Studying the Effect of Chemical Solution on Corrosion Behavior of SiC and Al_2O_3 Reinforced Aluminum Composite Materials

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Abstract

Corrosion behavior of aluminum matrix composites (MMCs) with (10, 20 &30) weight fraction of each alumina and silicon carbide was investigated in 10% (NaCl, NaOH &HCl) solutions at different temperatures (40, 60, 80 &100) °C also at room temperature. The results showed the corrosion rate was increased with increasing in weight fraction of alumina and silica as reinforcement due to discontinues protective film in addition to increasing in temperatures at 10 % HCl solution, it reached (8.252 mpy) by reinforced with SiC. Alumina was exhibited corrosion resistant better than SiC due to it is insulator; galvanic corrosion occurs when incorporation of semiconductor SiC only. Specimens were exposed to NaOH solution, aluminum reinforced with Al_2O_3 and SiC appears poor corrosion resistance. Finally, the results of effect NaCl were investigated, appeared an increase in corrosion rate with increasing in time.

Keywords: aluminum, SiC, Al_2O_3 & corrosion

دراسة تأثير محاليل كيمياوية على سلوك التأكل للالمنيوم المدعم بكل من الالومينا وكاربيد السليكون للمواد المتراكبة

الخلاصة

تم دراسة سلوك التأكل للا لومنيوم كمادة اساس المدعم بمواد سيراميكية مثـل الالومينـا وكاربيد السليكون بنسب وزنية هي (10,20&30) % فـي محاليـل كيمياويـة مثـل حـامض الهدروكلوريك وهيدروكسيد الصوديوم وكلوريد الصوديوم بنسبة 10% عنـد درجـات حراريـة مختلفة°C (40,60,80&100) وكذلك عند درجة حرارة الغرفة. النتائج اظهـرت ان معـدل التأكل يزداد بزيادة النسب الوزنية لمواد التدعيم بسبب قطع الغشاء الحامي كذلك يزداد بزيادة درجة الحرارة وعند المحاليل الحامضية حيث وصل الى اعلى قيمة له(8.252mpy) عنـد التـدعيم باشباه الموصلات مثل كاربيد السليكون اما التدعيم بالمواد العازلة مثل الالومينا فان معدل التأكل اقل بسبب عدم حصول تأكل كلفاني.كذلك العينات تعرضت الى محاليـل قاعديـة مثـل هيدروكسـيد الصوديوم وقد اظهرت العينات مقاومة ضعيفة للتأكل واخيرا تم دراسة تأثير المحاليل الملحية مثـل كلوريد الصوديوم على العينات فقد لوحظ ان معدل التأكل يزداد بزيادة وقت التعرض للملح.

Introduction

Metal matrix composites (MMCs) are engineered materials formed by the combination of two or more materials, at least one of which is a metal, to obtain enhance properties. MMCs tend to have higher strength/density and stiffness density ratio, compared to monolithic metals. They are also tending to perform better at higher temperatures, compared to polymer matrix composites. Aluminium and

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magnesium are lightweight materials, when compared to iron and steel [1].

Metal matrix composite (MMC) is normally fabricated using a ductile metal (e.g., Al, Ti or Ni) as the base material, which is reinforced by ceramic (e.g., alumina, SiC, or graphite). Combining the metallic properties such as good ductility and toughness of the matrix with ceramic properties such as high strength, hardness and elastic modulus of the reinforcement, the composites exhibiting good wear resistance can be obtained. Consequently, they have extensities interest from defence, aerospace and automotive industries and have become very promising materials for structural applications as well. Particulate reinforced MMCs are promising because of their homogenous and isotropic material properties, low cost and ability to be formed using conventional metal processing techniques. Among the many ceramic reinforcements SiC has been found to be excellent capability with the Al-matrix [2].

Aluminium matrix composites (AMCs) exhibited better resistance to mechanical wear than their alloy. One of the main disadvantages in used the metal matrix composites is the influence of reinforcement on corrosion rate. This is particularly important in aluminium alloy based composites, where a protective oxide film imparts corrosion resistance. The addition of a reinforcing phase could lead to discontinuities in the film, thereby increasing the number of sites where corrosion can be initiated and making the composites more susceptible for corrosion [3].

