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A Study on the make Fire Scenario for Residential Facility Combustible Materials

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[Abstract]

In the case of residential facilities, general fire scenarios cannot be applied. Becauseit is difficult to quantify due to the types of combustibles and various fire loads. Existing research conducting surveys of combustibles, but research on fire characteristics is insufficient. Therefore, in this study, an Excel macro that can be quantified by experimenting with the HRR experiments of sofa, drawer, mattress, chair, desk and TV, which are typical combustibles. As a result of experimenting 6 loading combustibles in domestic residential facilities by using a furniture calorimeter, values of 2,391.26kW appeared from the sofa, 1,891.80kW from the drawer, 1,778.95kW from the mattress, 1,104kW from the chair, 291kW from the desk, and 135.09kW from the TV. Also, by applying the α value of the fire growth rate by classifying fire-growing speeds at NFPA 72 (National Fire Alarm Code 2007, Annex B), the mattress can be defined as Very Fast, the sofa and drawer Fast, the TV Slow, the desk Slow, and the chair Medium.

▸ **Key words**: Furniture Calorimeter, Data Base, Fire growing rate, Fire Scenario, Residential Facility

[요 약]

본 연구는 주거시설의 화재위험성을 예측할 수 있는 화재시나리오를 작성에 앞서 주거시설내의 대표적인 가연물 6개를 선정하여 이를 통한 발열량을 실험을 실시하고 데이터를 정량화 할 수 있는 방안을 제시하였으며, 향후 화재시나리오 적용될 화재성장곡선의 기준값을 선정하고자 연구를 수행하였다. 주거시설의 경우에는 일반적으로 화재시나리오가 적용되지 않고 있는데 이러한 문제점은 가연물의 종류 및 다양한 화재하중 등으로 인하여 문제시될수 있기 때문에 정량화에는 어려움이 있다. 기존의 연구에서는 가연물의 조사를 실시하고 있으나 이를 통한 화재특성에 대한 연구가 미흡한 실정이기 때문에 대표적인 가연물들을 통하여 소파, 서랍장, 매트리스, 의자, 책상, TV의 발열량 실험을 통하여 정량화 할 수 있는 엑셀 매크로를 작성하였으며, 이를 통하여 NFPA 72에서 제시하고 있는 화재성장율과 비교하였을 때 각 가연물별로의 추세값이 제시할 수 있었다. 이를 통하여 향후 주거시설에서 발생할 화재시나리오에 기초적인 자료를 활용하고자 한다.

▸ **주제어**: 퍼니쳐칼로리미터, 데이터베이스, 화재성장곡선, 화재시나리오, 주거시설

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I. Introduction

Generally, combustible materials in buildings can be divided into fixed combustible materials such as the floor and ceiling that are fixed onto the building structure and live fire load for storage such as furniture and clothing. Recently, from economic development and convenience of users, the variety of combustibles is increasing. In particular, live fire load differs from users and not by a fixed standard. These live fire load can produce a big influence in the fire behavior of the building[1].

In this regard, there has been consistent overseas researches on the effect of combustibles on fire incidents for the safety of buildings. On the contrary, in Korea, generally, the standard of property of combustibles found is used, but considering that the types and sizes of combustibles differ by each country, elementary data has to be researched in Korea.

Therefore, this research aims to suggest ways to establish database on combustibles in domestic residential facilities in the future by obtaining data on properties of combustibles. To do this, a furniture calorimeter experiment will be carried out by selecting 6 representative combustibles in residential facilities in order to obtain elementary information on combustibles before estimating fire behavior of residential facilities among buildings in Korea.

II. Experiment of Fire Behavior of Live Fire Load

As for live fire load, users choose their load according to their preference and convenience. For example, when a user buys a couch, he would choose the item considering its design or comfortableness instead of its fire risk or safety. Because most of these live fire loads are chosen without consideration into safety (fire-resistant), it can be determined that they possess fire risk and may become the cause of spreading fire in case of fire[2].

