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Ceramic Selection as Based Coatings for Corrosion Prevention in Oil Preservation Tanks

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ABSTRACT

Glass frit mixtures were examined in order to select the best type of ceramic coating to protect oil pipelines and tanks. The particle size of glass frit's mixtures has been determined by laser light diffraction instrument and chemical composition analysis by X-ray fluorescence. Particle size analysis results showed the highest value was (7.0928μm) and lowest value (4.5821μm). X-ray fluorescence results illustrate the presence of many element oxides such (Al_2O_3, 2SiO, CaO, K_2O) and other additives. Various dispersion slips have been utilized with glass frit mixtures. Melting temperatures were selected, and fixed at 700°C. The coating surface structural properties have been conducted by field emission-scanning electron microscope as well as, atomic force microscope for evaluating, comparing, choosing the best protection of crude oil and petroleum tanks from corrosion. Microscopic images showed success of two glass frit, with best homogeneity coating surface and high mechanical properties.

Keywords: Ceramic coatings, glass frit, A dipping process, oil preservation tanks

1. INTRODUCTION

Coatings on metallic materials have been improved significantly since 1970. Metals and metallic alloys required great attention in different fields due to their applications in technology progressed [1]. In comparison with polymeric and ceramic materials, metallic materials offer better production qualities; therefore, metals have been used in a variety of manufacturing processes [2]. Steel has excellent electrical and thermal conductivity, high stiffness, and strength in addition to its low cost when compared to other engineering materials [3]. The challenge that the metals suffered from in general, they are significantly influenced by their surroundings, particularly the presence of oxygen, which causes corrosion. Corrosion resulting in damaged the metallic surface which growth above it through a chemical or electrochemical process. Corrosion occurs inside the aquatic environment because of oxygen, which can be found in the natural world [4, 5]. Corrosion is one of the major problems that should be considered and must find the solution to reduce it and prevent it from development in oil pipelines and tanks, as well as damage to portions of them. Therefore, results in significant losses, as well as need to stop the work to repair the damage with the high cost of the tools and materials used, which lead to effect on the economy of countries [6]. Corrosion prevention is very efficient in industries due to it hurting all aspects of life. Coating is the most technique that is widely utilized for reducing, avoiding or preventing corrosion because of the many choices of coating materials and processes that are available to be used in a wide range of applications [4,7]. In general coating protects metal when physical barriers have been formed between the metal as a substrate and the bound environment. Surface coatings may be split into two categories depending on the kind of material that they are made of metallic and nonmetallic coatings [7]. As shown in the chart below Figure 1, nonmetallic coatings were divided into organic and inorganic coatings based on their corrosion resistance. Coatings made of organic materials to prevent corrosion such as epoxy, polyurethane, chlorinated rubber, and polyvinyl chloride ceramics and glass coatings are examples of inorganic coatings [2].

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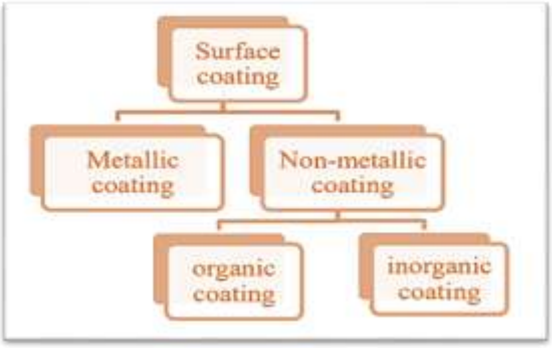


Figure 1. Coating categories.

Coatings may be applied using a variety of processes that depend on the qualities of the surface that needed to be coated, such as dipping method [8, 9]. Dip-coating is a simple and low-cost method for depositing compounds above different types of substrates, such as ceramic, metallic, films, fibrous, and polymer materials. The method has been defined as the application that could be applied for coating solutions in an aqueous-based liquid phase to the surface of different types of substrates [10, 11]. The benefits of a ceramic coating on metals illustrated as the following [11]:

- A less than complicated.
- Inexpensive.
- Coatings dry rapidly.
- Coat a 3D porous substrate very easy.