Zuhair studied corrosion behaviour of 6061/Al_2O_3 composite with two volume fraction of reinforced were examined in 3.5% NaCl. He observed that the number of pit sites appears to increase with volume fraction of the reinforcement [4].

Geetha studied of corrosion behaviour of 6061 aluminium alloy and its composite Al-15vol.SiC in different concentration of 1:1 mixture of hydrochloric acid and sulphuric acid at different temperatures by electrochemical methods lead to that the corrosion resistance of the base alloy is greater than that of the composite[5].

<u>The aim of this work</u>

Studying the effect of (NaCl, NaOH& HCl) solutions on corrosion rate of SiC and Al_2O_3 Reinforced Aluminum Composite Materials

Experimental work

Materials

1. Pure aluminum (99.9%)
2. SiC
3. Al_2O_3

- Equipment.

1- Sensitive balance.
2- Oven.

Experimental setup

1. The composites studied were aluminium matrix reinforced with (10, 20 &30) % wt. of each Al_2O_3 and SiC particles.
2. Using powder metallurgy technique, aluminium powder hand mixed with Al_2O_3 and SiC powder alone.
3. Test specimens have (1cm) diameter and (0.5cm) thickness.
4. Specimens were grinding with (600, 800 &1200) grit, polished

the surface and rinsed in distilled water.

5. These were exposed to corrosion medium of 10% (NaCl, NaOH& HCl) solutions at different temperatures (40, 60, 80 &100) °C and 2 hours also it was exposed to10% NaCl solution at room temperatures for 4 weeks.
6. Before and after immersion test, the weight of specimen was measured.

7. Corrosion rate were calculated according to the following correlation[6]:

$$\text{CORROSION RATE (mpy)} = \frac{534\ W}{A\rho t}$$

W: weight loss (mg)

ρ: density of specimen material (g/cm^3)

A: area (in^2)

t: time of exposure

Results And Disscussion

Metal matrix composites (MMCs) are combinations of metal with a finite fraction (by weight) of second phase, generally ceramic. Aluminium has been used as a matrix for a variety of reinforcements: Al_2O_3 and SiC as particles with (10, 20 &30) weight fraction. The corrosion behaviour of metal-matrix composite in various environments is one important consideration when choosing a suitable material for a particles purpose such as temperatures, solutions, types of reinforcement and weight fractions. Some of these environment caused accelerated corrosion of metal matrix composites as shown in figures (2-12) and Tables (1-8).

Microstructure

Figure 2&3 show microstructure of the specimens. After 2 hours and 100°C of exposure to HCl, NaOH solutions and 4 weeks at room temperature of exposure to NaCl. The specimens showed non-uniform corrosion and pitting corrosion, also these figures exhibited differences in corrosion behavior between SiC and Al_2O_3 reinforced aluminum.

Effect of temperatures

The effect of temperatures on corrosion rate of aluminium matrix reinforced with different weight percentage of Al_2O_3 and SiC in 10% (NaCl, NaOH & HCl) solutions are given in tables (1-3) and(5-7). Figures (1-3) and (5-7) represent the variation of corrosion rate with temperatures in different solutions, it is clear that corrosion rate increases with increasing temperatures of composites. It is logical, that as the temperature increases the oxide passive film becomes thin, porous and less protective as a result of dissolution of the protective film by the electrolyte.

Effect of weight fraction

The effect of weight fraction of Al_2O_3 and SiC reinforced aluminium was investigated also; these figures show the corrosion rate appears to increase with increasing weight fraction of the reinforced due to the addition of a reinforcing phase could lead to discontinuities in the protective film, thereby increasing the number of corrosion sites.

Effect of reinforcement

In comparing of corrosion behaviour between SiC and Al_2O_3 reinforced aluminium, the corrosion damage in both composite was pitting attack on the surface (aluminium is susceptible to this type of corrosion) also corrosion rate of SiC reinforced aluminium was more prone to corrosion than those incorporating insulators Al_2O_3. One reason for this tendency is the establishment of galvanic cell linking their two constituent phases (metallic matrix and reinforcement) where the reinforcement is electrically conductive. For this reason, corrosion can vary greatly in aluminium reinforced with semiconductors such as SiC can either promote galvanic reaction. Galvanic corrosion is not usually a problem within aluminium reinforced with insulating materials such as Al_2O_3. Since the degree of galvanic corrosion in MMCs depends on the matrix and on the reinforcement electrochemistry, as well as on the environment. The reinforcement's effect on corrosion appears to be also related to their geometry, volume fraction and electrical properties.

