

Analysis of Non-Fuel Evaporative Pollutants Emitted by Automobile Seats

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ABSTRACT

With the increasing stringency of emission standards, the challenge for conventional passenger vehicles to meet evaporative emission requirements has intensified. Evaporative emissions from vehicles are primarily derived from the fuel system and the non-fuel system, with the latter accounting for 30% to 50% of total vehicle emissions. Thus, the study of non-fuel system evaporative pollutants in passenger vehicles has become especially important. This research conducted tests on automobile seat assemblies and their components to identify the main pollutants. Through the contribution of concentration ratios, a predictive formula was established to validate tests related to seat assemblies and components, aiding enterprises in effectively controlling non-fuel evaporative pollutants from automobile seats.

KEYWORDS

Non-fuel; Evaporative Pollutants; Seats

1. INTRODUCTION

Evaporative emissions, the release of volatile substances into the atmosphere from a vehicle [1], are a significant source of environmental pollution [2], primarily consisting of hydrocarbons. These emissions, which occur due to temperature variations and other conditions, pose considerable risks to both human health [3], affecting the respiratory and nervous systems, and the global environment by contributing to issues like ozone depletion and smog formation [4]. In response to the growing concern over these emissions, national environmental protection and public health standards have evolved, leading to the continuous updating of regulatory standards aimed at mitigating the adverse impacts of vehicular evaporative emissions on health and the ecosystem [5].

Within the scope of total vehicle emissions, evaporative emissions are not solely derived from the fuel system [6], which includes components such as carbon canisters, fuel lines, fuel tanks, and pumps, predominantly metallic and providing a relatively consistent source of hydrocarbon emissions [7]. A significant portion also emanates from non-fuel systems [8], encompassing a variety of components, semi-finished products, and materials that do not directly interact with fuel, such as plastics, foam, rubber, and leather. Research indicates that these non-metallic materials and their derivatives contribute to 30% to 50% of total vehicle emissions, highlighting the necessity of addressing these sources to effectively reduce overall emissions [9]. This urgency is further emphasized by updates to standards like the GB 18352-2016 "Limits and Measurement Methods for Emissions from Light-Duty Vehicles", which have notably lowered permissible levels of evaporative emissions and extended testing durations, indicating a shift away from the previously acceptable practices, such as the use of activated carbon canisters, to ignore non-fuel system emissions.

Focusing on automobile seats within the non-fuel system, this study engages in experimental analyses of seat assemblies and their components to identify and quantify hydrocarbon emissions. By obtaining a comprehensive hydrocarbon spectrum, the research not only sheds light on the specific contributions of different materials used in seat construction to the overall emission profile but also proposes targeted strategies for material improvement. Starting from the base materials, these strategies aim to reduce the source of evaporative pollutants, thereby contributing to the development of environmentally friendlier automobile seats. Additionally, by establishing a formula that relates the concentration of hydrocarbons in the assembly and components, this study provides a foundational tool for predicting and verifying the efficacy of proposed improvements in reducing evaporative emissions, offering valuable insights for both manufacturers and regulators in the pursuit of sustainable automotive design and production practices.

2. EXPERIMENTAL PART

2.1. Seat Requirements

Seats selected for testing were in good condition and not subjected to pre-treatment processes such as exposure, baking, or ventilation. For precise data analysis, two seats from the same batch and model, produced within a week and sealed, were used. According to relevant standards, seat packaging was removed prior to testing, and the seats were stored in a standard environment as specified in GB/T 2918 for a week.

2.2. Experimental Equipment and Analysis Conditions

The experimental equipment and analysis conditions used in this study primarily include:

VOC pre-treatment chamber for components, Shengwei V-MH-12-2, with a temperature control range of 15°C to 100°C;

Sealed chamber system ENGIE-MINI-SHEN, temperature control range: 15°C to 65°C, volume: 11.25m³ ±0.5K/±100Pa, background emission: less than or equal to 1mg;

1 cubic meter VOC release chamber, WKE-1000/RT130, temperature control range: 20°C to 130°C; humidity control range 30% to 90% r. F.;

Four-channel VOC sampling pump, Fresenius, channels 1-2: 0.1L/min to 0.5L/min; channels 3-4: 1L/min to 4L/min;

Atmospheric sampling pump, SP208-1000Dual II, 100-200ml/min—within ±10%; 201-1000ml/min—within ±5%;

Flame Hydrogen Ion Detection Instrument (GC-FID): Durag, with a maximum permissible error of the indicated value not greater than ±10%, repeatability not greater than 2%, and response time not greater than 10 s;

Thermal Desorption-Gas Chromatography-Mass Spectrometry (GC-MS), Agilent UNITY2-GC7890B-MS5977A, mass axis stability: better than 0.10amu/48 hours.

