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EFFECT OF MECHANICAL PROPERTIES OF COMPOSITE MATERIAL UNDER THE INFLUENCE OF DIFFERENT COMMERCIAL OILS

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***Abstract*-** **Composite materials are used in several engineering applications, where can be exposed to a range of corrosive environments during their in-service life. Thus, it is necessary understanding the impact of a corrosive environment in the working life of composite. Therefore, glass fiber/epoxy composites were subjected to oil immersion tests, using universal multi-grade engine oil (20W-40) and an extra high performance hydraulic brake fluid (DOT3), in order to study the effects of oil absorption behaviour on flexural and tensile strength properties of glass fiber/epoxy composites. The study has been completed with weight changes, after and before immersion both solutions affect the flexural properties and the tensile strength. Flexural and tensile behaviours are the main mechanical properties evaluated, although they are supplemented with Rockwell hardness, obtaining complete mechanical information. However, for all tests performed, the automotive brake fluid (DOT 3) promotes the lowest values comparatively to the automotive engine oil (20W40). Nowadays, composite materials are used in several engineering applications, as a consequence of their high specific strength and stiffness, competitive cost, good static and dynamic properties, good resistance to corrosion and simplified fabrication. In this context, these materials are exposed at different environment conditions, which affect significantly their mechanical properties. Glass fiber/epoxy composites were subjected to oil immersion tests, using an universal multi-grade engine oil (20W-40) and an extra high performance hydraulic brake fluid (DOT 3), in order to study the effects of oil absorption behavior on flexural and tensile strength properties of glass fiber/epoxy composite. Both solutions affect the flexural properties and the Tensile strength. However, for all tests performed, the automotive brake fluid promotes the lowest values comparatively to the automotive engine oil.**

***Index Terms*-** **Composite Materials, Universal Multi Grade Engine oil, Rockwell Hardness Test, Flexural Behaviour, Immersion Test.**

I. INTRODUCTION

As a result of the rapid development that the world witnesses and the challenge in using metal materials in tribological industrial applications, the tribological behavior of polymeric composites has recently experienced a creative development, and attention by many researchers. Fiber reinforced polymeric composites have numerous advantages compared to the metal materials due to their competitive mechanical properties of high specific strength, low weight, low cost of raw materials, low processing cost…etc. Recently, composites materials are heavily used in many applications that have been determined for these materials. Furthermore, composites materials have been provided superlative solutions to produce structural materials of aerospace industries. Tribological properties of such materials have been a core of interest for many scholars and researchers. The friction and wear performance are the significance characteristics that have been taking place by several researches focusing on the composite application in brakes, clutches, bolts and nuts. Wear, the resistance to remove of solid surface, has been defined in various aspects such as weight loss, wear resistance and specific wear rate. A composite material is a material system composed of a mixture or combination of two or more macro constituent differing in form and /or material composition from each other and that are essentially insoluble in each other. A composite can and often does have much more desirable properties than do the individual pure materials from which it was made. The composite materials of interest herein are polymer composites, which consist of reinforcing fibers embedded in a resin matrix binder. The fibers carry structural loads within the composite while the matrix binds the fibers together and transfers loads between them. In addition, FRP properties can be tailored by a judicious choice of design factors such as resin, fiber, and composition. Another essential characteristic of many glass fiber composites is that they exhibit good corrosion resistance to both aqueous solutions and organic solvents when they are exposed to these chemically harsh environments for prolonged periods of time. Epoxy is a common choice, and it is employed as an adhesive for bonding the reinforcing fibers because of its low shrinkage after curing and good serviceability at elevated temperatures (up to 350°F). It possesses high chemical resistance, and has excellent adhesion and chemical properties. Because of these promising properties of epoxy, there is increasing interest in the understanding of epoxy's mechanical properties. However, many mechanical properties of both the polymeric matrix component and fibrous reinforcement degrade after prolonged exposure to the environment as may occur during their service time. Environmental factors such as heat, stress, moisture, corrosive fluids and ultraviolet rays, etc., can initiate changes in thermal, chemical, and physical properties of the composite. The rate of material degradation after exposure to such environments depends upon the intensity, the time duration, and the type and sources of exposure. This makes degradation processes in composites complex and often Unpredictable. Numerous research works have been done on the evaluation of mechanical properties such as static stiffness and strength of neat resins and composites. However, most of the research works, which is related to the influence of fluids or aqueous solutions on the change in properties of glass fiber reinforced composites, has been limited to water. The effects of water absorption on the mechanical properties of both neat resin and composite have been well documented by many researchers. However, effect of aqueous solutions with different levels of pH on the properties of neat resin and reinforcing fibers has not been studied in-depth. The initiation and growth of cracks in the matrix as well as the interaction of fiber flaws with the composite matrix are poorly understood. The failure mode is not predictable from measurements of the tensile strength and modulus, and the question of what measurable properties are critical to behavior in use has not been resolved.