Effect of solution

Metal matrix composites reinforced with alumina and silica in 10% (NaCl, NaOH &HCl) solutions was studied, the maximum corrosion rate was in acid solution where hydrochloric acid is the most difficult of the common acids to handle from the standpoint of corrosion. This acid is very corrosive to most material.

Aluminium reinforced with alumina and silica was exposed to alkalis such as NaOH solution, it exhibits poor corrosion resistance, since aluminium and alloy are rapidly attacked even by dilute solutions of alkalis. At last, the specimens were immersed in NaCl solution for 2 hours and 4 weeks, the results showed corrosion rate increase with increasing of time. When chloride is placed in water it is decompose over time. Furthermore, because it is strong oxidant, the rate of corrosion will occur faster as its reacts with the metal surface.

Conclusions

1. Corrosion rate was increased with increasing in weight fraction of alumina and silica as reinforcement.
2. Alumina reinforced aluminum was exhibited corrosion resistant better than SiC.
3. Specimens were exposed to NaCl solution, aluminum reinforced with Al_2O_3 and SiC appears poor corrosion resistance.
4. Corrosion rate increases with increasing temperatures of composites for each SiC and Al_2O_3 reinforced aluminium.
5. The maximum corrosion rate was in HCl solution, it reached (8.252 mpy) by reinforced with SiC.

References

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Table1: Corrosion rate of SiC-Al in 10% NaCl at different temperatures

C.R.(mpy)				
Wt%(SiC)	**40 °C**	**60°C**	**80°C**	**100°C**
10	0.824	0.8242	0.8244	0.8248
20	0.828	0.831	0.834	0.836
30	0.842	0.844	0.848	0.852

Table2: Corrosion rate of SiC-Al in 10% NaOH at different temperatures.

C.R.(mpy)				
Wt%(SiC)	**40 C°**	**60C°**	**80C°**	**100C°**
10	4.02	4.024	4.027	4.03
20	4.05	4.053	4.055	4.058
30	4.06	4.063	4.065	4.068

Table3: Corrosion rate of SiC-Al in 10% HCl at different temperatures

C.R.(mpy)				
Wt%(SiC)	**40 °C**	**60°C**	**80°C**	**100°C**
10	8.24	8.241	8.244	8.248
20	8.242	8.243	8.246	8.25
30	8.246	8.247	8.249	8.252

Table 4: Corrosion rate of SiC-Al in 10% NaCl at room temperatures

C.R.(mpy)				
Wt%(SiC)	**Week1**	**Week2**	**Week3**	**Week4**
10	0.8	0.812	0.831	0.838
20	0.833	0.838	0.842	0.844
30	0.836	0.843	0.848	0.853

Table5: Corrosion rate of Al_2O_3-Al in 10% NaCl at different temperatures

C.R.(mpy)				
Wt %(Al2O3)	**40 °C**	**60°C**	**80°C**	**100°C**
10	0.78	0.81	0.812	0.817
20	0.8	0.811	0.815	0.82
30	0.812	0.817	0.821	0.824

Table6: Corrosion rate of Al_2O_3-Al in 10% NaOH at different temperatures

C.R.(mpy)				
Wt %(Al2O3)	**40 °C**	**60°C**	**80°C**	**100°C**
10	3.56	3.58	3.63	3.68
20	3.61	3.65	3.67	3.72
30	3.64	3.66	3.68	3.73

Table7: Corrosion rate of Al_2O_3-Al in 10% HCl at different temperatures

C.R.(mpy)				
Wt %(Al2O3)	**40 °C**	**60°C**	**80°C**	**100°C**
10	7.67	7.69	7.72	7.75
20	7.68	7.7	7.73	7.77
30	7.73	7.76	7.78	7.81