Analysis conditions: Thermal desorption: Tenax tube pre-blowing for 1min at a purge flow rate of 20mL/min; desorption temperature: 280°C, desorption time: 8min; desorption gas flow: 40mL/min; cold trap temperature: -10°C; cold trap heating temperature: 300°C, heating time: 3min; split ratio: 62:1. Mass spectrometry: solvent delay time: 3min; ion source temperature: 230°C; detector temperature: 150°C; scanning mode: full scan 30-550amu; electron impact energy: 70Ev. Gas chromatography: carrier gas: helium; column flow rate mL/min; chromatographic column: Agilent 122-5562DB-5MS (60 m×0.25mm×0.25 μm); temperature program: hold at 40°C for 10min, then heat at a rate of 5°C/min to 120°C, and at 10°C/min to 280°C, holding for 8min.

2.3. Experimental Procedure

After the pre-treatment of the experimental seats, we swiftly packed the seat assembly and the disassembled seat components neatly into boxes for subsequent testing. Both the vehicle assembly and components were tested following the procedures outlined in GB 18352.6—2016 Appendix F for evaporative pollutant emission tests (Type IV tests), which include hot soak tests, ambient soak tests, and a two-day diurnal emission test. The substance composition of hydrocarbons was analyzed using a gas chromatography-mass spectrometry system, acquiring the full spectrum data of the assemblies and components through gas collection.

3. EXPERIMENTAL RESULTS

Upon completing the tests for the assemblies and components, an analysis of the results was conducted. The components were categorized into three types: foam (such as seat foam), plastics (including the base material and seat backplates), and leather (including seat covers and seat fabric). To simplify the analysis, we decided to focus on the top ten data of the full hydrocarbon spectrum. This decision was based on the higher concentration levels of the initial ten data, with subsequent data having a minimal impact on the overall results and thus considered negligible in this analysis. The full spectrum results are presented below, with the full spectrum for seat sample 1 shown in Table 1, and the full spectrum for type components shown in Tables 2-6.

