**Why the Dhul-Qarnayn's dam is impenetrable?**

**Chemical and physical study**

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**Abstract**

By Development of human scientific abilities, more miracle aspects and wonders of Quran have been recognized. Stating the story of Dhul-Qarnayn and constructing of dam, verses (Al-Kahf, 83-98), have pointed some valuable scientific aspects regarding chemistry, physics and metallurgy. The instruction for the structure reveals the non-accidental process, because the precise expected physical, chemical and metallurgical properties.

The three-layer structures of dam with dendrite-like microstructure in its matrix, will guarantee the durable structure against most chemical destructive agent, mechanical damage and thermal threats. Hence the powerful people of Gog and Magog could not to overcome the high tensile strength of iron, high ductility of copper and the high toughness of Cu-Fe alloy. The high thermal and temperature resistance are the evidence for more structural power. Such masterpiece of engineering, in technology of alloying, could not base on common knowledgeable craftspeople of that time, but must be based on superhuman wisdom.

Consequently: although Quran is guidance book, but it reports some original scientific issues, such Dhul-Qarnayn story. These were not known in the age of revelation and after progressing in science, the truth of considered issues has been proved. However, because the clear instruction, and the precise prediction of properties, it is possible to use the verses as an excellent idea for science progression, other than reporting events.

**Keywords:** Dhul-Qarnayn's dam, Miracle of Quran, Copper, Iron.

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1. Introduction

The Statue of Liberty, in Small Island in New York Harbor, may be one of the biggest metallic structures in the world. The design of such statue was a very difficult job because of its size. So the engineers decide to make her skin out of thin copper sheets, then attaching them on a metal iron frame.

As another application of Copper-Iron structure, the Swedish waste of nuclear fuel is today stored in Clab, a central interim storage facility. During moving these to a final repository, it was stored there for 30 to 40 years. The waste is encapsulated in an insert made of iron with surrounding copper. The iron insert provides the mechanical strength and the copper canister gives corrosion protection (Svensk Kärnbränslehantering, 2006).

Also, Dhul-Qarnayn’s dam is one of the famous antiquarian (What the author means by antiquarian?) structures that made out of Copper-Iron metals. As mentioned in holy Quran, this dam is a durable protective wall, separating two areas on earth.

Dhul-Qarnayn appears in Quran, (Al-Kahf, 83-98), who travels a long way of east and west and erect a dam between two mountains, separates between mankind and Gog and Magog (Yajuj and Ma’juj) (Cook, 2005).

The verses (Al-Kahf, 96-97), reproduced below show that Dhul-Qarnayn built a dam which Gog and Magog (Yajuj and Ma’juj) could not penetrate it: "Give me pieces of iron" - till, when he had leveled up (the gap) between the cliffs, he said: "Blow!" - till, when he had made it a fire, he said: "Bring me molten copper to pour thereon". And (Gog and Magog) were not able to surmount, nor could they pierce (it). The Gog and Magog could penetrate each barrier and they have special abilities (Al-Anbiya, 96), but mentioned dam is so strong that they were not able to pierce it.

Aforementioned dam is also very durable and long lasting: "He said: This is a mercy from my lord: But when the promise of my Lord comes to pass, he will make it into dust; and the promise of my Lord is true." (Al-Kahf, 98). So not only they could not to destroy it, but also it cannot be corroded easily, in weather and environmental conditions.
Developing of human abilities, miracle aspects of the Holy Quran can be recognized. Therefore, it’s a high time of studying: Why this structure is so strong? Wouldn’t they destroy it by any known chemical materials or to overcome it by physical powers such thermal and mechanical tools?

So the story of Dhul-Qarnayn and studying of his dam constructions can be regarded as a high technology in safety industry, impenetrability and consolidation of iron through putting a coating copper on its surface.

Accordingly, all aspects of durability and stability of aforementioned structure are considered in chemical and physical views.

2. Problem statement

One of the miracle aspects of Quran is its scientific miracle. We imagine the miracle as revealing of some point in science, which nobody knew it before: 

"That is from the news of the unseen which we reveal to you, [O Muhammad]. You knew it not, neither you nor people, before this. So be patient; indeed, the [best] outcome is for the righteous." (Hud, 49). So, some subjects in Quran, which has not been mentioned before in scriptures or in scientific centers or human could not comprehend it alone, can be interpreted as scientific miracles (Rezaei, 2001).

