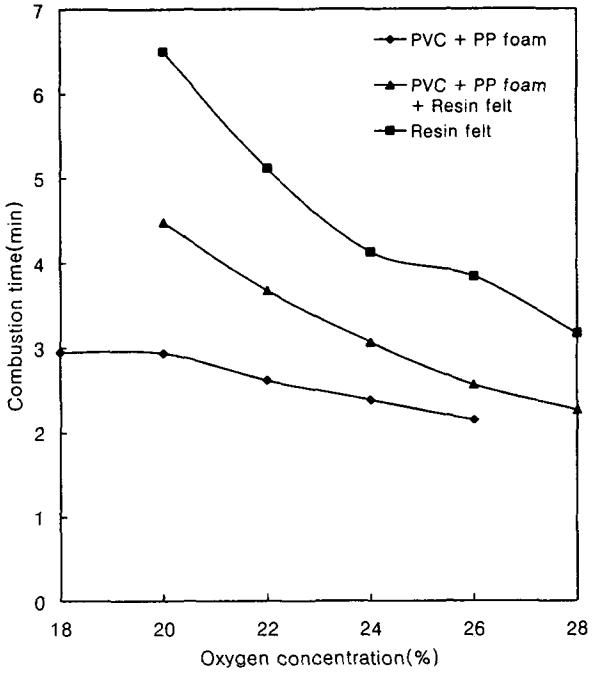


Fig. 3 Combustion time according to the variation of oxygen concentration
[Ignition time : 5sec, downward flame, sample : D/Trim]

Table. 3 Data analysis of smoke density for each of samples

Type	Layer Construction	Weight (g)	Smoke Density(%)	Max. smoke Density(%)
D/Trim	PVC + PP foam + resin felt	1.59	19	29
	PVC + PP foam	1.11	67	83
I/Panel	PVC	4.34	73	89
P/Tray	wall paper + wood stock	3.35	13	18
H/Line	non-woven fabric+PP foam	0.75	5	9
F/Carpet	non-woven fabric+ resin felt	0.99	25	33

Fig. 4 Shows smoke densities of samples according to the time. The I/Panel shows high smoke evolution and H/Line shows low smoke evolution. The maximum smoke evolution rate of samples was appeared within 30-90sec after ignition.

Therefore, there is great risk for passenger at beginning point of vehicle fire.

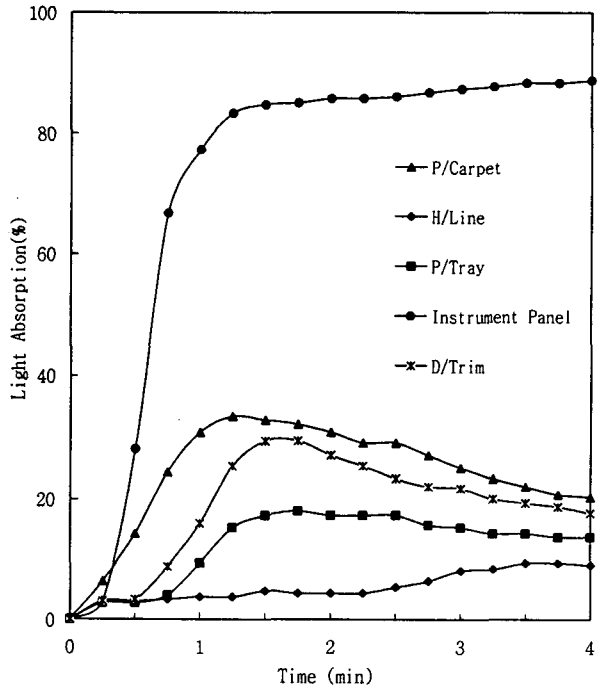


Fig. 4 Smoke density according to the time of each parts of vehicle uphosteries

4. Thermal characteristics

The thermal characteristics of sample are tabulated in table 4. The rank of melting point shows F/carpet < P/Tray < H/Line < I/Panel < D/Trim. This result is similar to the result of Table 2.

DSC curve of H/Line shown in Fig. 5. The PP foam layer was first melted at 113℃ and non-woven fabric layer was the last melt at 313℃. In combustion of H/Line, foam layer is first melted by combustion heat and non-woven fabric and resin felt are attracted with each other by molten foam. Therefore, The combustion characteristic of multi layer material strongly depends on thermal characteristics of single layer materiel.

Table. 4 Data analysis of thermal characteristics for each part of samples

Section	Layer Construction	Tg (Glass transition temperature)	Melting point (℃)	Heat of fusion (mCal/mg)
D/Trim	PP foam	118	123	0.20
	PVC	291	320	5.22
P/Tray	Wall paper	249	256	0.78
	Wood stock	164	172	2.28
F/Carpet	1 layer	219	225	1.55
	2 layer	257	265	0.80
	3 layer	112	120	5.10
I/Panel	PVC	296	316	6.63
H/Line	Non-woven fabric	250	257	0.86
	PP foam	106	111	0.89

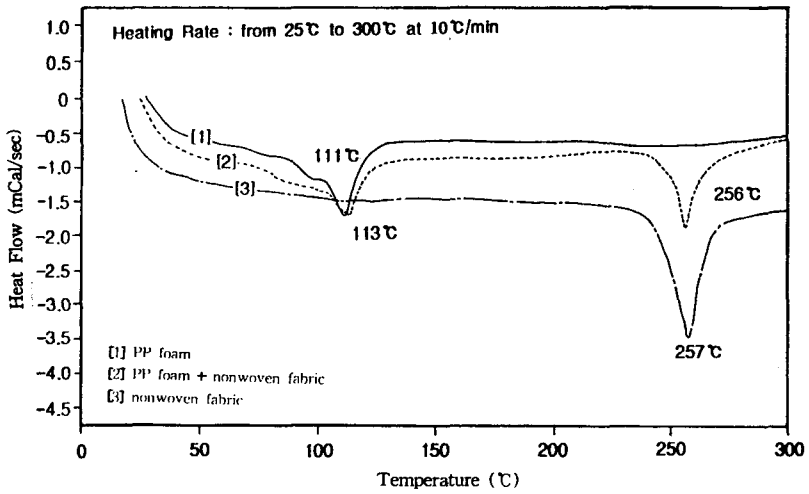


Fig. 5 DSC curve of H/Line

CONCLUSTION

1. All LOI values of sample appear less than 21, that is, all samples do not have an abilities to resist in air. Especially, F/Carpet has weak fire proof ability.

2. The combustion phenomena of vehicle upholsteries primarily depend on properties of each layer material.

3. PVC is the main material in smoke evaluation of vehicle upholsteris. And the maximum Smoke evaluation was within 30 – 90sec after ignition. There is great risk for passenger at beginning point of vehicle fire.

4. The combustion characteristic of multi layer material primarily depends on thermal characteristic of single layer material.

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