Table 1. Full Spectrum Data of Seat Assembly

No.	Molecular Formula	Name	CAS No.	Proportion	Main Use
1	C ₆ H ₁₂ N ₂	Triethylenediamine	280-57-9	8.36%	Triethylenediamine, also known as triethyl diamine, is a white or pale yellow crystal with an ammonia smell. It is an intermediate in organic synthesis, used for synthesizing light-stabilizing materials, and is extensively utilized in polyurethane foams, elastomers, plastic products, and molding processes. Additionally, it serves as a polymer initiator, applicable as a catalyst for the polymerization of ethylene and epoxide, with its derivatives functioning as corrosion inhibitors and emulsifiers.
2	C ₁₂ H ₂₆	2, 6-dimethyldecane	13150-81-7	7.25%	Chemical reagent, fine chemical, pharmaceutical intermediate, material intermediate.
3	C ₈ H ₂₀ N ₂ O	Bis (2-(dimethylamino-ethyl) ether	3033-62-3	6.70%	As an efficient tertiary amine catalyst, it is almost suitable for the production of all foam plastic products, mainly used in soft foam products, particularly appropriate for high resilience products.
4	C ₁₀ H ₂₂	decane	124-18-5	6.62%	Employed as a solvent, in organic synthesis, and in fuel research.
5	C ₁₅ H ₃₂	2,6, 11-trimethyl dodecane	31295-56-4	6.22%	For scientific research purposes only, not intended as a drug, household medication, or for other uses.
6	C ₁₀ H ₁₈ O ₄	Dimethyl 1, 2, 3-diethylsuccinate	26474-32-8	4.21%	----
7	C ₆ H ₁₁ N _O	1-ethyl-2-pyrrolidone	2687-91-4	4.21%	Primarily used in refining oil products and producing gunpowder, medicines, dyes, pesticides, daily chemicals, coatings, heat-resistant resins, etc. Lithium batteries, dry glue degreasing, photoresist stripper, coating spreader, epoxy resin edge cutting.
8	C ₁₆ H ₃₄	cetane	544-76-3	4.05%	[Use 1] Used as a solvent and in organic synthesis. [Use 2] Used as a solvent, gas chromatography comparison sample, and a standard substance for determining diesel combustion quality. The cetane number of diesel is equal to the volume percentage of hexadecane in the standard fuel (a mixture of hexadecane and α -methyl-naphthalene) when the combustion quality under specified working conditions is the same as the diesel being evaluated. The cetane number ranges between 40-55. In recent years, synthetic 2,2,4,4,6,6,8,8-heptamethyl-nonane (HMN) has been used to replace α -methyl-naphthalene as the standard substance, with its cetane number defined as 15. The cetane number of standard fuel is calculated using the formula: Cetane = 100×(% Hexadecane) + 15×(% HMN). For example, a mixture containing 35% hexadecane and 65% HMN would have a base cetane number of: 100×0.35 + 15×0.65 = 45. [Use 3] As a stationary liquid in gas chromatography (maximum operating temperature 50°C, solvent: toluene), for the separation and analysis of low-level hydrocarbons and metal chlorides. A standard for gas chromatography analysis. Solvent. Organic synthesis.
9	C ₁₃ H ₂₈	tridecane	629-50-5	3.32%	Used for producing tridecanedioic acid (brassylic acid), serving as a solvent-based raw material oil for industries such as paint, rubber, latex, and plastics.
10	C ₉ H ₂₀	2, 4-dimethylheptane	2213-23-2	2.87%	standard for gas chromatography analysis

Table 2. Full Spectrum Data of Chair foam

No.	Molecular Formula	Name	CAS No.	Proportion
1	C ₈ H ₂₀ N ₂ O	Bis (2- (dimethyl amino) ethyl) ether	3033-62-3	39.34%
2	C ₆ H ₁₂ N ₂	Triethylenediamine	280-57-9	36.46%
3	C ₄ H ₁₀ O ₂	1-methoxy-2-propanol	107-98-2	11.73%
4	C ₁₆ H ₄₈ O ₆ Si ₇	cetamethyl-heptasiloxane	541-01-5	2.64%
5	C ₁₃ H ₂₈	tridecane	629-50-5	1.93%
6	C ₁₂ H ₂₆	dodecane	112-40-3	1.41%
7	C ₁₄ H ₄₂ O ₅ Si ₆	Tetradecyl methyl-hexasiloxane	107-52-8	1.37%
8	C ₈ H ₁₀	p-xylene	106-42-3	0.62%
9	C ₈ H ₁₀	ethylbenzene	100-41-4	0.53%
10	C ₁₆ H ₃₀ O ₄	2,2, 4-trimethyl-1, 3-pentanediol diisobutyrate	6846-50-0	0.40%

Table 3. Full Spectrum Data of Base material

No.	Molecular Formula	Name	CAS No.	Proportion
1	C ₁₅ H ₃₂	2,6, 11-trimethyl-dodecane	31295-56-4	19.52%
2	C ₁₄ H ₃₀	4, 6-dimethyl-dodecane	61141-72-8	16.54%
3	C ₁₂ H ₂₆	2, 4-dimethyl-decane	2801-84-5	8.48%
4	C ₈ H ₁₈ O	2-ethyl-1-hexanol	104-76-7	5.50%
5	C ₁₁ H ₂₄	undecane	1120-21-4	3.58%
6	C ₈ H ₁₀	ethylbenzene	100-41-4	3.48%
7	C ₈ H ₁₀	p-xylene	106-42-3	2.53%
8	C ₃ H ₆ O	acetone	67-64-1	1.94%
9	C ₁₀ H ₂₂ O	1-heptanol-2-propyl	10042-59-8	1.83%
10	C ₈ H ₁₀	o-xylene	95-47-6	1.75%

