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IMPROVEMENT OF GFRP PROPERTIES EXPOSED TO FIRE

Ahmed G. Asran1, Hatem Hamdy Ghith2, Mohamed Nooman3, Mosaad Sadawy4 and Shady Khairy5

[1]Prof. Reinforced Concrete Dept., Faculty of Engineering, Al-Azhar University, Cairo, Egypt
[2]Prof.Reinforced Concrete Dept., Building National Research Center, and Cairo, Egypt
[3]Ass. Prof. Civil Engineering Dept, Faculty of Engineering, Al-Azhar University, Cairo, Egypt
[4]Ass. Prof. Metallurgy Dept., Faculty of Engineering, Al-Azhar University, Cairo, Egypt
[5]Teaching Ass. Civil Engineering Dept., Higher Technological Institute10th of Ramdan City, Egypt

الملخص

فى هذا البحث تم دراسه مدى امكانية تصنيع اسياخ بوليمريه مسلحه بالالياف الزجاجيه المقاومه للحريق و لدرجات الحراره العاليه بالاضافه الى دراسه خواصها الاساسيه . أيضا تم دراسه مدى الاختلاف بين الاسياخ البوليمريه المسلحه بالالياف الزجاجيه بمواد خلط مختلفه لمقاومه الحريق باختبار تحديد درجه الانصهار لمواد الخلط و بنسب مختلفه لتحديد مدى تاثير المواد على الخصائص الاساسيه للاسياخ المصنعه تحت ظروف الحريق.

تم اختبار عدة عينات من مواد مختلفة لتحديد درجه الانصهار لهذه المواد في صورة اسطوانات بقطر 10 مم و ارتفاع 5مم بمواد خلط مختلفه (الماغسيوم – المونيوم – أكسيدالحديد – اكسيد منجنيز - كربون الجرافيت–التيتانيوم - كربون الكاوتشC330 -كربون الكاوتشC550) يتوقع ان يكون لها خاصيه مقاومه الحريق و هذا ما تم دراسته لتحديد مدى التاكد من وجود هذه الخاصيه عندما يتم خلطها ميكانيكا مع المواد البوليمريه المستخدمه فى تصنيع السيخ (البوليستر و المصلد البروكسيد) و بنسب مختلفه (2% و 6% و 8% و 10%) كنسبه من اجمالى حجم الخليط. تم عرض نتائج الاختبارات في صورة منحنيات وجداول توضح ميزة كل اضافة ودرجة تحملها لدرجة الحرارة.

ABSTRACT

The use of glass fiber reinforced polymer (GFRP) as reinforcements in concrete structures has increased rapidly in the last decades due to their excellent corrosion resistance and high tensile strength properties. Glass fiber reinforced polymer (GFRP) composites are known to be susceptible to deterioration under elevated temperature. To evaluate the feasibility of achieving a fire-rated FRP system,an investigation was undertaken to examine and document the performance of near surface mounted (NSM) GFRP strengthened concrete elements under fire effect. The parameters of the current study were the types of resins of GFRP bar. Base resin (polyester and peroxide) with additives of different materials was studied. Seven types of additive materials with different percentages (2%, 6%, 8% and 10%) were, namely, Tire carbon C330, Tire carbon C500, Graphite carbon C, Manganese oxide MNO, Iron oxide FeO, Aluminum oxide ALO and Magnesium Mg were used.The experimental results in the form of Differential Thermal Analyzer (DTA) curves are presented and discussed.The significant parameters on GFRP bars behavior are highlighted.

Keywords:FRP bars**,**Fire, DTA, GFRP bars, Carbon resin, high temperature, Tire carbon.

1- Introduction

The last decades have been marked by degradation of numerous concrete structures due to the corrosion of steel reinforcements that required costly repairs or replacements. To mitigate the corrosion problem, several methods, such as epoxy coated re-bars, synthetic membranes, or cathodic protection, have been developed. However, many of these efforts have showed limited success [7].In recent years, research has been focused on fiber reinforced plastic (FRP) bars as an alternative to steel reinforcement. These FRP re-bars have already shown excellent corrosion resistance in many projects, especially in bridge decks and Parking garages [1, 2, 9 and 10].Among the advantages of FRP reinforcement are its high tensile strength, corrosion resistance, and magnetic transparency. Also, it has light weight and lower thermal and electric conductivity. Adding short fibers to concrete mixes have been proven to improve the concrete structural behavior, especially under service conditions [3 and 5]. The combination of FRP reinforcement and short polypropylene fibers may eliminate problems related to corrosion of steel reinforcement while, providing requisite strength, stiffness and desired ductility [12 and 13].