Ghazi of Soroor [12] examined the characteristics of ceramic coatings and conducted a comparative examination utilizing cyclic voltammetry, Tafel test, X-Ray diffraction, and FE-SEM. In comparison with Zn-Ni-Al_2O_3, the Zn-Ni coatings for corrosion resistance have been improved dramatically, in addition to the alumina nanoparticles. As compared with Zn-Ni coatings, Zn-Ni-Al_2O_3 coatings show homogenous and compact deposition. Popoola A. P. I [13] discovered that when the Zn-ZnO-Yttria material was coated on mild steel resulted in considerable improvements in wear resistance, corrosion resistance as well as hardness. Yttria has been added to mild steel for enhanced the corrosion and wear resistance also to increase surface hardness, according to the company. The aims of this work found the best ceramic coating material (glass frit mixtures) for protecting oil pipelines and tanks, petroleum products, and crude oil transportation, as well as to evaluate the effect of these ceramic coatings on reducing corrosion and wear in the oil industry and extending the life of oil preservation tanks and pipelines.

2. MATERIAL AND METHODS

2.1 Metallic Substrate Preparation

The metallic substrate (SA-178 Gr.A) has been used to be coated, the metal was cut into many pieces with size (40cm*40cm) which have been taken from oil tanks that belonging to (the Iraqi Ministry of Oil – Middle Refineries Company–Dora filter). Chemical composition of metallic substrate was analyzed by SPECTRO MAXX device which illustrated with Figure 2, in State the (Iraqi Ministry of Industry and Minerals – State Company for Steel Industries).

Figure 2. Spector Maxx.

2.2 Sample Preparation Before Deposition

Low carbon steel alloys were utilized in oil tanks. The following steps were taken to prepare the samples:

• Cutting: Because the surface condition of the samples is a significant impact on corrosion resistance, it is crucial to establish a homogeneous surface. As a result, square specimens with dimensions 1.5 cm×1.5 cm×4 mm were obtained as a final product, as illustrated in Figure 3.

• Grinding and Polishing: To scratch the surface of the specimens, SiC emery sheets with (60, 100, and 120) grits were utilized, and certain steel specimens were roughed with hydrofluoric acid (HF) to remove the oxidation surface layer, other surface contaminants and enhance the surface roughness.

• Cleaning: The cleaning stage was done ultrasonically in acetone for 30 minutes at 25 C^{o} to remove leftover oil and distilled water before dried and stored.

Figure 3. Specimens after cutting.

2.3 Frit Manufacturing

Six types of glass frit mixtures used as a ceramic coating material, chemical analysis of these glass frit mixtures was studied a by X-ray fluorescence at the University of Baghdad, College of Science, Department of Geosciences, to find out the components of each type.

2.4 Particle Size

The particle size was performed for all six glass frit mixtures, which was determined by a laser light diffraction instrument (Model: 90 plus. Signal processing: dynamic scattering, DLS) in the nanotechnology & advanced materials research center.

2.5 Temperature

To create the slips, glass frit mixture powder was mixed in the same weight ratio using a magnetic stirrer for 2 hrs. Then the slips were coated on the substrate and placed in the furnace to determine the proper melting temperature for the glass frit mixing (400, 450, 500, 550, 600, 650, 700 °C).

2.6 Slip Preparation

The frit powder is processed for application of the coating by combining it with specified mill additives to generate a thick slurry termed "slip" that can be applied uniformly and thinly after clean metal objects using the dipping technique. The rheological properties for coating material slip considered a crucial for application proper coating on the substrate. As indicated in the chart Figure 4, three types of dispersants were utilized to make the suspensions in this study, and the best among them was chosen to prepare as coating.