Table 4. Full Spectrum Data of Seat guard

No.	Molecular Formula	Name	CAS No.	Proportion
1	C ₁₂ H ₂₆	dodecane	112-40-3	19.68%
2	C ₁₅ H ₃₂	pentadecane	629-62-9	18.54%
3	C ₁₄ H ₃₀	4, 6-dimethyl-dodecane	61141-72-8	8.87%
4	C ₉ H ₂₀	2, 4-dimethyl-heptane	2213-23-2	7.36%
5	C ₁₁ H ₂₄	undecane	1120-21-4	4.66%
6	C ₁₄ H ₂₂ O	2, 4-di-tert-butylphenol	96-76-4	3.36%
7	C ₁₂ H ₂₆	2, 4-dimethyl-decane	2801-84-5	3.02%
8	C ₁₅ H ₃₂	2,6, 11-trimethyl-dodecane	31295-56-4	2.99%
9	C ₉ H ₁₈ O	Nonyl aldehyde	124-19-6	2.37%
10	C ₁₂ H ₂₆	dodecane	112-40-3	2.16%

Table 5. Full Spectrum Data of Seat cover

No.	Molecular Formula	Name	CAS No.	Proportion
1	C ₄ H ₁₀ O ₂	1-methoxy-2-propanol	107-98-2	11.32%
2	C ₅ H ₉ NO	1-methyl-2-pyrrolidone	872-50-4	7.82%
3	C ₈ H ₁₆ O ₂	2-ethyl-caproic acid	149-57-5	7.37%
4	C ₆ H ₁₁ NO	1-ethyl-2-pyrrolidone	2687-91-4	6.02%
5	C ₃ H ₇ NO	Dimethylformamide	68-12-2	4.90%
6	C ₁₂ H ₂₆	dodecane	112-40-3	3.99%
7	C ₈ H ₁₈ O ₃	2- (2-butoxyethoxy) - ethanol	112-34-5	3.41%
8	C ₈ H ₁₈ O	2-ethyl-1-hexanol	104-76-7	2.95%
9	C ₃ H ₆ Cl ₂ O	1, 3-dichloro-2-propanol	96-23-1	2.70%
10	C ₁₃ H ₂₈	tridecane	629-50-5	2.63%

Table 6. Full Spectrum Data of Seat fabric

No.	Molecular Formula	Name	CAS No.	Proportion
1	C ₈ H ₁₀	p-xylene	106-42-3	21.47%
2	C ₈ H ₁₀	ethylbenzene	100-41-4	12.38%
3	C ₆ H ₆ O	phenol	108-95-2	12.34%
4	C ₄ H ₁₀ O ₂	1-methoxy-2-propanol	107-98-2	9.91%
5	C ₁₆ H ₃₀ O ₄	2,2, 4-trimethyl-1, 3-pentanediol diisobutyrate	6846-50-0	8.79%
6	C ₈ H ₁₀	1, 3-dimethylbenzene	108-38-3	7.95%
7	C ₈ H ₁₀	o-xylene	95-47-6	6.38%
8	C ₇ H ₁₂ O ₂	Butyl 2-propionate	141-32-2	4.82%
9	C ₇ H ₈	toluene	108-88-3	3.09%
10	C ₄ H ₈ O ₂	Ethyl acetate	141-78-6	2.93%

In the specialized field of automobile seat manufacturing, the application of specific chemicals is paramount due to their unique properties, which significantly contribute to the development of various components of the seat, including foam, elastomers, and coatings. Among these, triethylenediamine, also known as triethyl diamine, plays a crucial role as an intermediate in organic synthesis. This compound is primarily employed in the fabrication of light-stabilizing materials and is extensively utilized in the production of polyurethane foams, elastomers, and plastic products, including their molding processes. The substance's utility extends to acting as an initiator for polymers, rendering it suitable as a catalyst in the polymerization of ethylene and ethylene oxide, among other applications. Furthermore, its derivatives are effectively used as corrosion inhibitors and emulsifiers, showcasing the versatility and indispensability of triethylenediamine in the automotive seat manufacturing process.