However, FRP has lower fire resistance and high price due to its limited use. Due to the degradation of GFRP bars at high temperature, guidelines for design of GFRP strengthened structures [13 and 14] specify that composite interaction between the concrete member and the FRP strengthening under the fire should be ignored unless a fire- protection system is used. This because the load carrying capacity of strengthened structural members with GFRP under fire exposure is affected by thermo-mechanical properties of the adhesive.

During this research, components of GFRP bars that expected to resist the high temperatures were studied.The parameters of the current study were the types of resins of GFRP bar. Base resin with additives of different materials was studied. Seven types of additives materials with different percentages were, namely, Tire carbon C330, Tire carbon C500, Graphite carbon C, Manganese oxide MNO, Iron oxide FeO, Aluminum oxide ALO and Magnesium Mg were used. Each material was added to the basic resin with percentages of 2%, 6%, 8% and 10% from the volume of the resin. Specimens of the produced GFRP resins were tested to determine their melting point with (DTA) test, Differential Thermal Analyzer.

2-Materials

The GFRP reinforcing bars consisted of about 70% E-glass Fiber and 30% a polyester resin [14, 15].The percentage of the component resulted in significantly ductile bars. The following materials could be used in GFRP mix:

2-1 Fibers

Glass fiber roving forms from continuous un twisted strands that are bonded together with a polyester-compatible size. According to the manufacturer, the fiber combines the mechanical properties of traditional e-glass and the acid corrosion resistance. The glass fiber, has a specific gravity of 2.54, a TAX of 2400 (TAX=weight in grams of 1 km length of roving), tensile strength of 3250 MPa, tensile modulus of 69 GPA and tensile elongation of 4.5% according to manufacturer data sheet as shown in Figure 1, [14].

2-2 Resin

The resin used in fabricating theGFRP bars is suitable for various fabrication processes such as hand lay-up, winding and pultrusion. The basic resin mainly consisted of polyester and peroxide was extensively used in fabricating water pipes and other corrosion resistance applications. In the present study, the resin used belongs to the Vipel® F737 series resins produced by AOC, USA under the name of isophthalic polyester as shown in Figure1. The resin has suitable mechanical properties in terms of tensile strength (86 MPa), tensile modulus (3.4 GPa) and tensile elongation (4.0%) according to ASTM D638 test method and a specific gravity of 1.12 as reported by the manufacturer. To enhance the resin properties against high temperature, seven types of additive materials were added individually to the basic resin. The additive materials were: Tire carbon C330, Tire carbon C500, Iron oxide FeO, Graphite carbon C,Aluminum oxide ALO,Magnesium Mg and Manganese oxide MNO. Each material was added to the basic resin with percentages of 2%, 6%, 8% and 10% from the volume of the resin.

(a) (b)

Fig. (1): (a) Glass fiber roving – (b) package of polyester

3- DTA Test Specimens

Differential Thermal Analyzer (DTA) indicates the specimen thermal properties such as transition temperature, melting point, reaction temperature and distinction between heat absorption and generation. The DTA test was carried out to determine the melting point of the specimens of the mixed resin to determine the most suitable additive for manufacturing GFRP bars that can withstand high temperatures.

(a) Reference resin (b) C330 (c) C550 (d) FeO (e) C (f) ALO

(g) Mg (h) MnO

Fig. (2): Tested specimens of resin with 10 mm diameter and 5 mm height by DTA at Micro Analytical Center of Cairo University.

The discs of reference resin and mixed resins were cut into 10 mm diameter and 5 mm height as shown in Fig.(2). The DTA test was carried out at Micro Analytical Center at Faculty of Sciences, Cairo University, Egypt, as shown in Fig. (3). Base resin and four percentages from seven resin specimens were tested with DTA.