Table 8: corrosion rate of Al_2O_3 -Al in 10% NaCl at room temperatures

C.R.(mpy)				
Wt %(Al2O3)	**Week1**	**Week2**	**Week3**	**Week4**
10	0.56	0.564	0.568	0.571
20	0.57	0.574	0.581	0.586
30	0.573	0.577	0.582	0.588

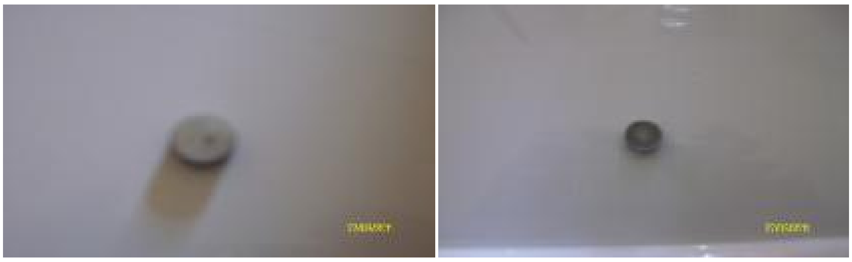

Figure 1: represent the specimen a / SiC- Al and b/ Al_2O_3-Al

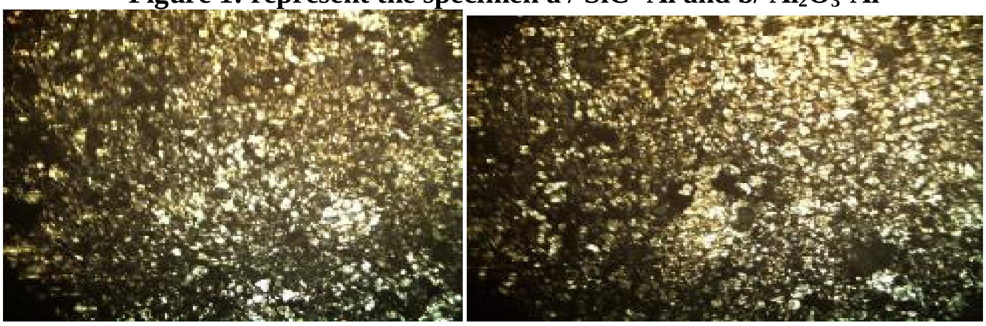

Figure 2: represent the specimens SiC-Al after immersion in HCl, NaOH &NaCl respectively

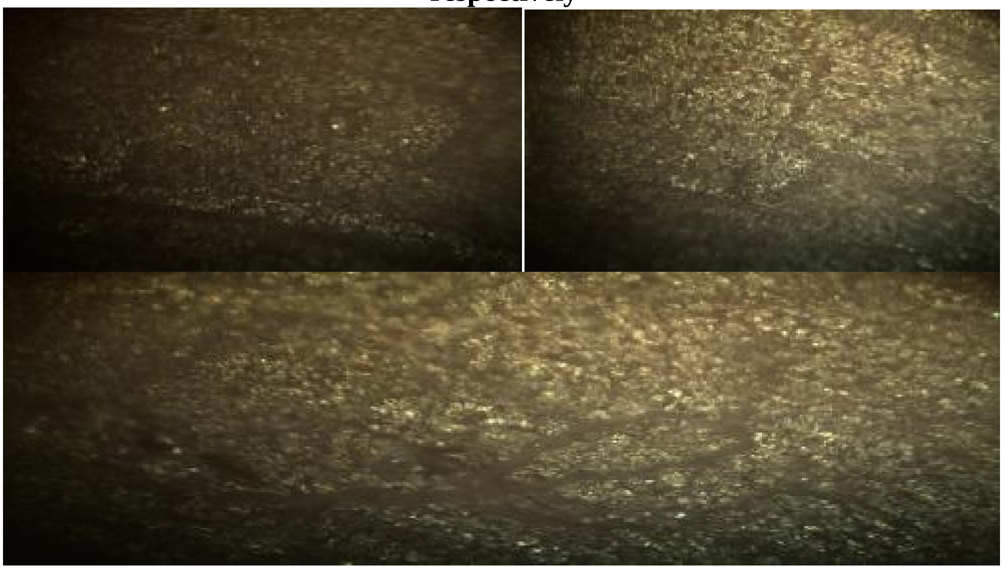

Figure 3: represent the specimens Al_2O_3-Al after immersion in, NaCl NaOH & HCl respectively