2, 6-Dimethyldodecane, serving as a chemical reagent, is recognized for its applications as a fine chemical product, pharmaceutical intermediate, and material intermediate. This highlights its significance in the chemical synthesis processes essential for developing materials with specific properties required in the automotive industry.

Bis(2-(dimethylamino)ethyl) ether is distinguished for its efficiency as a tertiary amine catalyst. Its application is widespread across the production of foam plastic products, with a particular emphasis on soft foam products. Its suitability for high resilience items underlines its importance in enhancing the comfort and durability of automotive seats.

Decane is utilized as a solvent, in organic synthesis, and in fuel research, indicating its broad range of applications in both the development and testing of automotive materials.

2, 6, 11-Trimethyldodecane is specifically earmarked for scientific research purposes, underscoring its role in advancing the understanding and development of new materials and technologies within the automotive sector.

Ethyl-2-pyrrolidone is extensively used in refining oil products and in the production of explosives, medicines, dyes, pesticides, daily chemicals, coatings, heat-resistant resins, and more. Its role in lithium batteries, degreasing adhesives, photoresist agent stripping, spreading agent for coatings, and in the removal of epoxy resin glue edges, demonstrates its critical function in enhancing the performance and sustainability of automotive materials.

Hexadecane's primary application encompasses its use as a solvent and in organic synthesis. It serves as a solvent, gas chromatography comparison sample, and a standard substance for determining the quality of diesel combustion. Its use as a stationary phase in gas chromatography for the separation and analysis of low-level hydrocarbons and metal chlorides further exemplifies its utility in ensuring the quality and performance of automotive components.

Tridecane is predominantly used in the production of tridecanedioic acid (brassylic acid), serving as a solvent-type raw material oil in industries such as paint, rubber, latex, and plastics, which are integral to the automotive manufacturing process.

2, 4-Dimethylheptane's main use as a standard in gas chromatography analysis underlines the importance of precision and accuracy in the quality control of automotive manufacturing processes.

Upon a comprehensive analysis of the full spectrum, it becomes evident that the seat foam significantly contributes to the presence of amines, especially triethylenediamine, in the tested seat assembly. This is due to its use in the polymerization and molding processes of foam materials. Additionally, ethers, particularly bis(2-(dimethylamino)ethyl) ether, utilized primarily as a tertiary amine catalyst, are found to have a relatively high content in the full spectrum. These findings underscore their significant contribution and highlight the complex chemical interactions that underpin the manufacturing of automotive seats, offering insights into the materials' composition and facilitating further advancements in automotive seat design and manufacturing.

In the context of manufacturing plastic and fabric components for seating, it becomes imperative to understand the chemical composition of these materials to mitigate any potential environmental impacts effectively. Specifically, the plastic parts, such as the base and seat backplates, predominantly consist of alkanes, such as 2, 6, 11-trimethyldodecane, and their derivatives. This chemical presence underscores the necessity for a thorough examination and potential modification of the synthetic processes involved in material preparation to ensure environmental sustainability and safety.

Similarly, fabric components, including seat covers and the seating surface, are largely made up of alcohol-ketone compounds, with (1-ethyl-2-pyrrolidinone) being a notable example frequently employed in coating paints. The distinct chemical signatures of these substances across the full spectrum analysis provide a robust foundation for conducting more detailed examinations and evaluations of the materials used in seat manufacturing.

In light of the above, during the synthesis and preparation phases of material manufacturing, particular attention must be paid to the properties and origins of the primary hydrocarbons involved. By adopting a series of strategic measures, it is possible to significantly reduce the environmental footprint of the manufacturing process. These strategies include:

Diminishing the reliance on foam polymers, catalysts, adhesives, and associated organic solvents, aiming to lower the residual solvent content. This approach not only enhances the product's environmental profile but also contributes to healthier indoor air quality by reducing potential off-gassing.

Replacing polycyclic aromatic hydrocarbons with additives that possess shorter carbon chains, thereby making the preparation process more benign to the environment. This substitution is crucial for reducing the release of harmful compounds during both the manufacturing process and the product's lifecycle.

Curtailing the utilization and residual presence of solvents throughout the production stages to bolster the eco-friendliness of the manufacturing operation. This minimization effort plays a pivotal role in lessening the overall environmental impact and promoting sustainable manufacturing practices.