Therefore, this research selected representative combustibles in residential facilities such as TVs, mattresses, drawers, couches, chairs and desks by analyzing existing research results on combustibles in residential facilities and also selected experiment samples for furniture calorimeter experiment based on useropinions and customer preferences. This experiment aimed to find out the combustion characteristics on each representative combustibles by carrying out the experiment based on the ISO 9705 Fire test – a full-scale room test for surface products.

1. Furniture Calorimeter Experiment

From the furniture calorimeter experiment in this research, the amounts of heat released, CO, CO2,and SPR were measured. Also,by measuring the surface area and weight of the sample before the experiment, basic data on combustibles was collected. 50mℓ of heptane was placed as an ignition source where it is easy for fire to spread. Also, the combustion values on combustibles were measured every 3 seconds. Generally, the furniture calorimeter experiment was carried out in a compartment measuring W2.4m, L3.6m, H2.4m with an opening measuring W0.8m, L2.0m according to KS F ISO 9705 Room Test. The basic data for combustibles used in this research is shown in Table 1.

Table 1. Experimental Sample's conditions of Furniture Calorimeter

	Size (W x D x H) [mm]	Weight [kg]
TV	510 x 470 x 470	17.75
Drawers	720 x 460 x 1110	38
Mattress	1090 x 200 x 2000	21.40
Sofa	1180 x 650 x 960	24.95
Desk	1200 x 700 x 700	41.65
Chair	490 x 500 x 750	13.5

2. Furniture Calorimeter Experiment Results

The results of furniture calorimeter in this research are shown in Table 2, and the results show the peak values for each combustibles and changes in weight before and after combustion for each item for measurement. Couches made of fabric and sponge were measured to show the

Table 2. Experimental results of Furniture Calorimeter

	HRR [kW]	CO [ppm]	CO_2[%]	SPR [m^2/s]	Weight(kg)	
					Before	After
TV	135.09	199.6	0.12	14.17	17.75	14.90
Drawers	1891.8	1288	3.38	9.23	38.00	13.90
Mattress	1778.9	454.9	3.11	18.72	21.40	-
Sofa	2391.2	3069	4.20	49.62	24.95	5.10
Desk	281.26	2.817	0.386	1.77	41.65	18.1
Chair	1104	49.54	1.43	21.29	13.5	3.8

highest results, implying the highest fire risk. In this research, in order to analyze HRR values from measured items of furniture calorimeter experiment, the changes in results of heat release rate (hereinafter referred to as HRR) were suggested for figures 1 – 6.

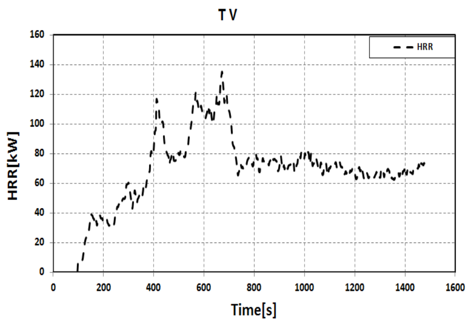

Fig. 1. HRR results value of TV.

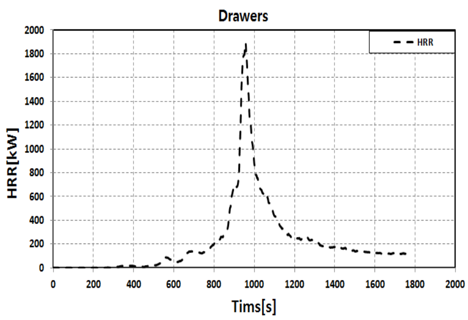

Fig. 2. HRR results value of Drawers.

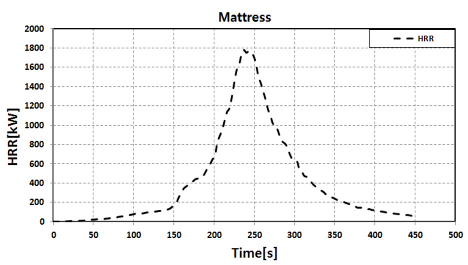

Fig. 3. HRR results value of Mattress.