Dhul-Qarnayin's dam also can be considered as a miraculous aspect of the holy Quran. He was a capable man, who was learned a lot of skills through revelation and know how to achieve everything: "Verily we established his power on earth, and we gave him the way and the means to all ends." (Al-Kahf, 84).

This story is purely through inspiration and the people were not aware of it: 

"and they ask you, [O Muhammad], about Dhul-Qarnayn. Say, I will recite to you about him a report." (Al-Kahf, 83).

The peoples he helped them, don’t know such grade of technology, because they asked him for help: "They said: “O Dhul-Qarnayn! The Gog and Magog (people) do great mischief on earth; shall we then render thee tribute in order that thou mightiest erect a barrier between us and them?" (Al-Kahf, 94). Also, as will depicted, historical studies indicate that such grade of technology in alloying could not base on common knowledgeable craftspeople, and some copper alloys were accidental and perhaps not even distinguished from copper.
So, we looking for some points and hints about Dhul-Qarnayn's dam, which could be understand as a modern science. The verses (Al-Kahf, 83-98), related to dam, its structure and some of its properties, so we seeking for some valuable scientific and technologic point, profound thinking about mentioned dam.

3. Result and discussion

The high-powered Gog and Magog could not to penetrate through Dhul-Qarnayn's dam. But why wouldn’t they destroy it by any known tool? From What material it was produced and what was its properties? What was the grade of impenetrability and consolidation of the mentioned structures?

As far as chemical and physical aspects are regarded, we try shedding some light on its hidden properties. Hence, on the whole, all possible destructive agent and factors can be classified in two part: chemical and physical. The chemical can be classified in structural and chemical reactions such as phase exchange and electron transfer. The physical is also classified in thermal and mechanicals.

3.1. What material was produced?

First it must be cleared what the compound was produced from, then discussing its chemical and physical properties. Hence the method of constructing the structure is discussed. As mentioned, the iron pieces were heated, then the molten copper was poured on it.

Heating iron is very important, as a transformation of pure Copper and Iron into Cu-Fe alloys (Figure 1). Without heating, the layer of copper is placed on iron surface, without any change in pure iron and coppers structure. Studying the phase diagram of copper- Iron (Cu-Fe) reveals that the Cu_{70}Fe_{30} alloy is simply available, also rapid solidification of this alloy may cause some dendrite-like microstructures, which are clearly visible with optical microscopes (Chen et al. 2007) (Figure 2). Whereas at that time, many aspects such phase separation, nucleation, solidification and microstructure evolution in boundary condition and contacting edge between copper and iron were not known.

Therefore heating is a very important process, because diffusing some Fe atoms in Cu matrix, constructing the dendrite-like microstructures of iron inside the Cu-Fe alloy and finally pure layer of copper, as the farthest layer contacting
with environment, all is the consequences of heating. Hence Dhul-Qarnayn applied the bulk undercooling techniques for Fe-Cu alloys.

As stated in the verses, Gog and Magog were not to surmount or pierce such high technologic engineering structures. Consequently, aforementioned structures must have a high grade in chemical and physical resistance.

Before investigating the properties of aforementioned structure, it must be emphasized that such grade of technology in alloying could not base on common knowledgeable craftspeople. Because the composition of the early “brass” and "bronze" objects are highly variable and the Zinc or Tin contents were lower than in copper alloys produced by cementation. These may be "natural alloys" manufactured by smelting zinc or tin rich ores in production process. So, it is possible that some copper alloys were accidental and perhaps not even distinguished from copper (Craddock & Eckstein, 2003). Therefore, forms of brass or bronze have been in use since prehistory, its true nature as a copper alloy were not known until post-medieval period, because the zinc or tin vapor which reacted with copper were not recognized as metals (Thornton, 2007; Ruette, 1995). So, in historic quotation, the word “brass” can mean any "bronze" alloy or copper, an even less precise definition, than the modern one.