Employing surfactants of superior purity to ensure the production of high-quality, sustainable products. The use of such high-purity surfactants is instrumental in achieving optimal product performance while maintaining an environmentally responsible manufacturing process.

Transitioning to acrylates from volatile water-based solvents, minimizing the incorporation of alkanes, and reducing the use of softeners to mitigate environmental degradation. This shift not only addresses environmental concerns but also aligns with the growing demand for more sustainable manufacturing solutions.

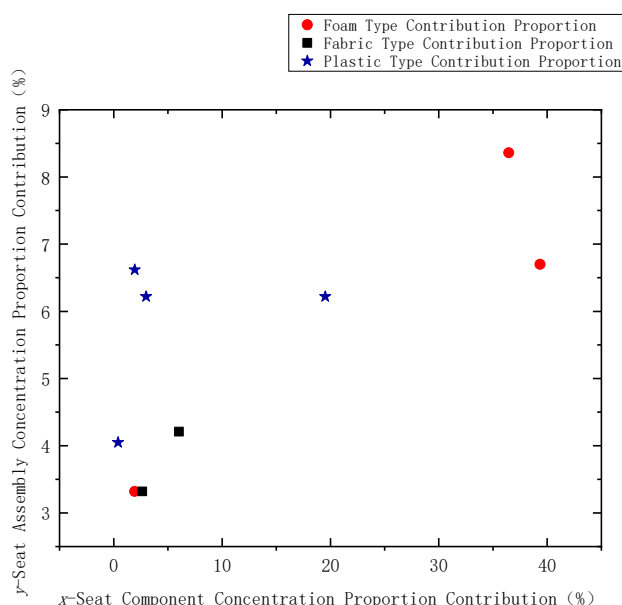
Regulating the application of oil agents by selecting those of higher purity, which enhances product performance and environmental sustainability. This selective approach ensures that the final products meet both functional and ecological standards.

Giving precedence to raw materials that have a lower alkane content during the selection, processing, and synthesis stages, with the aim of diminishing adverse environmental effects. This prioritization is critical for developing products that are both effective and environmentally considerate.

By integrating these strategies into the material preparation and synthesis processes, manufacturers can significantly improve the environmental profile of seat production, paving the way for more sustainable manufacturing practices that prioritize both product quality and ecological stewardship.

Table 7. Concentration Proportion Contribution of Assembly and Type Components

No.	Contribution of Assembly Concentration Proportion	Contribution of Dispersed Type Component Concentration Proportions	Molecular Formula	Name	CAS No.
1	8.36	36.46	C ₆ H ₁₂ N ₂	Triethylenediamine	280-57-9
2	6.7	39.34	C ₈ H ₂₀ N ₂ O	Bis (2- (dimethylamino-ethyl) ether	3033-62-3
3	3.32	1.93	C ₁₃ H ₂₈	tridecane	629-50-5
4	6.22	2.99	C ₁₅ H ₃₂	2,6, 11-trimethyl-dodecane	31295-56-4
5	4.05	0.4	C ₁₆ H ₃₄	cetane	544-76-3
6	6.62	1.94	C ₁₀ H ₂₂	decane	124-18-5
7	6.22	19.52	C ₁₅ H ₃₂	2,6, 11-trimethyl-dodecane	31295-56-4
8	4.21	6.02	C ₆ H ₁₁ NO	1-ethyl-2-pyrrolidone	2687-91-4

**Figure 1.** Schematic Diagram of Seat Assembly and Type Component Proportion Contribution

Comparing the full spectrum of the seat assembly and components, we focused on analyzing the corresponding hydrocarbons between the two and delved into the contribution of components to the non-fuel hydrocarbons in the assembly. Specifically, substances in the component full spectrum were also reflected in the assembly full spectrum. Theoretically, this contribution is not a simple summation but relates to the content and material of the components, as well as the physical and chemical changes occurring during the emission process in the assembly and components.