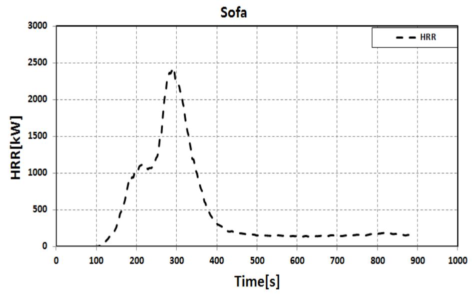

Fig. 4. HRR results value of the sofa.

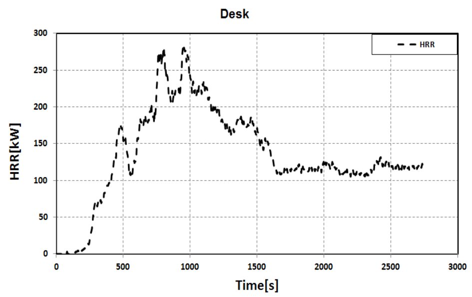

Fig. 5. HRR results value of Desk.

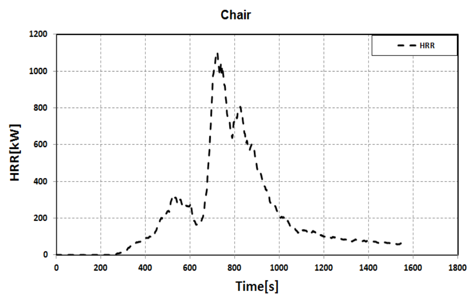

Fig. 6. HRR results value of Chair.

III. DB Establishing Method for Characteristics of Combustions

Generally, the heat release rate of combustibles in compartments can be established by determining the heating velocity of combustibles from measured values from experiments by reproducing status and arranging combustibles, but as there are varying types of combustibles, purposes of buildings and uses of compartments, it is unrealistic to establish by reproducing experiments.

In this research, as a basic information to establish database on combustibles in residential facilities, a way of establishing the database for domestic purpose for use in future assessment of fire risk is suggested by carrying out an HRR typing job which can be applied to simulations that are generally used in Korea. For this, 6 samples will be experimented using the establishment method for combustibles suggested by the Architectural Institute of Japan in 2006.

1. Modeling Method for Heating Velocity

The changing patterns of fire shown in Figure 7 as the HRR values of the furniture calorimeter, are divided into 4 timings and 4 sections. The categories are the starting time of the growth of fire (t_0), the completion time of maximum combustion(t_{max}), the decaying time of fire(t_{decay}) and the maximum amount of heat in Qmax. Also, the sections for each timing were divided into 4 sections and were defined as follows[3].

◆ Smoldering period (τ_0):The period of smoldering state from ignition to before growth of combustion($0\sim t_0$).

◆ Growth period (τ_{grow}):The period from the start of growth of combustion until maximum combustion ($t_0\sim t_{grow}$).

◆ Normal period (τ_{max}):The period of normal combustion at the state of maximum combustion velocity($t_{grow}\sim t_{max}$).

◆ Decaying period (τ_{decay}):The period from the start of decaying until the flame is extinguished ($t_{max}\sim t_{decay}$).

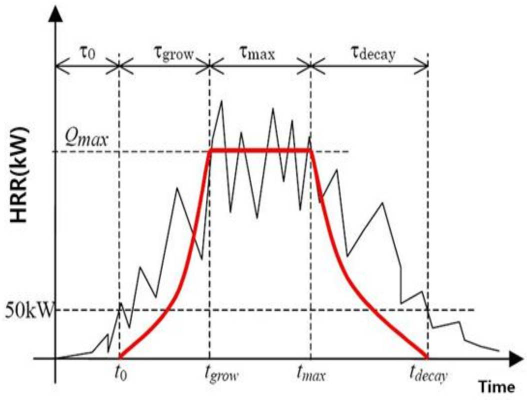

Fig. 7. Modeling of heating-speed curves

In order to model the HRR values of the furniture calorimeter from this research, appropriate information was inserted into the database sheet in Figure 8.