Figure(3): Differential Thermal Analyzer (DTA) to determine thermal properties and melting point for samples

3-2 Results and Discussion

Table (1): The details of mixed resin with GFRP bars tested with DTA

		Resin(%)	Temp.(C)	Time(min.)
GFRP	Base resin		340.68	32.4
Tire carbon C 330	C-GFRP 330	2%	400	37.3
		6%	400	36.5
		8%	400	37.2
		10%	400	37
			551.03	52.5
Tire carbon C 550	C-GFRP 550	2%	280.85	26.4
		6%	376.25	34.8
		8%	372.12	34.6
		10%	372.56	35.7
Iron oxide FeO	Fe-GFRP	2%	361.22	33.6
		6%	371.15	35.2
		8%	360.45	32.7
		10%	369.69	34
Graphite carbon C	C-GFRP	2%	378.06	34.7
		6%	362	33.4
		8%	370.33	34.2
		10%	375.09	35.6
Aluminum oxide ALO	AL-GFRP	2%	374.24	35.6
		6%	368.14	33.7
		8%	369.47	34.3
		10%	363.58	34.2
Magnesium Mg	Mg-GFRP	2%	400	38.1
		6%	367.66	34.9
		8%	322.19	29.5
		10%	388.57	36
Manganese oxide MNO	MN-GFRP	2%	377.09	34.9
		6%	319.38	34.6
		8%	375.73	34.2
		10%	373.73	30.2

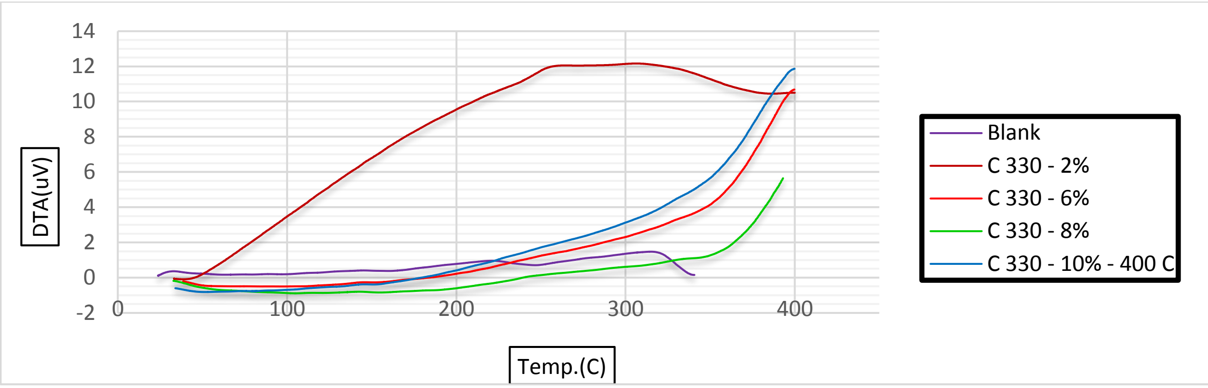

Fig. (4): DTA-Temp. Curve of Base resin and C330 specimens at 400°C.

The test results of the base resin were endured of 350 Celsius as shown in Fig. (4). DTA-Temperature curves of all specimens of tire carbon (C330) specimens by 2%, 6%, 8% and 10% were endured temperatures of 400 Celsius and all specimens of C330 were stable at 400 Celsius.