II. SPECIMEN PREPARATION

The E glass fiber 200 gsm woven roving's laminates, standard epoxy resin(araldite) AW106, hardener HV953 IN are used for glass fiber preparation by using hand lay technique. The E glass fiber sheets are made up of 300*300*3 mm size. The specimens used in the experiments were cut from these thin plates, using a diamond saw and a moving speed chosen to reduce the heat in the specimen. The static three point bending (3 PB) tests were performed using specimens cut nominally to ASTM D-790. The tensile tests were performed using cut nominally to ASTM 3039.

i. Specimen Size

ASTM D-790
- Length – 154mm
- Width – 12.7mm
- Thickness – 3mm

ASTM 3039
- Length – 280mm
- Width – 18mm
- Thickness – 3mm

A. Oil Dipping Setup and Calculation

The universal engine oil (20W40), hydraulic brake fluids (Dot 3) are taken in different trays as shown in fig.1 and fig.2.

Fig.1: Oil Dipping Setup1

Fig.2: Oil Dipping Setup2

The E glass fiber specimen for tensile, bending and hardness tests are dipped for 15 and 30 days after that obtained the results for above tests. Due to the impact of oil absorbance the mechanical properties will definitely fluctuate.

After the immersion process for 15 and 30 days in different commercial oils, weighted to obtain the current wet weight (CWW). The weight gain percentage (W %) was calculated by using following equation.

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$$W\% = \frac{CWW - DW}{DW} \times 100$$

W%- weight gain percentage
CWW- current wet weight
DW- dry weight

B. Universal Testing Procedure

The bending and tensile tests were performed according to ASTM D790-2,ASTM 3039, using a kalpak's universal testing machine equipped with a Kalpak's Windows based software UTM-TEST-C for control of the Machine software at a displacement rate of 2 mm/min. All 3Point bending and tensile tests were also carried out at room temperature. Some data's we have to entered to the software depend up on the tests were performed. The parameters like load cell capacity, test speed can be selected as shown in fig.3.

Fig.3: Kalpak Universal Testing Machine
(Model KIC-2-XXXX-C Maximum capacity 250 KN)

C. Rockwell Hardness Machine

The Rockwell hardness machine (AL-RAS/137-2009/10) was used obtain the results of hardness of specimens under different solution environments and exposure time. The machine is equally convenient for hard and soft material.

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load *F0* usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter, is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration. When equilibrium has again been reach, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

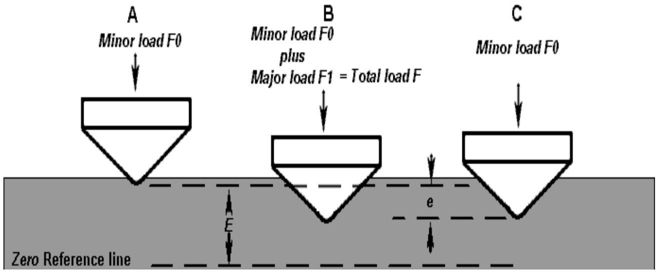

Fig.4: Testing method

F0 = preliminary minor load in kgf.
F1 = additional major load in kgf.
F = total load in kgf.
e = permanent increase in depth of penetration due to major load F1 measured in units of 0.002 mm.
E = a constant depending on form of indenter: 100 units for diamond indenter, 130 units for steel ball indenter.
HR = Rockwell hardness number.
D = diameter of steel ball.