We matched the hydrocarbon concentrations of different types of components in the assembly and component full spectrums to their concentration proportion contributions in the assembly. The concentration proportion contribution is defined as a dimensionless parameter, calculated as the concentration of a certain hydrocarbon over the concentration of all substances within the full spectrum. Table 7 lists the concentration proportion contributions of substances related to the assembly and components, presented schematically in Figure 1.

Figure 1 shows the proportion contributions of evaporative pollutants from the seat assembly, foam, fabric, and plastic components. The horizontal axis represents the concentration proportion of a single hydrocarbon in the seat assembly, while the vertical axis indicates its concentration proportion in the seat components. These graphs reveal the pattern of hydrocarbons produced by components in finding their corresponding chemicals in the assembly full spectrum, further proving the contribution of hydrocarbons emitted by components during the assembly's emission process. According to the analysis, as the dispersion proportion contribution increases, the growth trend of the assembly proportion contribution gradually slows. This pattern allows for nonlinear curve fitting to derive a corresponding formula.

The establishment of this formula aims to calculate the corresponding hydrocarbons in components after identifying certain hydrocarbons significantly impacting the seat assembly's evaporative pollutants or to verify the reliability of the component's corresponding hydrocarbon concentration proportion during the experimental process based on the assembly's full spectrum hydrocarbon concentration values.

To ensure the formula's universality, it is set as a power function type, expressed as follows:

$$y=a*x^b+c \tag{1}$$

Formula 1 Schematic Formula for Concentration Contribution of Assembly and Type Components

Within this context:

"y" represents the concentration proportion contribution of the assembly's corresponding hydrocarbons, in percentage.

"x" denotes the concentration proportion contribution of the component's corresponding hydrocarbons, also in percentage.

"a", "b", and "c" are constants.

Upon substituting the relevant data, the resulting fit formula is as follows, with the corresponding fit curve depicted in Figure 2.

$$y = (0.2012 \pm 0.96158)x^{(0.76358 \pm 1.20641)} + (4.24153 \pm 1.5835) \tag{2}$$

Formula 2 Formula for Concentration Contribution Relationship between Assembly and Type Components

Model	NewFunctionABC (User
Equation	$a*x^b+c$
Graphing	B
a	0.2012 ± 0.96158
b	0.76358 ± 1.20641
c	4.24153 ± 1.5835
Reduced Chi-Sq	2.05446

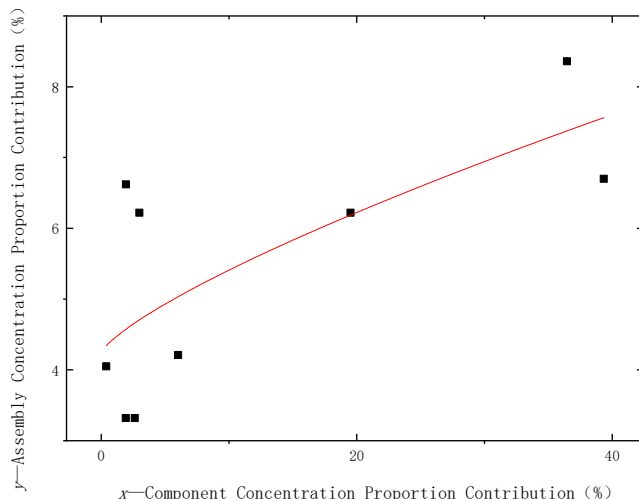


Figure 2. Non-linear Curve Fitting Results

In the context of evaluating the material composition and environmental impact of automotive seats, the utilization of a specialized formula for predicting and analyzing the concentration proportion contributions of hydrocarbons presents a significant advancement. This methodological approach allows for the detailed examination of the specific hydrocarbons present within both the complete seat assembly and its individual components. The strategic importance of this analytical capability cannot be overstated, as it facilitates highly accurate predictions and analyses of the hydrocarbon concentration proportion contributions. Consequently, this analytical tool provides a solid foundation for the rational selection of seat materials and the meticulous optimization of associated technological processes.

Consider, for example, the practical application of this formula in the analysis of a specific seat sample. By conducting identical evaporation tests on both the assembled seat and its disassembled components, researchers can accurately determine the concentration proportion contributions of the individual components. Following this initial analysis, the aggregate concentration proportion contributions of the complete assembly can be calculated utilizing the formula. This step-by-step process not only enables a thorough understanding of the material composition of the seat but also allows for the identification of potential areas for material substitution or process improvement.