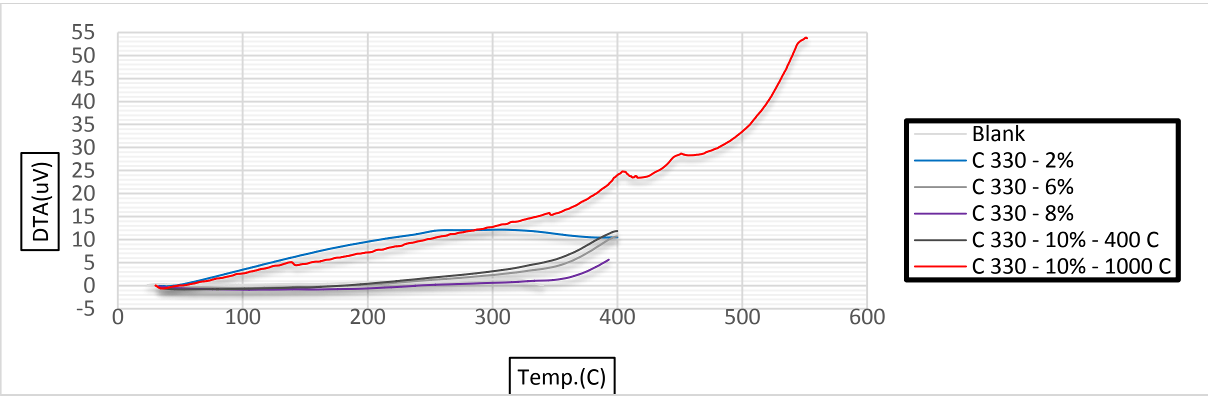

Fig. (5): DTA-Temp. Curve of C330 specimens at 1000°C.

Figure (5) shows that C330 by 10% was endured temperature of 551.03 Celsius for duration of 52.5 minutes. This shows that tire carbon (C330-10%) has high efficiency to resist the high temperatures with melting time longer than that for the reference specimen. Reference specimen resisted temperature to 340.7 Celsius for 32.4 min.

Figure (6) shows the endured temperature and the duration of each percentage of the tire carbon C330.

				Time(min.)
	Blank		340.68	32.4
كربون الكاوتش	C 330	2%	400	37.3
		6%	400	36.5
		8%	400	37.2
		10%	400	37
			551.03	52.5

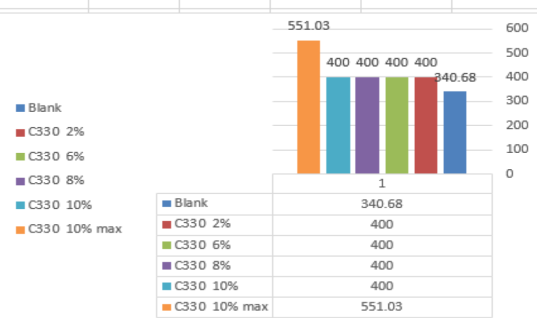

Fig. (6): The temperature distribution on the changing proportions of C330

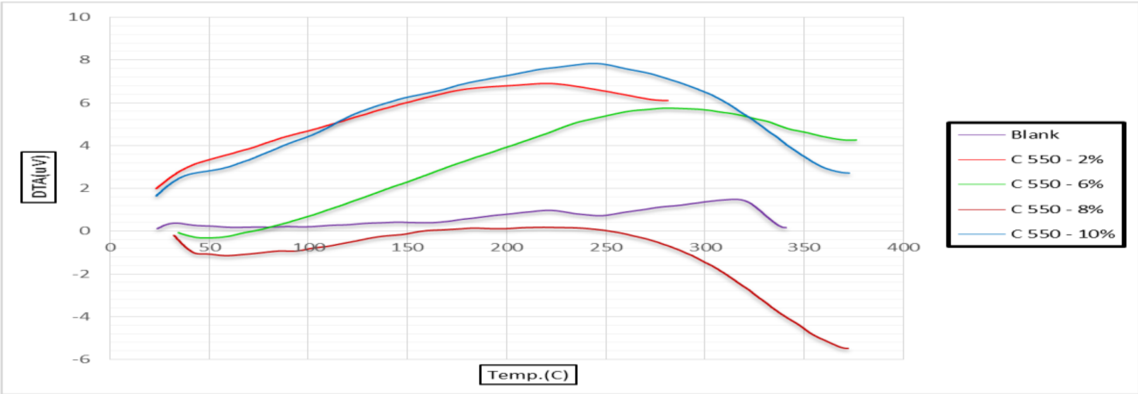

Fig. (7): DTA-Temp. Curve of Reference and C550 specimens at 400°C.