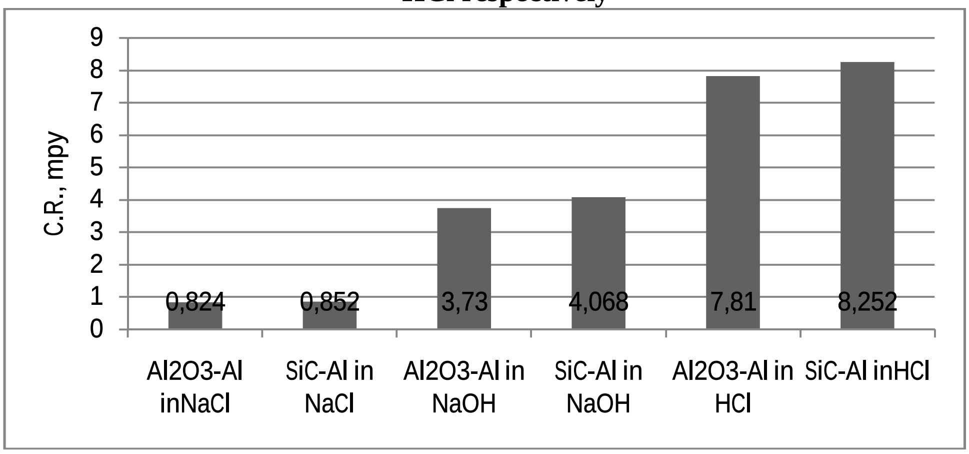

Figure4: Corrosion rate of aluminium matrix reinforced with 30% of each $Al_2O_3$and SiC at 100°C