3.2. Kinetically the chemical corrosion is unsuitable

Durability and stability are important factors in metal structures that should ensure long life. Both of these are strongly dependent on the environmental conditions. For instance, the iron metal is well durable in dry and oxidative free medium. But in moist air it easily suffers corrosion with Oxygen melted in moisture. Hence protected iron with semi-stable metal, such as copper, thermodynamic and kinetically is durable in corrosive environment. A durable and stable structure does not merely depend on its internal properties such an atomic bond strength or its crystalline form, but completely conditional on probable events. As mentioned, (Al-Kahf, 98), Dhul-Qarnayn's dam is well durable and stable, so physically or chemically had to be protected against the oxidative agent.

As presented in former section, this structure is formed with equilibrium separation along the thermal gradient in copper-iron phase diagram (Chen et al.
2007). So, it is the thermodynamically semi-stable structure and any structural changes yield the same structural composition.

On the other hand, as will explained, the chemical electron transfer is also kinetically an unsuitable reaction. When metallic materials are put into corrosive environment, they tend to have chemical reactions with the air and/or water. Corrosion is a natural process that convert a refined metal into more chemically-stable form such as oxides.

The effects of corrosion become evident on the surface of these materials. For example, after putting a piece of iron into a corrosive atmosphere for an extended period, it starts rusting due to oxygen interaction with water on the surface of the iron. So, it is the gradual destruction of metals by chemical and/or electrochemical reaction by their environment. Because corrosion is a diffusion-controlled process, it occurs on exposed surface to oxidant. So, reducing the exposed surface, such passivation or plating with other stable materials, can increase materials corrosion resistance (Mofidi, 1998).

On the one hand the resistance of all grade of copper to atmospheric corrosion is good due to its relatively high positive electrode potentials. So, copper corrosion occurs at negligible rates in air, also it achieves a higher resistance as developing the adherent protective coatings, initiated with cuprous oxide (Cu$_2$O) then after a few years converts to cupric oxide (CuO) (Skoog et al., 2003). Also due to high electrical conductivity of the metals such a copper, silver and gold, they can act as destabilizing perturbing potential field (tunneling effect) on the adsorbing oxidizing species and consequently reducing their corrosion activity (Moghaddasi & Zahedi, 2017).

Therefore, in coated iron with copper, Cu can act as a passive protective layer and remain largely stable in extended periods of time. Such passivation or plating with other stable materials, can increase materials corrosion resistance, consequently make it durable and stable against corrosive agents.

3.3. Why the mechanical penetration of this structure is so hard?

The mechanical properties of metals determine the range of usefulness of the metal and establish the ability that can be expected. So, it represents how metals will respond to external force. Mechanical properties are characterized by stress
and strain (such as tension and torsion), elastic deformation and plastic deformation (such as tensile strength, ductility and toughness).

Most commonly strength of material is marked by reporting its "tensile strength". It is defined as the maximum force in tension a material will withstand before fracturing, or the ability of a material to resist being pulled apart by opposing forces.

But it not showing the whole properties, so other parameters such as ductility is also reported. Ductility is the property which allow the material to be stretched or otherwise change in shape without breaking, and to retain the varied shape after the external forces are removed. Therefore, it is the ability of a material, such as copper, to be stretched permanently without fracture. Also, the lack of ductility is brittleness or the lack of showing any permanent deformation before the metal cracks (such cast iron).

Most commonly tensile strength is reported in N/mm$^2$ and ductility is reported with the percentage of stretching of length. So, these parameters refer to the local behavior of materials in external forces and don’t represent the whole dynamic behavior along the stretching process. The ability of a metal to deform plastically and to absorb energy in the process before fracture is termed toughness. Recall that ductility is a measure of how much something deforms plastically before fracture, but just because a material is a ductile does not make it tough. The key to toughness is a good combination of strength and ductility. A material with high strength and high ductility will have more toughness than a material with low strength and high ductility. Therefore, one way to measure toughness is by calculating the area under the stress strain curve from a tensile test (Figure 3). This value is simply called “material toughness” and it has units of energy per volume.