In my work E glass fiber hard composite was used under load -150kg-f. The diamond cone 120° indenter selected for testing. In composites there is a chance for varying hardness from point to point so I took three set of readings and its average.

Fig.5: Rockwell Hardness Testing Machine (AL RAS)

III. RESULTS AND DISCUSION

A. The Effect of Oils and Exposure Time on Weight Gain

Table 1: The Effect of Oil Sand Exposure Time on Weight Gain

Solution	Exposure Time (Days)	Weight Gain %
20W40(Tensile Specimen)	15	0.44
	30	1.55
DOT3(Tensile Specimen)	15	0.67
	30	1.97
20W40(Bending Specimen)	15	0.53
	30	1.76
DOTS(Bending Specimen)	15	0.63
	30	1.91

According to type of solution and exposure time the rate of absorption have varied. From the above results we can see that, DOT 3 oil is more effective than 20W40 oil. The DOT 3 and 20W40 oils have difference in chemical properties like composition, viscosity etc.

Table 2: Sample Tensile Test Batch Report

Test Name: Tensile Test Test Type: Normal			Test Speed[mm/min]:2.0 Test Mode: Tensile	
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**% Elongation**	**UTS[N/mm^2]**
001	75.00	7595.46	2.967	101.269
002	75.00	7244.58	2.907	96.989
003	75.00	8453.67	3.987	112.717
Summary Report:				
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**% Elongation**	**UTS[N/mm^2]**
Minimum	75.00	7244.58	2.907	96.589
Maximum	75.00	8453.67	3.987	112.717
Average	75.00	7764.57	3.287	103.525
Standard Deviation	0	622.034	0.607	8.297
Variance	0	386925.86	0.368	68.843
Median	75.00	7595.46	2.967	101.26

Table 3: dot 3(15 days) Tensile Test Batch Report

Test Name: Tensile Test Test Type: Normal			Test Speed[mm/min]:2.0 Test Mode: Tensile	
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**% Elongation**	**UTS[N/mm^2]**
001	75.00	6957.890	2.667	92.773
002	75.00	7122.197	2.707	94.961
003	75.00	7290.066	2.547	97.197
Summary Report:				
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**% Elongation**	**UTS[N/mm^2]**
Minimum	75.00	6957.890	2.547	92.773
Maximum	75.00	7290.066	2.707	97.197
Average	75.00	7123.384	2.640	94.977
Standard Deviation	0	166.091	0.083	2.212
Variance	0	27586.349	0.007	4.894
Median	75.00	7122.197	2.667	94.961

Table 3 presents tensile strength of the specimen after 15 days dipping in dot 3 oil.0.67% weight gain happened during this time, in terms of average reference values of samples, observed that 8.25% decreased in tensile strength.

Table 4: dot 3(30 days) Tensile Test Batch report

Test Name: Tensile Test Test Type: Normal			Test Speed[mm/min]:2.0 Test Mode: Tensile	
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**% Elongation**	**UTS[N/mm^2]**
001	75.00	4944.132	1.940	65.923
002	75.00	7049.034	3.327	93.990
003	75.00	6244.349	2.00	83.257
Summary Report:				
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**% Elongation**	**UTS[N/mm^2]**
Minimum	75.00	4944.132	1.940	65.923
Maximum	75.00	7049.034	3.327	93.990
Average	75.00	6079.172	2.422	81.057
Standard Deviation	0	1062.128	0.784	14.162
Variance	0	1128116.099	0.615	200.563
Median	75.00	6244.349	2.000	83.257

Table 4 presents tensile strength of the specimen after 30 days dipping in dot 3 oil.1.97% weight gain happened during this time, in terms of average reference values of samples, observed that 21.7% decreased in tensile strength.