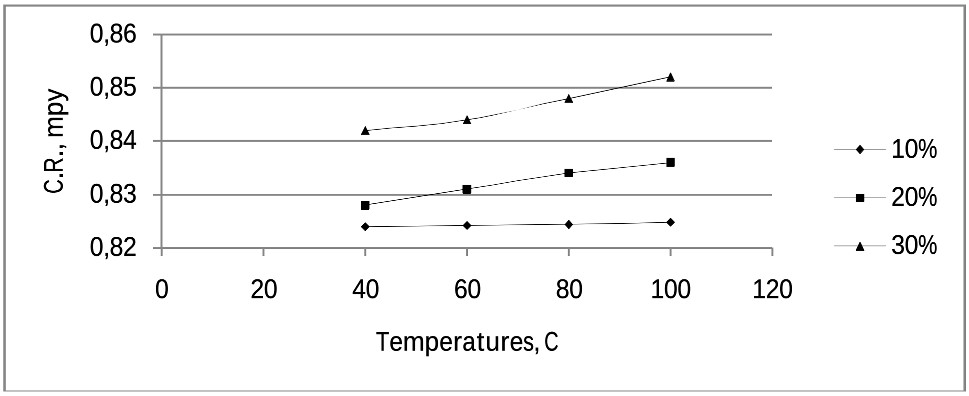

Figure5: Corrosion rate of SiC-Al in 10% NaCl at different temperatures

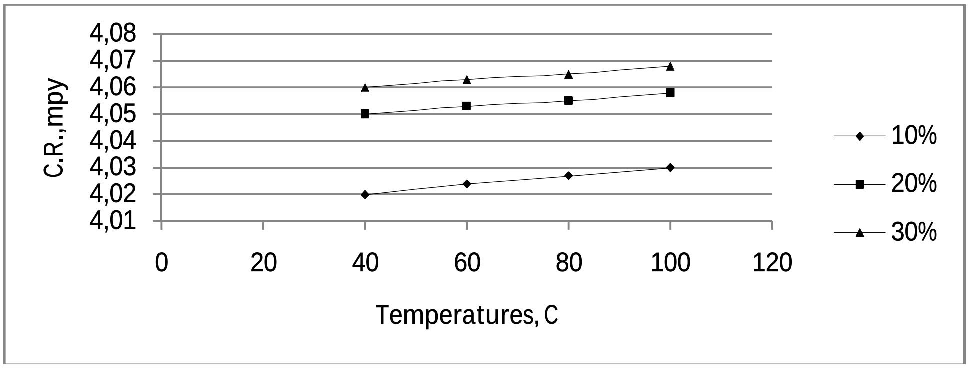

Figure 6: Corrosion rate of SiC -Al in 10% NaOH at different temperatures

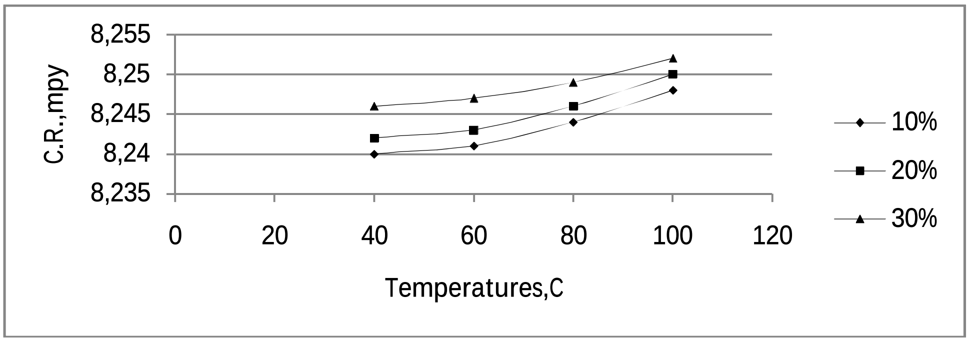

Figure 7: Corrosion rate of SiC -Al in 10% HCl at different temperatures

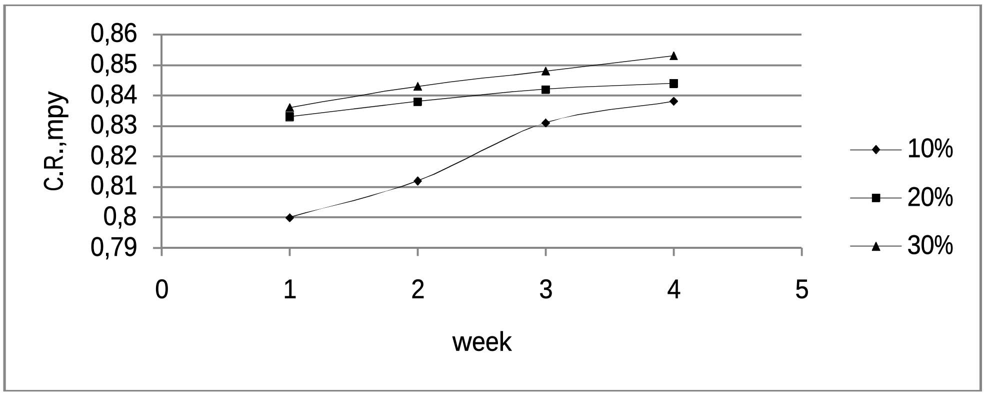

Figure 8: corrosion rate of SiC -Al in 10% NaCl at room temperatures

