Using Nonwoven Hollow Fibers to Improve Cars Interior Acoustic Properties

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Abstract: The necessity and importance of protecting our environment is evident in this time and the high developed industrial nations are responsible in the first position The industrial fabrics industry will continue to develop to meet the needs of society and the growth of the industry is assured because industrial fabrics are leading the way for materials to be structured to solve problems and to be engineered to meet the special performance of products. In the past few years, car manufacturers have focused on automobile interiors from a merely function as not only do interior trims serve to differentiate models, but materials and designs can also be used to tailor the same model to different target groups. This research aims to produce nonwoven fabrics that can be used in car interior components (head liners, doors, side panels and trunk liners) to prevent noise from reaching the passenger compartment and so achieving comfort in the car interior. Two kinds of fibers were used polyester and hollow polyester fibers, both of 6 denier, to produce three different fabrics of 100 % polyester fibers, 75 % polyester /25 % hollow polyester fibers, and 55 % polyester /45 % hollow polyester fibers. Four fabric weights were produced 300, 400, 500 and 600 g/m^2. All samples were bonded using thermal bonding technique. More results were reached, for examples, samples produced with high percentage of hollow fibers had recorded the highest rates of sound absorption, whereas samples produced with 100% polyester fibers have recorded the lowest rates. It was also found that there are direct relationship between weight per m^2 and sound absorption efficiency. All samples have achieved the expected results and sample produced with 55% polyester/45% hollow polyester fibers and 600 g/ m^2, have achieved the best results.
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1. Introduction:

When talking about textiles most people think of clothing, home textile and the like; only few think about the automotive industry [1]. In fact automotive textiles are considered one of the most important markets in the technical textiles sector. Over the last decade [2], the field of non-conventional textiles has been witnessing a material revolution which has resulted in improved and economical products [3]. The automotive industry has become so competitive that manufactures are reluctant to divulge precise details of their process for fear that it could be helpful to their competitors .Industrial textiles are widely used in transportation vehicles and systems including cars, trains, buses, airplanes and marine vehicle [4], automotive textiles are growth markets in terms of quantity, quality, and product variety [5] The motor vehicle remains an important means for individual transport worldwide. The interior of transportation vehicles are receiving more attention these days. Acoustical insulation products are frequently used in automotive interiors to reduce heat levels [6]. That customers expect more comfort, better safety, good appearance, (both externally and internally), high performance and good fuel mileage [2]. Textiles make a major contribution towards realizing all these expectations due to its advantages which made it a preferable material, such as high capacity to take moisture, adjustable porosity, high – pile fibrous surface, low cost recycling and a wide range of ways to combine textiles with other materials.[7]. Due to the diverse product range, automotive textiles can be classed into upholstery, carpeting [8], which have a decisive influence on the acoustic comfort [9], interior components such as head liners, and doors and side panels [8], which are foam backed components to achieve easier installation and improve acoustical properties) [10] tires, safety devices (such as seat belts and airbags), filters and engine compartment items [8].

1-1. Noise in cars

Noise has become serious environment pollution in our daily life and is an increasing public health problem, as noise can cause serious health effects such as hearing loss, sleep disturbance, tiredness, cardiovascular and psychophysiology problems and performance reduction. Therefore it is very important to control or reduce noise from traffic, and in factories, offices and houses [11]. Car noise is essentially caused by the unit sound, the exhaust system noise, the air suction, noise, rolling and wind noises [12]. Nowadays dominant approach to achieving interior quietness relies to a large extent upon the ability to create impermeable enclosures around vehicle occupants through the use of several heavy interior layers (sound transmission loss), but recently a new concept has been emerged suggesting that sound can be reduced by replacing reflection (sound transmission loss) with dissipation (interior sound absorption area) by eliminating heavy barrier layers with light weight porous materials [13].

Nonwoven is employed as fabrics for different kinds of interior applications. The numerous applications of nonwoven in cars can be classified into functional or aesthetic but there is a third category that of substitutes for other materials. Nonwoven can be made in a wide range of densities and different forms, the use of nonwoven is increasing because it offers great versatility and cost effectiveness [14]. Each vehicle requires about 20 m^2 of nonwoven materials [11], which are used especially for insulation, noise dissipation and as filter materials ….etc. Woven and knitted fabrics are also used in producing automotive fabrics but to a lesser extent compared to nonwoven fabrics [15].