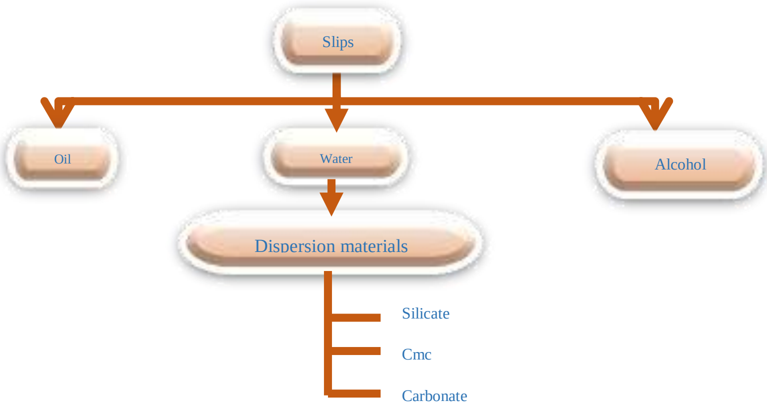


Figure 4. Types of dispersants.

2.7 Coating Procedure

Dip-coating was used to create the coating layers, with appropriate changes, that the cleaned metal was dipped into the slip. The dipping-method is considered a rapid and simple process that does not require any additional equipment, in which the specimen is submerged in enamel slip, removed, and left to drain as in references. At 120°C the coated specimen was dried in an oven for 15 minutes following the application of the coating slip to eliminate moisture. The fire procedure was the final stage in specimen preparation, and the crushed mixed specimens were placed in a stainless-steel container. As shown in Figure 5, the container was sealed with kaolin and then put in a furnace in an argon environment at 700 °C for 2 hours before being progressively cooled to room temperature.

Figure 5. Specimens firing after coating with different coated material.

2.8 Scanning Electron Microscope (SEM)

To examine the microscopic composition of sample (MIRA3 TESCAN) scanning electron microscope SEM were utilized. It produces a high-resolution picture of the specimen with a three-dimensional look and a broad depth of focus. The electrons interacted with the atoms in the specimen, for creating signals that are sent to a screen, which display information on the specimen's surface topography, composition, and other features [14,15,16].

2.9 Atomic Force Microscopy (AFM)

The AFM is made up of a cantilever with a sharp tip (probe) that is used to scan the surface of the material. The tip makes mechanical contact with surface of sample, and attraction forces between the tip and the surface are detected. The Van der Waals interactions between the tip and the surface are primarily responsible for these attractive forces. Angstrom Advanced Inc. USA, model AA3000 220V, is the manufacturer of the AFM instrument [17].

3. RESULTS AND DISCUSSION

3.1 Carbon Steel

Carbon steel was utilized in this work, the steel alloy with the chemical composition have been tabulated in Table 1.

Table 1 Carbon steel with chemical composition

Element	C%	Si%	Mn%	P%	S%	Cr%	Mo%	Ni%	Al%	Cu%	Fe %
sample Fe	0.0438	< 0.0005	0.280	0.0055	0.0224	0.0252	0.0037	0.0350	0.0124	0.0472	Bal.

Table 2 Chemical composition of glass frit.