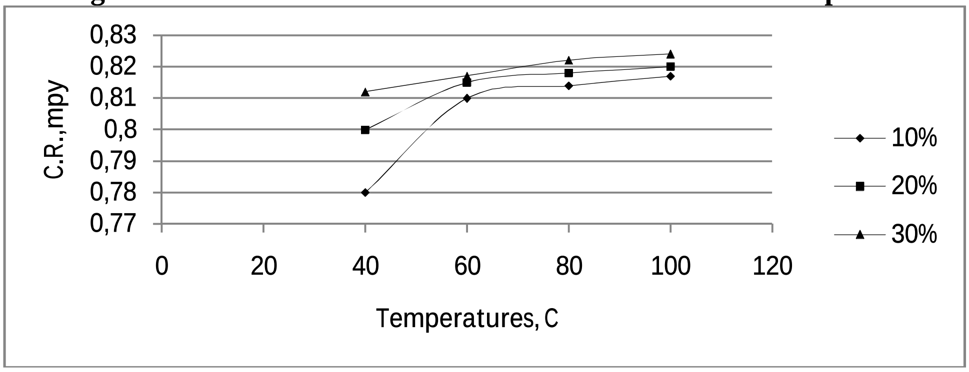

Figure 9: Corrosion rate of Al_2O_3-Al in 10% NaCl at different temperatures

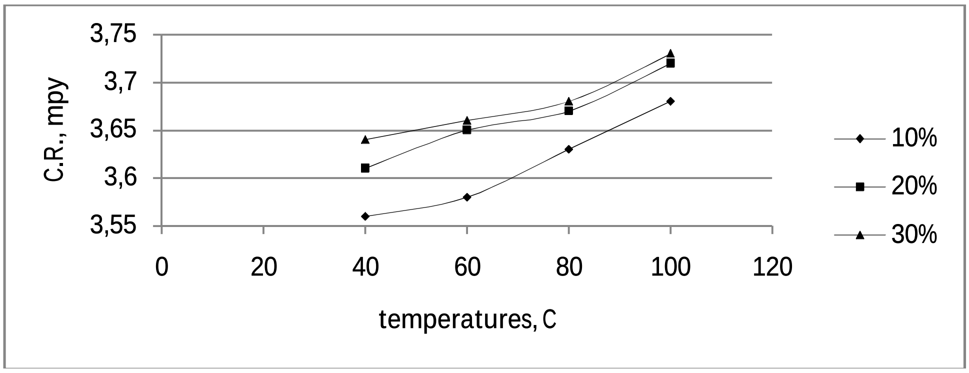

Figure 10: corrosion rate of Al2O3 -Al in 10% NaOH at different temperatures

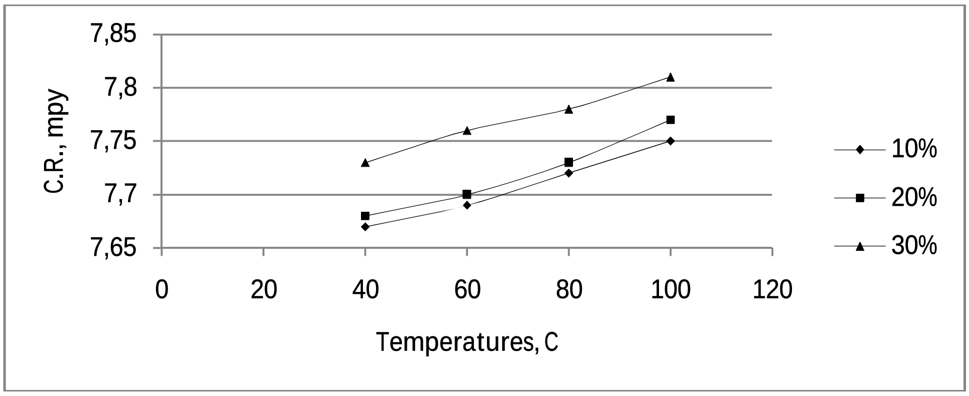

Figure 11: Corrosion rate of Al_2O_3-Al in 10% HCl at different temperatures

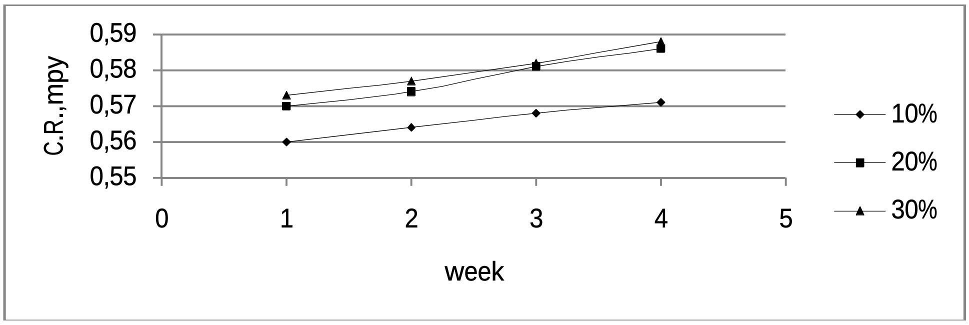

Figure 12: Corrosion rate of Al_2O_3-Al in 10% NaCl at room temperatures