The present work is undertaken with a view to produce nonwoven fabrics which can be used to induce comfort in the car interior. By virtue of their ability to prevent noise, there fabrics can be safely used to achieve comfort in the passenger compartment as a manifestation of preventing noise from reducing this compartment. The nonwoven fabrics are made of polyester and hollow polyester at different ratios and weights.

2. The experimental work

2-1. Specification of samples under study

In order to produce samples under study nonwoven technique was applied using cross-laid fiber orientation. Two kinds of textile materials were used polyester and hollow polyester fibers, both of 6 denier, to produce three different fabrics, of 100 % polyester fibers, 75 % polyester/ 25 % hollow polyester fibers and 55 % polyester/ 45 % hollow polyester fibers. Four fabric weights were also produced 300, 400, 500 and 600 g/m^2. All samples were bonded using thermal bonding technique (hot air method (by adding a small proportion of low–melting point polyester fibers (about 15 % and melting point 110^0c). Tables (1) and (2) illustrate the specification of all samples produced.

2-2. Hollow fibers

Hollow fibers are polymeric fibers that have a continuous hole running down the middle; the hole is created by the introduction of air or other gas (nitrogen) in the polymeric solution (in wet spinning process) or by melt spinning through specially designed spinnerets [16]. Hollow fibers provide greater bulk with less weight. They are, therefore often used to make insulation fabrics [17].

2-3. Tests applied to samples under study

In order to evaluate the performance properties of the produced samples, the following tests were carried out:-

1-Sound absorption coefficient test was carried out according to the ASTM-E 1050-1982 [18]. The sound (noise)absorption values (%)of samples under study were measured at 6 different frequencies,125,250,500,1000,2000, and 4000Hz.

2-Air permeability test was carried out according to the (ASTM-D 4491-92) [19].

3-Fabric thickness test was carried out according to the (ASTM D 1777) [20].

3. Results and discussion:

Table (1), shows the production specification of the samples under study; where as table (2), illustrates the specifications of three samples. On the other hand, dependence of air permeability on fabric thickness is shown in table (3).

Statistical analysis of the data were made with relationships between variables. Regression equation and correlation coefficient for the effect of fiber type on fabric sound absorption at weights of 300, 400 and 500 g/m^2 are set out in tables (4), (5) and (6), respectively.

On the other hand, tables (7), (8) and (9) depict the regression equation and correlation coefficient for the effect of weight g/m^2 on fabric sound absorption when the fabrics were made of 100% polyester, 75% polyester/25% hollow fiber and 55% polyester/45% hollow fiber, respectively.

In addition to the above, table (10) discloses the regression equation and correlation coefficient for the effect of weight g/m^2 and fiber type on fabric airpermeability. Meanwhile, table (11) reveals the regression equation and correlation coefficient for the effect of weight g/m^2 and fiber type on fabric thickness.

3.1 Sound absorption efficiency test

Figures from (1 to 4), signify that there is a direct relation between the increase in hollow fibers percentage in the fabric and its sound absorption efficiency. This is most probably due to the hollow structure of the fibers. Such structure would have air inside its lumen which increases the air volume in the fabric and, in turn, increases its ability to absorb sound waves rather than reflecting it.

Figures from (5 to 7), disclose that, the increase in fabric weight improves the sound absorption efficiency of fabrics at both low and high frequencies. We can state that this is mainly, because the increase in fabric weight means an increasing in the number of fibers per unit area and also an increase in fabric volume, and so the interconnected voids will be increased which absorb the sound waves rather than reflecting it, if the fabric was compacted, which means that the sound absorption efficiency will be increased.

3.2 Air permeability test

From table (3) and figure (8), it can be seen that there is an inverse relationship between fabric weight and its air permeability properties. We can state that the increase in fabric weight increases number of fibers per unit area and so free spaces in fabric will be decreased which delay the free passage of air through the fabric. Besides this the effect of heat bonding technique helps in this result because of the melting of fibers (polyester fibers of low melting point) which cause pore spaces of free area between fibers to be decreased leading to the decrease in fabric air permeability. It can also be noticed from figure (8) that, for the same weight, the more hollow fibers the less air permeability of the fabrics become due to the increase in number of hollow fibers, which leads to increase of the air volume in the fabric, because of the air entrapped into the fibers. Accordingly the free spaces into the fabrics will be decreased because of fabric bulkiness and so the ability of air flow to be passed through the fabric will be also decreased.