DTA-Temperature relationships of the tested tire carbon (C550) specimens were plotted in Fig. (7). Specimens with percentages of 6%, 8% and 10% were endured high temperatures compared to reference specimen. Increasing of the percentage of tire carbon C550, increases endurance temperature. C550 with 10% was endured temperature of 372.56 Celsius at 35.7 minute.

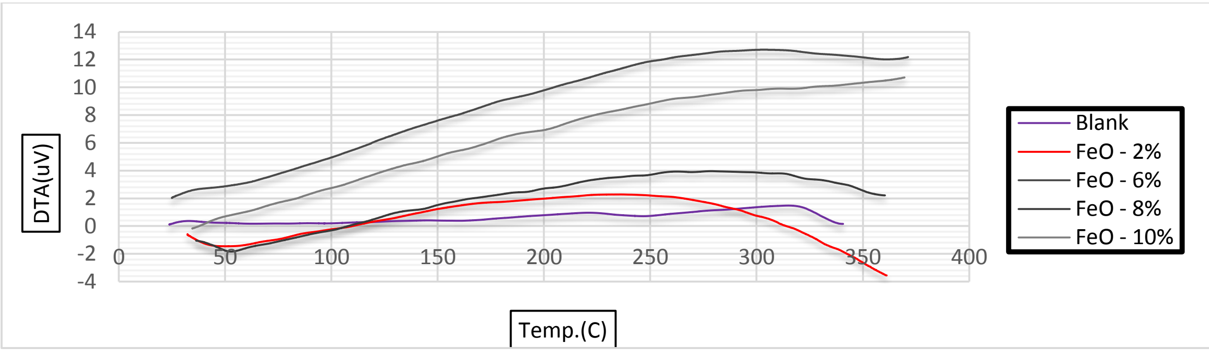

Fig. (8): DTA-Temp. Curve of Reference and FeOspecimens at 400°C.

DTA-Temperature relationships of the tested Iron oxide (FeO) specimens were plotted in Fig. (8). Specimens with percentages of 2%, 6%, 8% and 10% were endured high temperatures compared to reference specimen. Increasing the percentages from 2% to 6% of Iron oxide (FeO), slightly increases the endurance temperature. Increasing of the percentage from 8% to 10% of Iron oxide (FeO) reduces endurance temperature. FeO with percentage of 6% endured temperature of 371.15 Celsius at 35.2 minute.

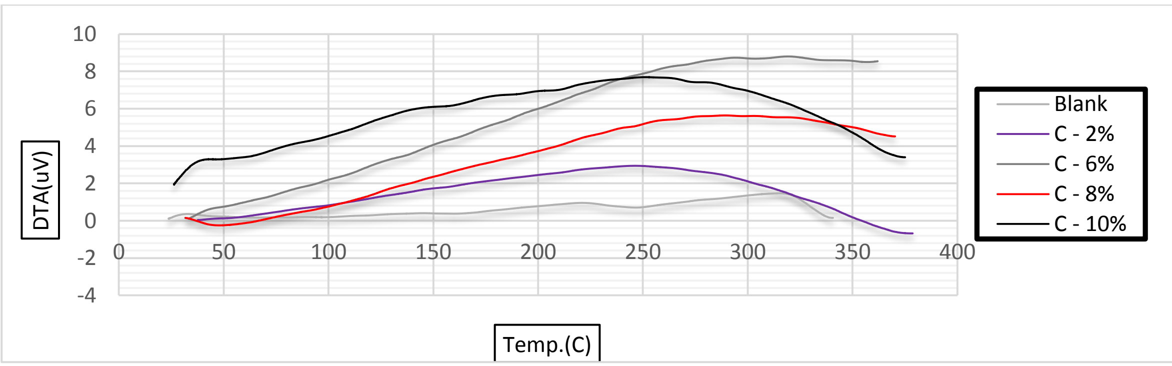

Fig. (9): DTA-Temp. Curve of Reference and C specimens at 400°C.

DTA-Temperature relationships of the tested Graphite carbon (C) specimens were plotted in Fig. (9). Specimens with percentages of 2%, 6%, 8% and 10% were endured high temperatures compared to reference specimen. Adding the percentage from 2% to 6% of Graphite carbon (C) reduces endurance temperature from 378.6 Celsius to 362 Celsius. Increasing the percentage from 8% to10% of Graphite carbon (C) increases endurance temperature from 370.33 Celsius to 375.09 Celsius. Graphite carbon C with percentage of 10% has the highest temperature endurance of 375.09 Celsius at 35.6 minutes.