Moreover, upon the completion of these evaporation tests on both the seat assembly and its components, the resulting experimental data can be systematically inputted into the formula for validation purposes. This crucial phase of the research process involves a rigorous assessment of the accuracy of the experimental data, primarily through the examination of deviations between predicted and actual concentration proportions. Such a validation process is instrumental in establishing the reliability and credibility of the experimental results, thereby providing a robust data foundation for future research and development efforts.

The implications of this analytical approach extend far beyond the immediate scope of hydrocarbon analysis. By enabling precise and reliable predictions of material composition, the formula serves as a cornerstone for the development of more sustainable and environmentally friendly automotive seating solutions. It empowers researchers and manufacturers to make informed decisions regarding material selection and process optimization, ultimately contributing to the advancement of the automotive industry's sustainability objectives. Through the meticulous application of this formula,

the industry can move towards the production of automotive seats that not only meet the highest standards of comfort and safety but also adhere to stringent environmental and sustainability criteria.

4. CONCLUSION

In the ambit of automotive seat manufacturing, the challenge of mitigating evaporative pollutant emissions presents a formidable hurdle, yet it also offers a unique opportunity for innovation and sustainability. This study, through its comprehensive analysis of evaporative pollutant tests conducted on both the seat assemblies and their individual components, has unearthed pivotal insights into the role of hydrocarbon emissions from non-fuel systems, particularly emphasizing the significant contribution of seat foam and other components. These findings serve not merely as an academic revelation but as a critical catalyst for the formulation of targeted strategies aimed at reducing these emissions. Such strategies, derived from an exhaustive examination of the collected data spectrum, propose a multifaceted approach to emission reduction, encompassing the minimization of foam polymer and solvent use, the advocacy for environmentally benign additives, and the stringent regulation of oil agent and surfactant usage. The implementation of these strategies heralds a tangible advance towards enhancing environmental sustainability within the automotive industry.

The meticulous dissection of the concentration proportion contributions of various components offers an invaluable perspective on their respective impacts on the seat assembly's hydrocarbon emissions. This detailed understanding is instrumental in guiding the optimization of material compositions and manufacturing processes, thereby significantly reducing the environmental footprint of automotive seat assemblies.

Building upon the empirical foundation laid by the experimental data, this study has formulated a novel relationship formula. This formula represents a breakthrough in predicting and validating evaporative emission data across diverse seat samples, enabling a more efficient and eco-conscious approach to seat design and production. This development signifies a pivotal shift towards environmentally responsible manufacturing practices within the automotive sector.

Looking forward, this research paves the way for several promising avenues of future investigation:

There is a marked interest in delving deeper into the potential for substituting traditional seat materials with alternatives that better align with environmental conservation goals. This exploration aims to uncover materials and manufacturing processes that further reduce hydrocarbon emissions, contributing to the automotive industry's sustainability efforts.

The expansion of component testing to include a broader spectrum of materials used in seat design and manufacturing is anticipated. This broader testing regime is expected to provide deeper insights into the hydrocarbon emission characteristics of various components, thereby enriching our understanding and guiding the selection of more environmentally friendly materials.

The horizon of innovation is set to expand with the exploration of cutting-edge technologies and materials, such as advanced seat sealing techniques and low-emission materials. These developments promise to redefine automotive seat design, steering it towards greater environmental compatibility and sustainability.

Continuous efforts to refine and enhance the precision and applicability of the relationship formula are underway. These efforts are focused on accommodating the variances observed across different seat samples, aiming to universalize the formula's applicability. This endeavor seeks to amplify the formula's utility and relevance, ensuring its effective application across a wide array of automotive manufacturing scenarios.

In summary, this study not only sheds light on the critical issue of hydrocarbon emissions from automotive seats but also charts a course towards their mitigation through innovative material selection, process optimization, and the application of a novel predictive formula. As the automotive

industry continues to evolve, these findings will undoubtedly contribute to the advancement of eco-conscious manufacturing practices, aligning automotive production more closely with the imperatives of environmental sustainability.

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