3.3 Fabric thickness test

It is obvious from table (3) and figure (9) that there is a direct relationship between fabric thickness and its weight. We can report that, this is because of the fact that the increase in fabric weight means an increase in number of fibers per unit area which leads to the increase in fabric thickness. It is also clear from table (3) and figure (9) that the increase in hollow fibers percentage in the fabric increases its thickness. This might to due to the structure of hollow fibers which have air in its internal voids which increases the volume ratio of fibers, leading to the increase in fabric bulkiness and also its thickness.

Table (1) specification of samples production

Sample No.	Property	Specification
1	Fiber type	Polyester and hollow polyester fibers
2	Fiber count	6 denier
3	Fiber length	64 mm
4	Fabrics material	100 % polyester fibers ,75 %polyester /25 % hollow polyester fibers and 55 % polyester / 45 % hollow polyester fibers.
5	Web formation	Cross-laid
6	Fabric weight (g/m^2)	300,400,500 and 600
7	Bonding technique	Thermal bonding

Table (2) specification of all samples under study

Sample No.	Fabric weight g/m^2	Fabric material
1	300	100 % polyester fibers
2	300	75 % polyester /25 % hollow polyester fibers
3	300	55 % polyester /45 % hollow polyester fiber
4	400	100 % polyester fibers
5	400	75 % polyester /25 % hollow polyester fibers
6	400	55 % polyester /45 % hollow polyester fiber
7	500	100 % polyester fibers
8	500	75 % polyester /25 % hollow polyester fibers
9	500	55 % polyester /45 % hollow polyester fiber
10	600	100 % polyester fibers
11	600	75 % polyester /25 % hollow polyester fibers
12	600	55 % polyester /45 % hollow polyester fiber

Table (3) results of Air permeability test.

Sample No.	Thickness (mm)	Air permeability (cm^3/ cm^2/sec)
1	3.3	212
2	4.5	196
3	4.9	195
4	6.1	195
5	7.7	182
6	7.8	160
7	9.8	152
8	9.9	148
9	10.1	129
10	11.4	127
11	13.6	122
12	15	108

Table (4) regression equation and correlation coefficient for the effect of fiber type on fabric sound absorption, at weight 300 g/m^2

Fiber type	Regression equation	Correlation coefficient
100%Polyester	Y=9.94247 X +0.0372916	0.952573722
75%Polyester /25%hollow fiber	Y=0.0001303 X +0.036958	0.958470874
55%Polyester /45%hollow fiber	Y=0.0001382 X +0.038416	0.95657395

Table (5) regression equation and correlation coefficient for the effect of fiber type on fabric sound absorption, at weight 400 g/m^2

Fiber type	Regression equation	Correlation coefficient
100%Polyester	Y=7.78871 X +0.027875	0.97704865
75%Polyester /25%hollow fiber	Y=0.0001233 X +0.029083	0.96701712
55%Polyester /45%hollow fiber	Y=0.0001055 X +0.033416	0.9624999

Table (6) regression equation and correlation coefficient for the effect of fiber type on fabric sound absorption, at weight 500 g/m^2.

Fiber type	Regression equation	Correlation coefficient
100%Polyester	Y=0.00013317 X +0.039376	0.95556476
75%Polyester /25%hollow fiber	Y=0.0001495 X +0.0420416	0.954627931
55%Polyester /45%hollow fiber	Y=0.000166 X +0.0345	0.961916708

Table (7) regression equation and correlation coefficient for the effect of weight g/m^2 on fabric sound absorption, at polyester 100 %.

Weight /m^2	Regression equation	Correlation coefficient
300	Y=8.1626 X +0.17199	0.976762
400	Y=0.0001044 X +0.02288	0.957373368
500	Y=0.0001387 X +0.023338	0.9609214
600	Y=0.000178 X +0.0246766	0.96088684

Table (8) regression equation and correlation coefficient for the effect of weight g/m^2 on fabric sound absorption, at 75 % polyester/25 % hollow fiber.