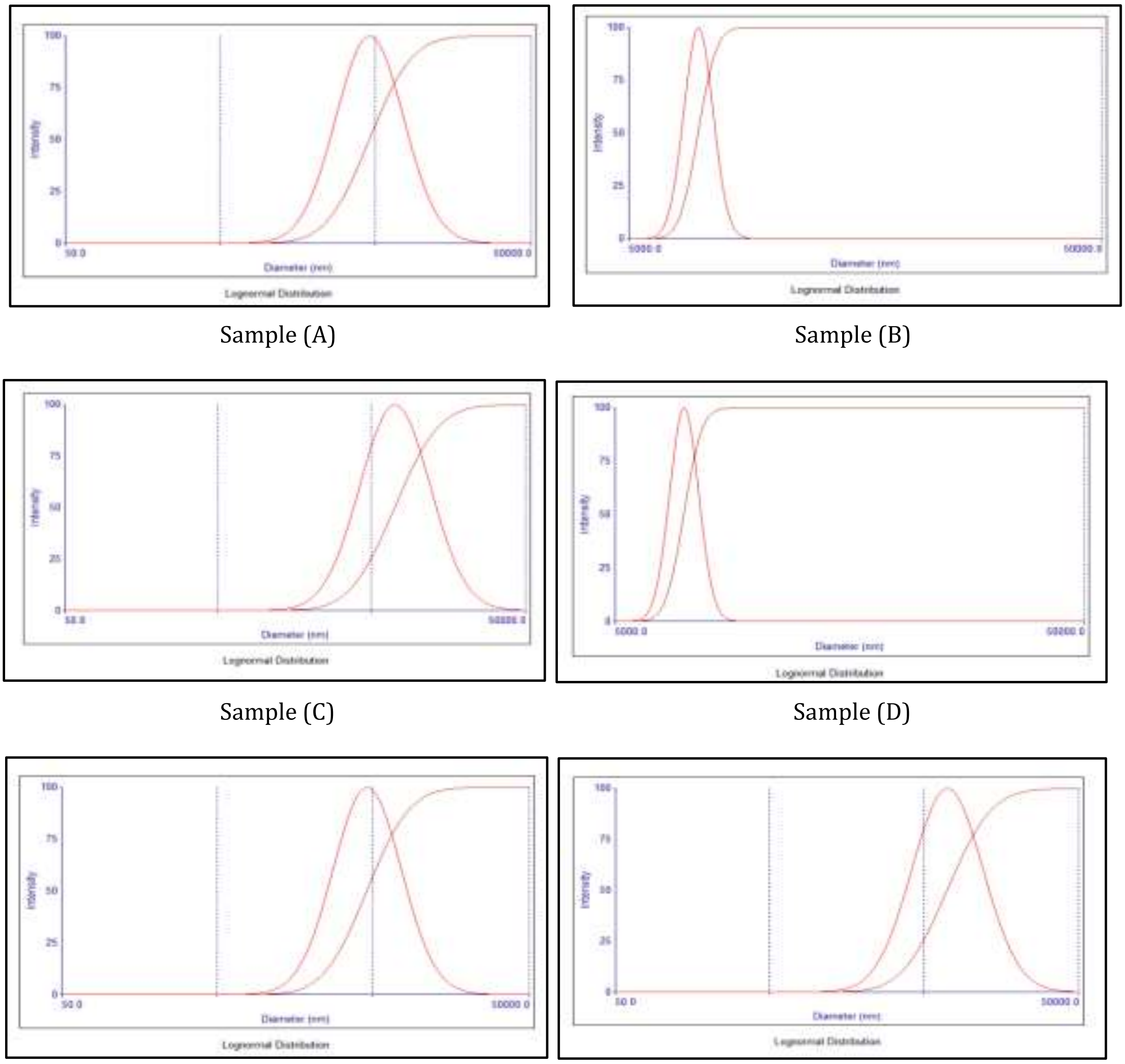
Glass frit	Na_2O	Al_2O_3	SiO_2	K_2O	CaO	ZnO	PbO	ZrO_2
A	4.54	7.32	50.32	4.40	6.90	5.44	7.33	0.31
B	5.48	9.12	52.92	4.07	4.49	0.16	1.17	0.13
C	7.13	9.81	58.20	8.41	6.42	2.11	2.16	0.26
D	7.26	10.77	62.55	7.33	6.14	2.12	2.30	0.31
E	6.16	6.82	51.54	0.21	0.37	0.17	34.01	0.09
F	6.17	7.76	46.44	1.45	4.25	2.43	28.85	0.0001

3.2 Glass Frit Analysis

The chemical composition of glass frit powders is illustrated in Table 2. The results revealed varied ratios of the components oxide (SiO_2, CaO, Al_2O_3) found in glass frit mixtures.