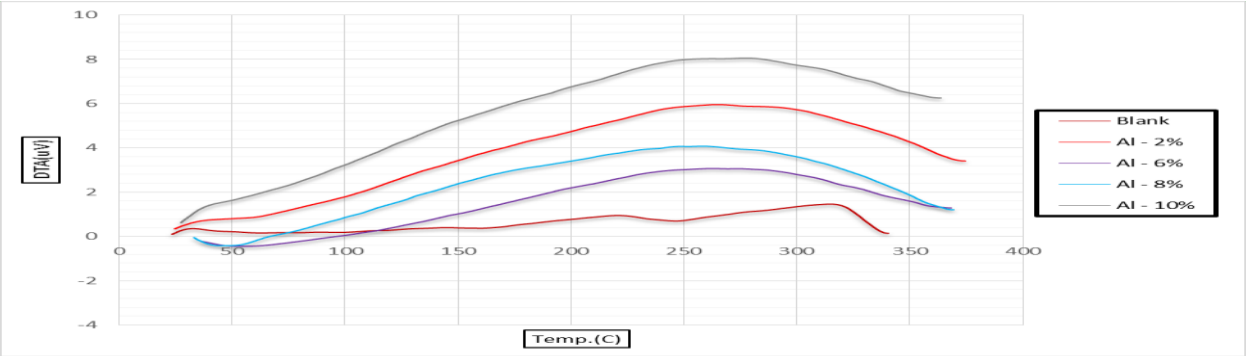

Fig. (10): DTA-Temp. Curve of Reference and ALO specimens at 400°C.

DTA-Temperature relationships of the tested Aluminum oxide (ALO) specimens were plotted in Figs. (10). Specimens with percentages of 2%, 6%, 8% and 10% were endured high temperatures compared to reference specimen. Adding the percentage of Aluminum oxide (ALO) by 2%, increases endurance temperature to 374.24 Celsius. Increasing the percentage from 6% to 10% of Aluminum oxide (ALO) reduce endurance temperature from 368.14 Celsius to 363.58 Celsius. ALO with percentage of 2% has the highest temperature endurance of 374.24 Celsius at 35.6 minutes.

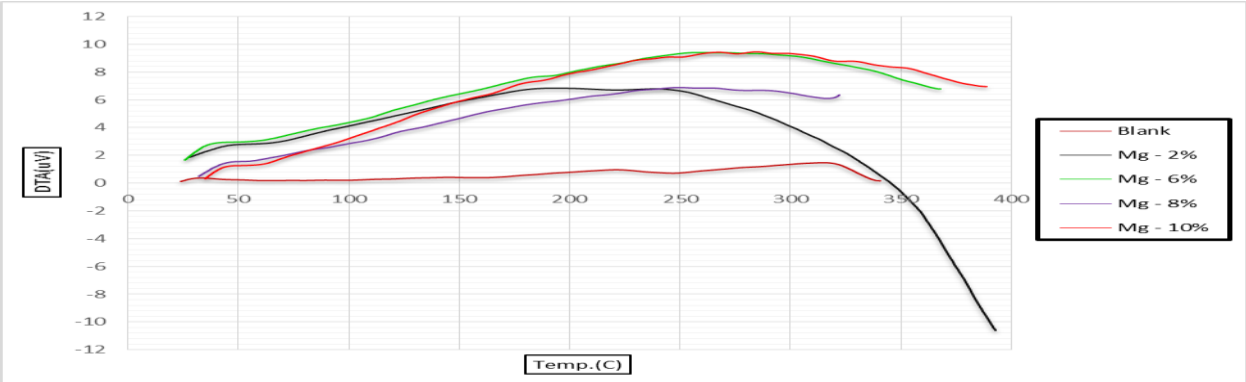

Fig. (11): DTA-Temp. Curve of Reference and Mg specimens at 400°C.