Weight /m^2	Regression equation	Correlation coefficient
300	Y=0.000127784 X +0.0162835	0.9706377
400	Y=0.000143 X +0.022208	0.9618994
500	Y=0.000172321 X +0.186616	0.966878
600	Y=0.000127784 X +0.016283	0.9706377

Table (9) regression equation and correlation coefficient for the effect of weight g/m^2 on fabrics sound absorption, at 55%polyester/45%hollow fiber .

Weight /m^2	Regression equation	Correlation coefficient
300	Y=0.00011024 X +0.01996517	0.9660334
400	Y=0.00013567 X +0.02176619	0.963322316
500	Y=0.00015565 X +0.02454228	0.960252268
600	Y=0.0001956 X +0.03019403	0.952865124

Table (10) regression equation and correlation coefficient for the effect of weight g/m^2 and fiber type on fabric air permeability.

Fiber type	Regression equation	Correlation coefficient
100%Polyester	Y=-0. 34 X +328	0.9885229
75%Polyester /25%hollow fiber	Y=-0.26 X +262.3333	-0.9938927
55%Polyester /45%hollow fiber	Y=-0.3 X +300.666	0.997050141

Table (11) regression equation and correlation coefficient for the effect of weight g/m^2 and fiber type on fabric thickness.

Fiber type	Regression equation	Correlation coefficient
100%Polyester	Y=0. 28 X +4.95	0.989825773
75%Polyester /25%hollow fiber	Y=0.0295X + 4.36	0.995418547
55%Polyester /45%hollow fiber	Y=-0.36 X -7.03333	0.9789502