Table 5: 20W40 (15 days) tensile test batch report

Test Name: Tensile Test Test Type: Normal			Test Speed[mm/min]:2.0 Test Mode: Tensile	
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**% Elongation**	**UTS[N/mm^2]**
001	75.00	2.667	108.440	2.667
002	75.00	2.907	96.776	2.907
003	75.00	2.513	80.736	2.513
Summary Report:				
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**% Elongation**	**UTS[N/mm^2]**
Minimum	75.00	2.513	80.736	2.513
Maximum	75.00	2.907	108.440	2.907
Average	75.00	2.696	95.317	2.696
Standard Deviation	0	0.199	13.909	0.199
Variance	0	0.039	193.465	0.039
Median	75.00	2.667	96.776	2.667

Table 5 presents tensile strength of the specimen after 15 days dipping in 20w40 oil.0.40% weight gain happened during this time, in terms of average reference values of samples, observed that 7.93% decreased in tensile strength.

Table 6: 20W40 (30 days) Tensile Test Batch Report

Test Name: Tensile Test Test Type: Normal			**Test Speed[mm/min]:2.0 Test Mode: Tensile**	
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**% Elongation**	**UTS[N/mm^2]**
001	75.00	7244.587	2.91	96.589
002	75.00	7122.197	2.71	94.961
003	75.00	6244.349	2.00	83.257
Summary Report:				
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**% Elongation**	**UTS[N/mm^2]**
Minimum	75.00	6244.349	2.00	83.257
Maximum	75.00	7295.46	2.907	96.589
Average	75.00	6887.33	2.538	91.602
Standard Deviation	0	545.9	47	7.27
Variance	0	298109.81	0.22	52.89
Median	75.00	7122.197	2.707	94.961

Table 6 presents tensile strength of the specimen after 30 days dipping in 20w40 oil.1.55% weight gain happened during this time, in terms of average reference values of samples, observed that 11.29% decreased in tensile strength.

Table 7: Sample Bending Test Batch Report

Test Name: Tensile Test Test Type: Normal			**TestSpeed[mm/min]:2.0 Test Mode: Tensile**
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**Flexural Strength[Mpa]**
001	39.000	813.318	656.911
002	39.000	776.167	626.904
003	39.000	567.744	.562458
Summary Report:			
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**Flexural Strength[Mpa]**
Minimum	39.000	567.744	458.562
Maximum	39.000	813.318	656.911
Average	39.000	719.076	580.792
Standard Deviation	0	132.367	106.913
Variance	0	17521.145	11430.296
Median	39.000	776.167	626.904

Table 8: dot 3(15 days) Bending Test Batch Report

Test Name: Tensile Test Test Type: Normal			**TestSpeed[mm/min]:2.0 Test Mode: Tensile**
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**Flexural Strength[Mpa]**
001	39.000	554.618	447.961
002	39.000	799.652	645.873
003	39.000	639.857	516.808
Summary Report:			
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**Flexural Strength[Mpa]**
Minimum	39.000	554.618	447.961
Maximum	39.000	799.652	645.873
Average	39.000	664.709	536.881
Stan. Dev	0	124.939	100.471
Variance	0	15473.654	10094.474
Median	39.000	639.857	516.808

Table 8 presents flexural strength of the specimen after 15 days dipping in dot 3 oil .0.693% weight gain happened during this time, in terms of average reference values of samples, observed that 7.5%% decreased in flexural strength.