DTA-Temperature relationships of the tested Magnesium (Mg) specimens were plotted in Figs. (11). Specimens with percentages of 2%, 6%, 8% and 10% were endured high temperatures compared to reference specimen. Increasing of the percentage to 2% of Magnesium (Mg), increases endurance temperature to 400 Celsius. Increasing of the percentage from 6% to 8% of Magnesium (Mg), reduces endurance temperature from

367.66 Celsius to 322.19 Celsius. Mg with percentage of 10% increase endurance temperature to 388.57 Celsius. Mg by 2% has the highest temperature endurance of 400 Celsius at 38.1 minute.

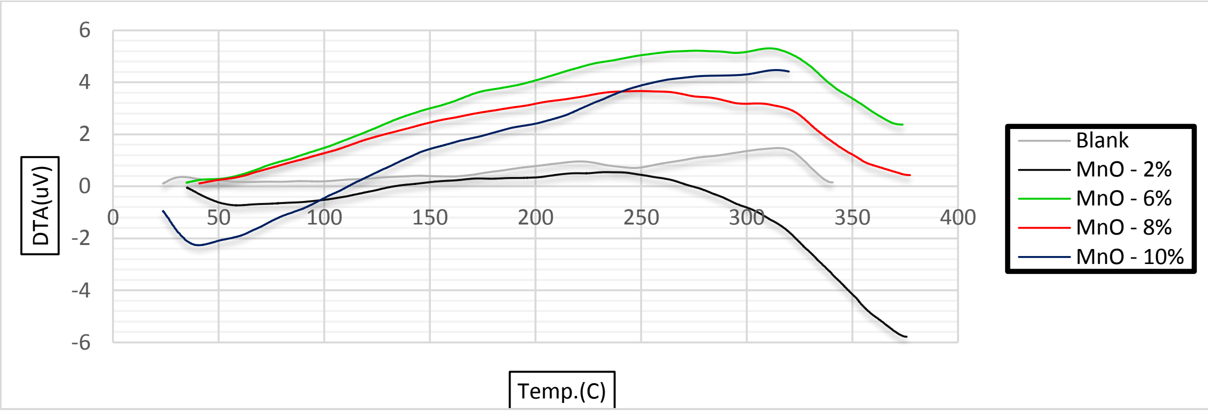

Fig. (12): DTA-Temp. Curve of Reference and MnOspecimensat 400°C.

DTA-Temperature curves of the tested Manganese oxide (MNO) specimens were plotted in Figs. (12). Specimens with percentages of 2%, 6%, 8% and 10% were endured temperatures of reference specimen. Adding a percentage of 2% of Manganese oxide (MNO), increases endurance temperature to 377.09 Celsius. Increasing of the percentage to 6% of Manganese oxide (MNO), reduces endurance temperature to 319.38 Celsius. MNO with percentages from 8% to 10% increases endurance temperature from 375.73 Celsius to 373.73 Celsius. MNO with percentage of 2% has the highest temperature endurance of 377.09 Celsius at 34.9 minute.

On light of the foregoing discussion, one could deduce that resistant of high temperature fundamentally depends on the material of resin.

4- Conclusions

From the analysis and discussion of the test results the following conclusions could be obtained:

1. The materials added to resin of the GFRP bars raised the efficiency of the bars for temperature resistance. These materials such as Tire carbon C330, Tire carbon C500, Graphite carbon C, Manganese oxide MNO, Iron oxide FeO, Aluminum oxide ALO and Magnesium Mg were used.
2. Different percentages 2%, 6%, 8% and 10% of refractory resins of bar gave the best alternatives of the reference specimen resistance to high temperature.
3. Fabricated C330-FRP bar by 10% may bear the high temperatures that reaches 551.03 Celsius compared to steel bars that bear 1500 Celsius.
4. Tire carbon C330 has proven successful in carrying temperatures exceeded 400 Celsius.
5. Fabricated C330-GFRP resin by 10% afford to fusion temperature 551.03 Celsius in a time of 52.5 minutes.

6. Improving the mixing properties of reference specimen by mechanically mixing fire- addition to the characteristic bars against corrosion and light weight such as the improvement of the disadvantages of rebar.

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