The Excel sheet used in this research was written as a code that displays solid lines on the top of the HRR values of the existing furniture calorimeter by creating modules on the contents of Table 3 using Microsoft Visual Basic for Applications and connecting them to "HRR" which is a function command other than a mathematical function. The "HRR" modules were structured so that HRR values are automatically applied when experiment results on 4 timings and 4 sections for changing patterns of combustion are analyzed and designated[1].

Also, the fire growth rate (α) from the applied heat release rate was structured so that it can be calculated as in formula 1, and the decaying rate of fire (αd[the secondary curve from maximum heat release rate until extinct of flame]) as in formula 2.

Also, visual inspection on confirmation of fire was recorded in the Excel sheet to allow comparison between the experiment results on furniture calorimeter and the route of fire spreading which was visually measured[4].

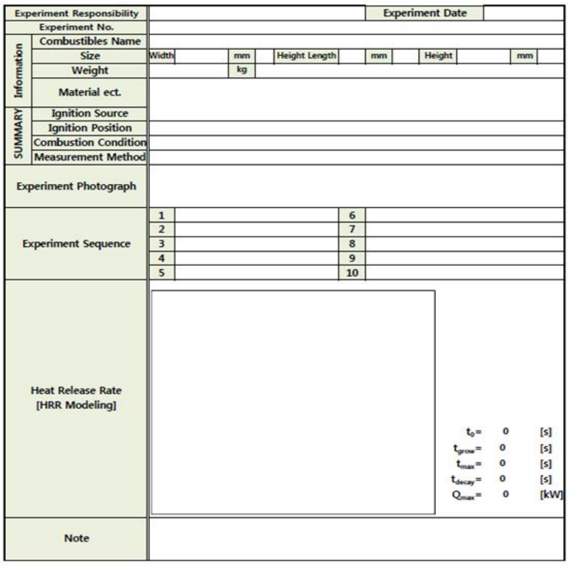

Fig. 8. Inputs sheet of furniture calorimeter data.

2. Analysis on Results of Furniture Calorimeter Using Modelling Method on Heating Velocity

As there are varying materials of combustibles, the resulting values of the furniture calorimeter in this research cannot be the representative characteristics of combustion. However, the basic information given in this research will be used as an established database on combustibles in future assessments for fire risks. The resulting values of modelling HRR are shown in Figures 9 - 14. The remaining HRR values in the experiment compartment for the furniture calorimeter were excluded and the timing and sections for modelling were configured as in Table 4.

After modelling, the remaining HRR values in the experiment compartment on the decaying parts of fire in TVs and desks were measured and displayed excluding the timing. Also, the Qmax modelling method from Fire Dynamics, Gregory et al. (2011)[5], was applied. Couches showed the highest heat releasing rate and it is determined that it showed a shorter fire growth rate at a combustion time compared to other combustion samples with a different combustion time. On the other hand, desks showed a low heat releasing rate next to TVs and it is decided that it will show a low fire growth rate as it has a longer combustion time compared to other samples. The slopes of a fire curve of 6 modelized samples were in the order of mattresses, couches, drawers, chairs, desks and TVs but this is on the result of modelized samples. The fire growth rates of 6 samples were calculated using Formula 1 and was suggested as in Table 5.

Table 3. HRR function's inputs at Excel

```
Function HRR(time, t0, tgrow, tmax, tdecay, Qmax)
If (time < t0) Then
HRR = 0#
Else
If (time < t0 + tgrow) Then
HRR = Qmax * ((time - t0) / (tgrow)) ^ 2
Else
If (time < t0 + tgrow + tmax) Then
HRR = Qmax
Else
If(time<t0+tgrow+tmax+tdecay)Then
HRR=Qmax*(((t0+tgrow+tmax+tdecay)-time)/tdecay)^2
Else
HRR = 0
End If
End If
End If
End If
End Function
```

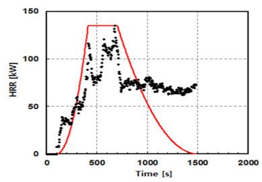

Fig. 9. Modeling on TV HRR results of furniture calorimeter.