3.3 Particle size analysis

The results are shown in Figure 6;



Sample (A) Sample (B)

Sample (C) Sample (D)

Sample (E) Sample (F)

Figure 6. Particle size analysis of glass frit mixtures.

One of the most significant work needs is the particle size analysis of glass frit mixtures; the results demonstrate that fine particle size powder is employed to generate an optimal solution for using in the coating process.

Table 3 Diameter of the Particle of glass frit mixture

Sample	Diameter (nm)	Diameter (μm)
A	4582.1	4.5821
B	7042.2	7.0422
C	4582.1	4.5821
D	7092.8	7.0928
E	7092.8	7.0928
F	7042.2	7.0422

3.4 Temperature

The optimal melting temperature of glass frit mixtures was found to be (700°C) for most glass frit. The melting temperature of the glass frit is shown in Table 4.

Table 4 Melting temperature of glass frit mixtures

Sample	Temperature (Tm) °C
A	650 → 700°C
B	700 → 750°C
C	700 → 800°C
D	700 → 750°C
E	650 → 700°C
F	550 → 600°C

3.5 Scanning Electron Microscopy (SEM)

The surface micrograph as well as, particle distribution for the coatings were performed by using a field emission-scanning electron microscope (FESEM). Figure 7 show the FESEM which give:

- Complete coverage of the metal surface.
- The surface homogeneity, which showed the absence of agglomerations particles in the coating material on the surface of the metal.
- It also showed the absence of micro cracks, pores, and gaps in the paint layer.

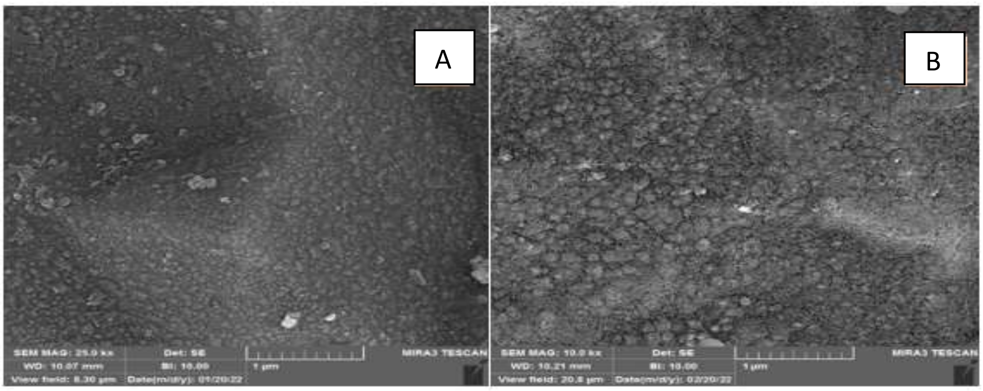


Figure 7. FESEM image for the coated specimen.

From Figure 8 we could result in the following points:

- Glass frit mixture at firing process melting in high temperature became liquid phase, at coating liquid phase transfer to solid phase with shrinkage by surface tension. Solid-phase volume less than liquid phase volume.
- It also showed micro cracks, pores, and gaps in the paint layer.
- Agglomerations of particles in the coating material on the surface of the metal.