Table 9: dot 3 (30 days) Bending Test Batch Report

Test Name: Tensile Test Test Type: Normal			**TestSpeed[mm/min]:2.0 Test Mode: Tensile**
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**Flexural Strength[Mpa]**
001	39.000	703.524	568.232
002	39.000	699.787	565.213
003	39.000	493.090	398.264
Summary Report:			
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**Flexural Strength[Mpa]**
Minimum	39.000	493.090	398.264
Maximum	39.000	703.524	568.232
Average	39.000	632.134	510.570
Standard Deviation	0	120.430	97.271
Variance	0	14503.349	9461.701
Median	39.000	699.787	565.217

Table 9 presents flexural strength of the specimen after 30 days dipping in dot 3 oil.1.91% weight gain happened during this time, in terms of average reference values of samples, observed that 12.09% decreased in flexural strength.

Table 10:20W40 (15 days) Bending Test Batch Report

Test Name: Tensile Test Test Type: Normal		TestSpeed[mm/min]:2.0 Test Mode: Tensile	
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**Flexural Strength[Mpa]**
001	39.000	540.619	436.654
002	39.000	841.620	679.770
003	39.000	715.051	577.541
Summary Report:			
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**Flexural Strength[Mpa]**
Minimum	39.000	540.619	436.654
Maximum	39.000	841.620	679.770
Average	39.000	699.097	564.655
Standard Deviation	0	151.133	122.069
Variance	0	22841.190	14900.884
Median	39.000	715.051	577.541

Table 10 presents flexural strength of the specimen after 15 days dipping in 20w40 oil.0.53% weight gain happened during this time, in terms of average reference values of samples, observed that 2.7% decreased in flexural strength.

Table11: 20W40 (30 days) Bending Test Batch report

Test Name: Tensile Test Test Type: Normal		TestSpeed[mm/min]:2 Test Mode: Tensile	
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**Flexural Strength[Mpa]**
001	39.000	974.869	787.394
002	39.000	567.204	458.126
003	39.000	404.574	326.771
Summary Report:			
Sample No	**CS Area[mm^2]**	**Peak Load[N]**	**Flexural Strength[Mpa]**
Minimum	39.000	404.574	326.771
Maximum	39.000	974.869	787.394
Average	39.000	648.882	524.097
Standard Deviation	0	293.790	237.292
Variance	0	86312.445	56307.512
Median	39.000	567.204	458.126

Table.11 presents flexural strength of the specimen after 30 days dipping in 20w40 oil.1.76% weight gain happened during this time, in terms of average reference values of samples, observed that 9.76% decreased in flexural strength. The tensile and bending tests were performed in order to evaluate the degradation of composite material under aggressive solutions. The fig shows load versus displacement curve for the sample and sample exposed at 20W40 and DOT 3 solutions, considering the different exposure time.

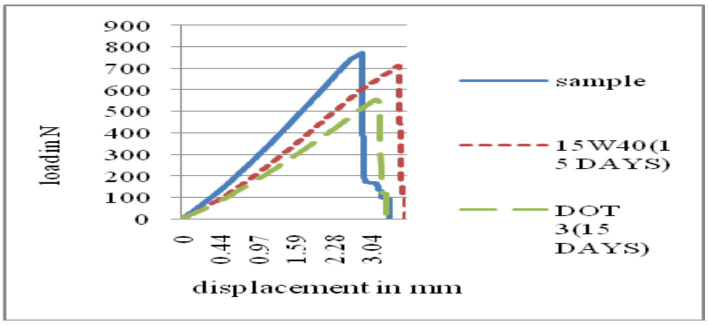

Fig.6: The Effects of Solutions for Bending Specimen (15days)