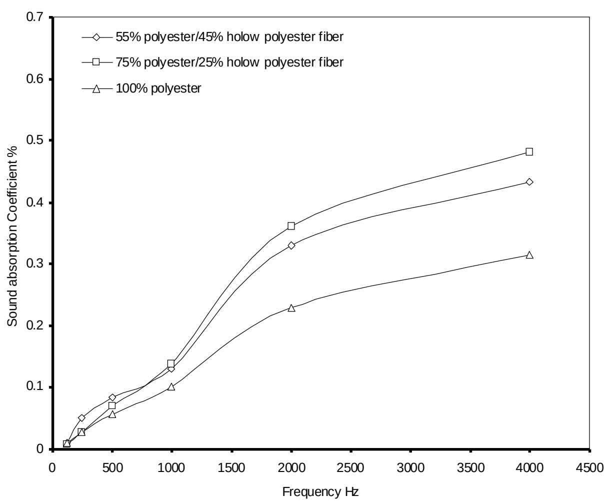

Fig.1, Effect of fiber type on fabric sound absorption at weight 300g/m^2

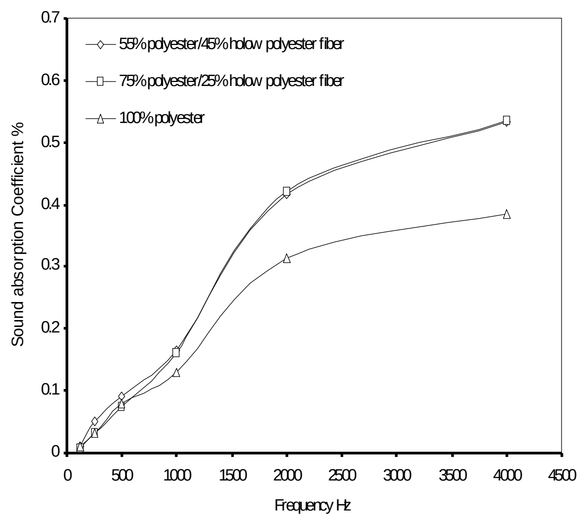

Fig.2, Effect of fiber type on fabric sound absorption at weight 400g/m^2

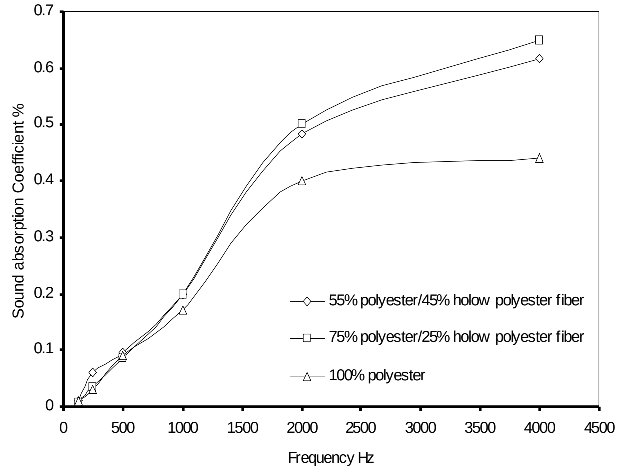

Fig.3, Effect of fiber type on fabric sound absorption at weight 500g/m^2

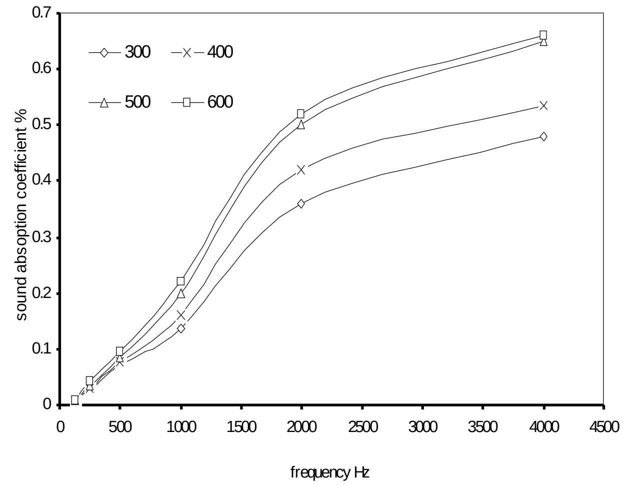

Fig.6, Effect of weight /m^2 on fabric sound absorption at 75%polyester/ 25% hollow fiber

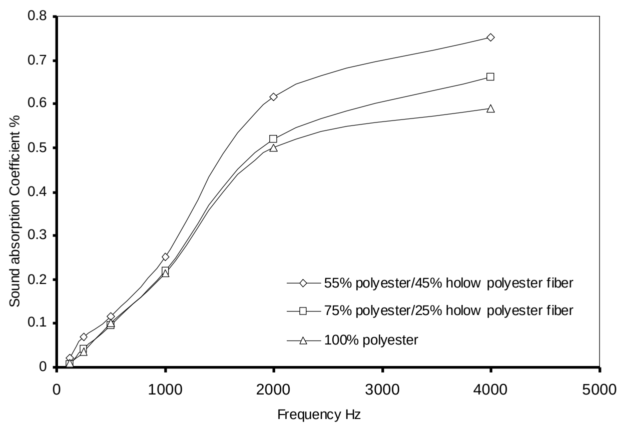

Fig.4, Effect of fiber type on fabric sound absorption at weight 600g/m^2

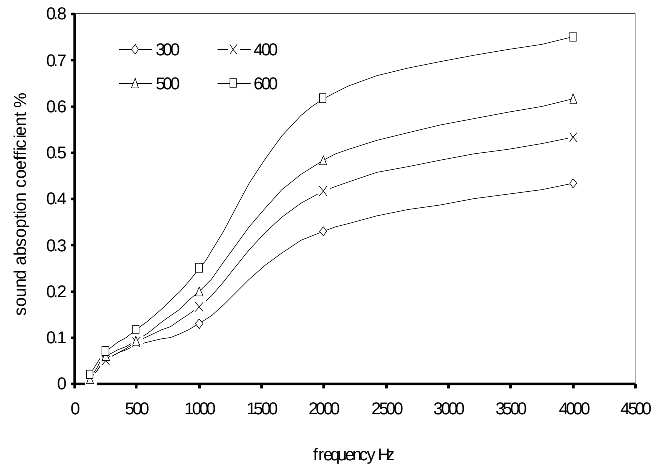

Fig.7, Effect of weight /m^2 on fabric sound absorption at 55%polyester/ 45% hollow fiber