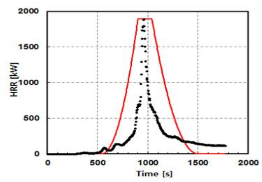

Fig. 10. Modeling on drawer HRR results of the furniture calorimeter.

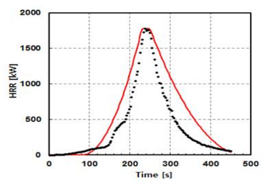

Fig. 11. Modeling on mattress HRR results of the furniture calorimeter.

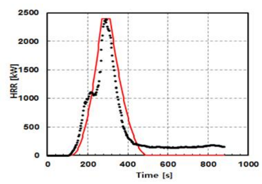

Fig. 12. Modeling on sofa HRR results of the furniture calorimeter.

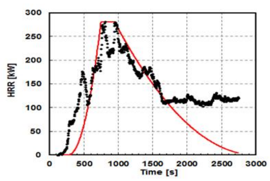

Fig. 13. Modeling on Desk HRR results of the furniture calorimeter.

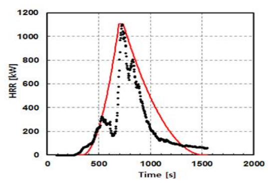

Fig. 14. Modeling on chair HRR results of the furniture calorimeter.

Table 4. Combustion period of combustibles for modeling the heating curve

	TV	Drawer	Mattress	Sofa	Desk	Chair
τ_0	99s	539s	80s	118s	275s	355s
τ_{grow}	312s	361s	150s	152s	475s	358s
τ_{max}	289s	140s	20s	42s	195s	42s
τ_{decay}	800s	460s	235s	188s	2055s	783s
Q_{max}	135.09 kW	1891.8 kW	1778.95 kW	2391.26 kW	281.3 kW	1104.39 kW

Table 5. Fire growth rate of each sample

	Fire growth rate α(kW/sec^2)
TV	0.000388
Drawer	0.019874
Mattress	0.190432
Sofa	0.090429
Desk	0.000825
Chair	0.007110

Table 6. Speed categories on fire growths of NFPA 72

	Growth Time (tg)	α (kW/sec2)	α (Btu/sec3)
Slow	tg=400sec (tc=600sec)	α=0.0066	α=0.0063
Medium	150=tg<400sec (tc=300sec)	0.0066<α =0.0469	0.0063<α =0.0445
Fast	tg<150sec (tc=150sec)	0.0469<α =0.1876	0.0445<α =0.178
Ultra-Fast	tg=75sec (tc=75sec)	α>0.1876	α>0.178

In the NFPA 72 (National Fire Alarm Code 2007, Annex B), the velocity of fire growth for combustibles were categorized as in Table 6. When the fire growth rate (α) in Table 5 calculated in this research is applied in Table 6, the combustible samples can be defined as follows: mattresses, ultra-fast; couches and drawers, fast; TVs, slow; chairs, slow and chairs, medium[6].

IV. Conclusions

When 6 common live fire loads are selected and put in a furniture calorimeter experiment to establish DB on representative live fire loads as basic information for assessment of fire risk in residential facilities, the following results were found.

1) The measured values showed 2,391.26 kW for couches, 1,891.80 kW for drawers, 1,778.95 kW for mattresses, 1,104 kW for chairs, 291 kW for desks and 135.09 kW for TVs. When the velocity of fire growth of combustibles in NFPA 72 (National Fire Alarm Code 2007, Annex B) was categorized and applied to the fire growth rate (α), mattresses were defined as ultra-fast, couches and drawers as fast, TVs as slow, desks as slow and chairs as medium.

2) Also, because the application method for DB on the live fire load in Korea is relatively poor, a tool for organizing data was suggested and from this tool, the HRR values that can be applied to general simulation method was suggested for easier modelling.

3) More research on basic data is needed in line with materials and environments suitable for domestic situation by utilizing overseas information and fire simulations and using this information, research on simulation and reproduction experiments needs to be carried out.

In future research, statistical analysis is applied to establish fire scenarios in residential facilities to conduct that can contribute to fire safety in residential facilities along with quantified values of combustibles.

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