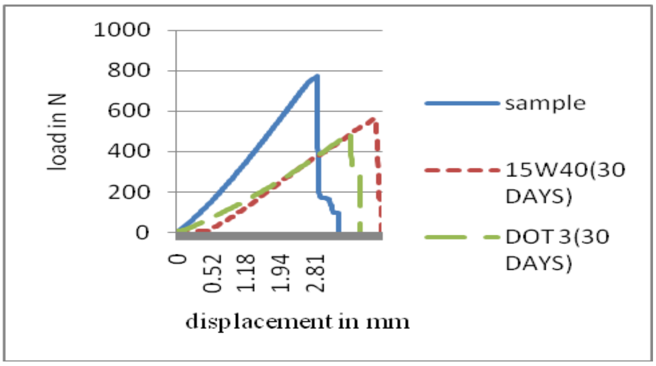

Fig.7: The Effects of Solutions for Bending Specimen (30days)

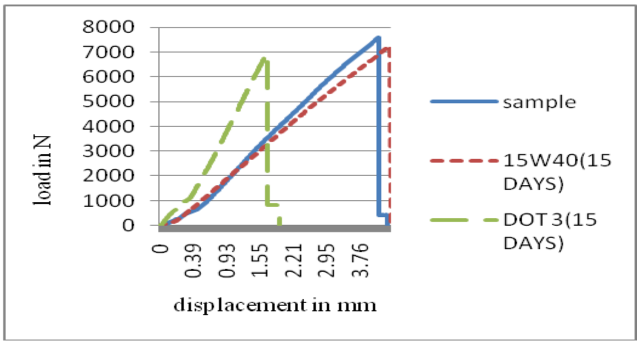

Fig.8: The Effects of Solutions for Tensile Specimen (15days)

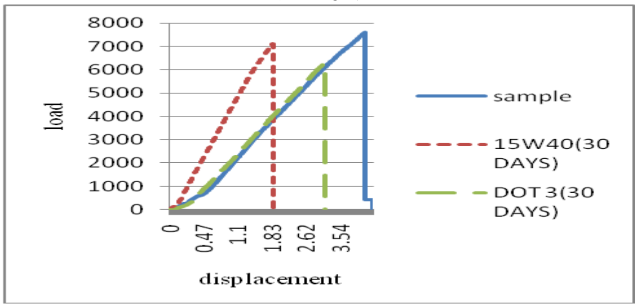

Fig6.34: The Effects of Solutions for Tensile Specimen (30days)

B. The Rockwell Hardness Test Result for all Specimens

Table 12: Rockwell Hardness Test Result for All Specimens

Specimen Type		Hardness (HRC)	Average (HRC)
Sample	1	84	83.66
	2	83	
	3	84	
Dot 3(15 Days)	1	91	92.33
	2	92	
	3	94	
Dot 3(30 Days)	1	98	96
	2	95	
	3	95	
20W40(15 Days)	1	84	85
	2	85	
	3	86	
20W40(30 Days)	1	90	89.33
	2	89	
	3	89	

By using Rockwell hardness machine, obtained the hardness values for the specimens before and after dipping .when go through the results, we can see that hardness varying depend up on the solution and exposure time. Some limitations have to measure the hardness of composite; it may vary throughout the length of specimen so we have to take the average of the two more values. According to exposure time and type of liquid we can conclude DOT 3 oil is effective than 20W40 oil.

IV. CONCLUSION

This work studied the flexural and tensile strength of a glass fiber/epoxy composite after immersion in universal multi-grade engine oil (20W-40) and in extra high performance hydraulic brake fluid (DOT 3).The weight gain is very noticeable, due to oil absorption flexural, tensile and hardness properties varied.

- The tensile strength of the specimen after 30 days dipping in dot 3 oil 1.97% weight gain happened, 21.7% strength decreased.
- The tensile strength of the specimen after 30 days dipping in 20w40 oil 1.55% weight gain happened, 11.29% strength decreased.
- The flexural strength of the specimen after 30 days dipping in dot 3 oil 1.91% weight gain happened, 12.09% strength decreased.
- The flexural strength of the specimen after 30 days dipping in 20w40 oil 1.76% weight gain happened, 9.76% strength decreased.

It is possible to conclude that both solutions affect the flexural and tensile strength. However, for all tests performed, the automotive brake fluid promotes the lowest values comparatively to the automotive engine oil.

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