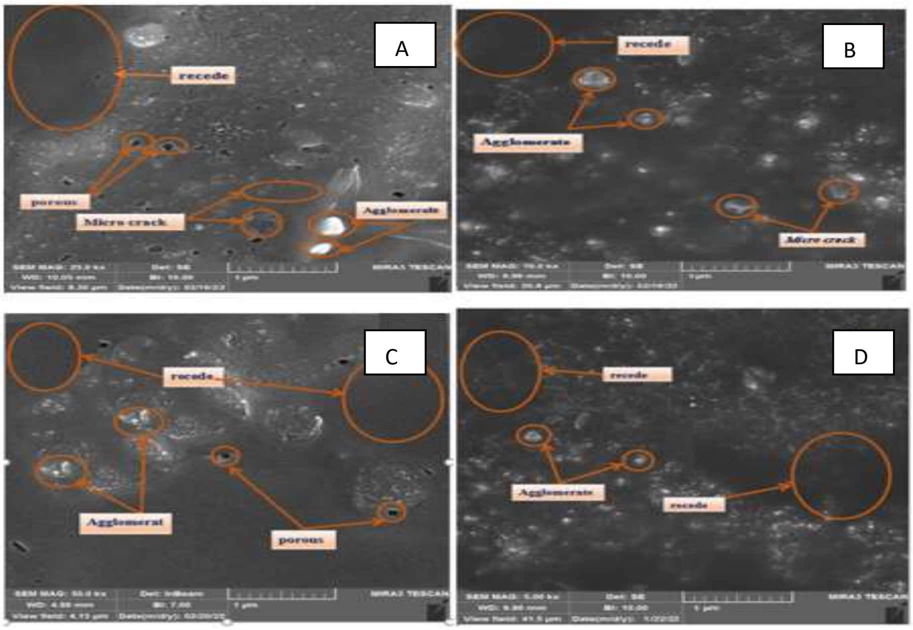


Figure 8. FESEM image for the coated specimen.

3.6 AFM Identification

The 3D AFM images of each sample were coated by the glass frit mixtures (C and D). Figure 9 shows that the low carbon steel substrate was coated by the dipping method and characterized by AFM which means a good dispersion of those particles and getting a rough surface of 4.52 nm.

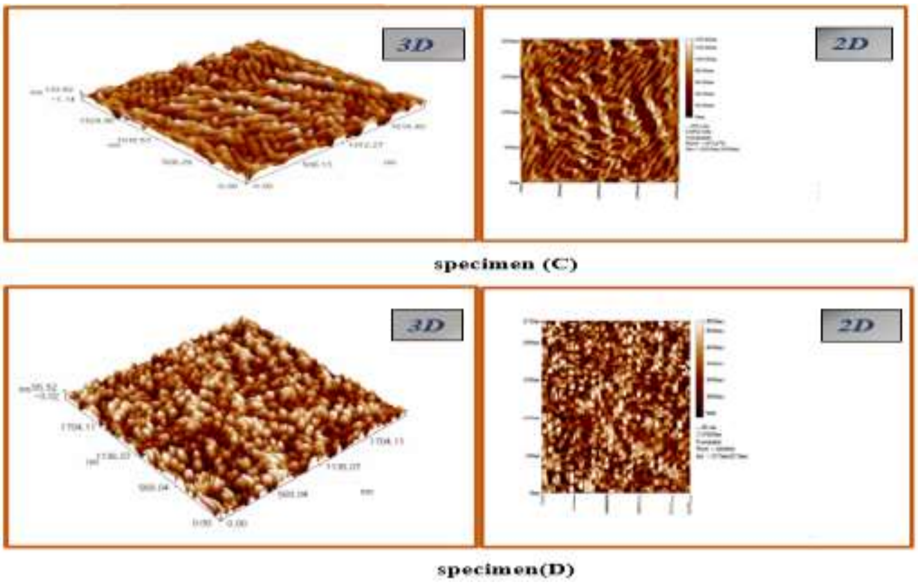


Figure 9. AFM image of the coated specimen.

Table 5 Roughness of the coated specimen

Material Coating	Roughness average (nm)
C	4.52
D	3.58

4. CONCLUSIONS

- The metal used in crude oil tanks, pipelines, and petroleum products includes a low amount of carbon, the carbon content must be raised to improve the metal's mechanical qualities.
- Selecting appropriate glass frit mixtures for coating low carbon steel metal to enhance mechanical qualities and extend its lifespan.
- Due to the particle size of the glass frit mixtures is critical, it is crucial to select an acceptable particle size in order to create a suitable coating that is free of material buildup.

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