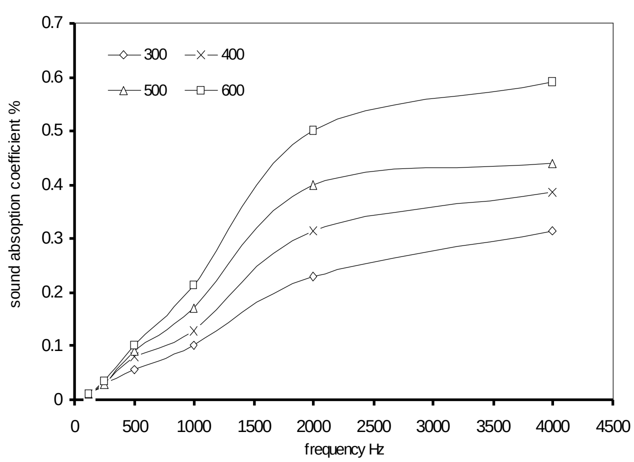

Fig.5, Effect of weight /m^2 on fabric sound absorption at 100%polyester

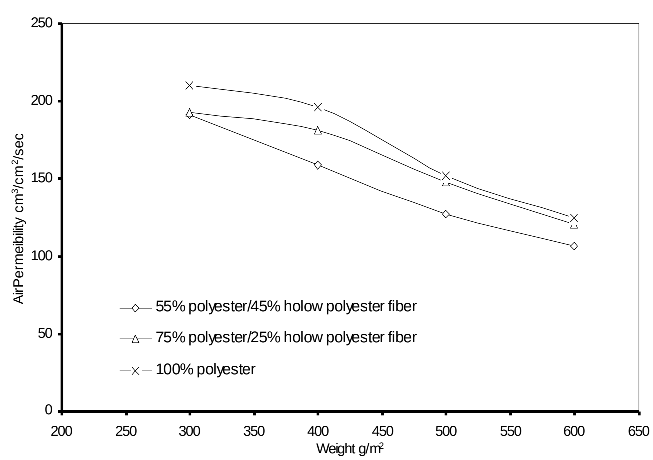

Fig.8, Effect of weight /m^2 and fiber type on fabric Air Permeability

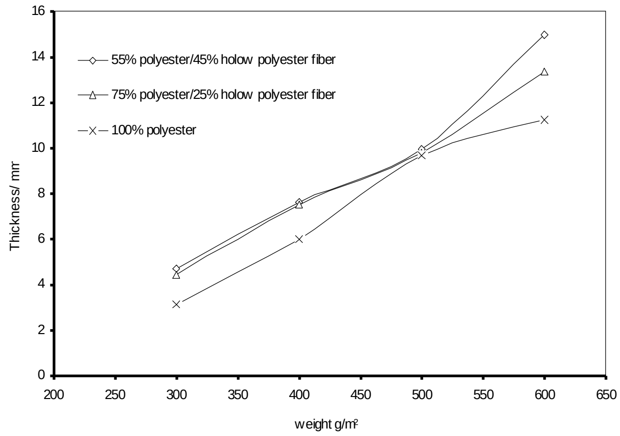

Fig.9, Effect of weight /m^2 and fiber type on fabric thickness

4. Conclusion

Over the past decade improvements in both functional and appearance durability of automotive trim have been significant. Technology applied in the form of better polymers, stabilizers and testing procedures has contributed to these improvements. Fabrics provide comfort and better appearance in car interiors while still meeting the performance and consistency requirements, these fabrics must also meet the needs of fashion function and durability required by the automakers. In the present research trials were made to produce fabric for sound insulation in automotive. Thus fabrics were developed for use in car interior components to minimize noise from reaching the passenger compartment and so achieving comfort in the car interior. Two kinds of fibers were used polyester and hollow polyester fibers, both of 6 denier, to produce three different fabrics of 100 % polyester fibers, 75 % polyester /25 % hollow polyester fibers, and 55 % polyester/45 % hollow polyester fibers. Four fabric weights were produced 300, 400, 500 and 600 g/m^2. All samples were bonded using thermal bonding technique. More results were reached, for examples, samples produced with high percentage of hollow fibers had recorded the highest rate of sound absorption, and samples produced with 100% polyester fibers have recorded the lowest rates. It was also found that there is direct relationship between weight per m^2 and sound absorption efficiency. Similarly samples produced with high percentage of hollow fibers recorded the highest rates of sound absorption, whereas samples produced with 100% polyester fibers recorded the lowest rates. Sample produced using 55% polyester/45% hollow polyester fibers and 600 g/m^2, displayed the best results.

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