As depicted in figure 3, iron has relative high strength and low ductility and likewise copper has relative low strength and high ductility. Therefore, these metals are classified in middle range of toughness. Agunsoye et al. demonstrated that the presence of copper in the melted iron causes a notable increase in toughness of Cu-Fe alloy (Agunsoye et al. 2014).

Therefore Dhul-Qarnayn's dam is an intelligent plan that will show phenomenal high ductility, high toughness and high tensile strength due to the outer pure copper, middle Copper-Iron alloy and inner pure iron respectively.
Also, as mentioned, the microstructure dendrite like structure of iron among the Copper-Iron alloy can highly increase these phenomenal properties.

3.4. Why the thermal penetrating of this structure is so hard?

While thinking of thermal properties of metals, a wide variety of properties and phenomena come to mind. Thermal properties are those properties of metals which are related to its conduction of heat. In other words, these are the properties which are exhibited by a material when the heat is passed through it.

Thermal properties of metals decide how it react when it is subjected to heat fluctuation. The thermal conductivity and melting point are two major components of thermal properties.

The melting point of substance is the temperature at which solid and liquid phases may coexist in equilibrium or the temperature at which matter changes from solid to liquid form. So, the melting point is the maximum possible temperature in heating a material, can withstand in solid phase, or the resistance ability of a material to melt, in solid phase, against temperature. For example, in materials under investigation, iron and copper have a melting pion of 1538 °C and 1084 °C respectively. Therefore, the temperature resistance of iron to melting is significantly higher than copper, and these temperatures must be generated by a thermal source.

On the other hand, if the whole system is not subjected to temperature increase, such a thermal cutting, the efficiency of thermal source is highly related to thermal conductivity of metal. Because the thermal flow from the heat affected zone to around, demand the stronger heat source, compensating wasted heat (Kermanpur et al. 2008). Also, the higher thermal conductivity indicates the dependence of the larger part of the system on melting (Figure 4). For example the copper and iron have the thermal conductivity of 400 (W/m.K) and 80 (W/m.K) respectively. Therefore, the thermal resistance of copper for melting the “thermal heat affected zone” is significantly higher than iron, because, it wastes the heat 5 times more than the iron in aforementioned area.

Therefore, melting a piece of metal in isolated condition and in contact with the environment, the output power of the source will be different. So, iron has to pass the “higher temperature resistance” than copper whereas the copper need higher thermal efficiency (higher thermal flow resistance) for heat source. The
key to “thermal flow resistance” is a good combination of “melting point” and “thermal conductivity”. A material with high melting point and high thermal conductivity will have more “thermal flow resistance” than a material with low melting point and high thermal conductivity. Therefore, one way to measure "thermal flow resistance" is by calculating the volume under the thermal behavior in heat affected zone curves (Figure 5). This value has the units of energy per minute (W).

Consequently, as depicted in Figure 5, Dhul-Qarnayn's dam has marvelous thermal properties, which resist any kind of fire. It has high thermal conductivity, high temperature resistance and high thermal flow resistance due to its efficient structure, related to its different layers.

4. Conclusion

The Quran is the guidance book, which want to guide people to prosperity. Although it is not a scientific book, but it has raised various scientific issues. In this holy book, some issues are discussed, which was not known in the age of Qurans revelation, or it was incorrectly common among people. Later, after progressing in science, the truth of considered issues have been proved.

Dhul-Qarnayn's dam can be considered as a miraculous aspect of the holy Quran. As can be understand in the verses, the instruction and the precise expected properties for the mentioned structure reveals the non-accidental process, because it needs progression in physics, chemistry and metallurgy.

The microstructure design of this structure indicates the masterpiece of engineering and indeed, the Cu-Fe alloy was armed with micro dendrite-like of iron. The mentioned alloy was also unknown at that time, beside its phenomenal thermal and mechanical properties. Consequently, this project requires extensive knowledge in modern science, chemistry, physics and metallurgy.

As mentioned, the construction method in verses confirms that he made multi structural-three-layer dam. Such structure is durable and stable against most chemical destructive agent. Also, it has the optimum mechanical and thermal properties. Therefore, the powerful people of Gog and Magog (Al-Anbiya, 96), could not to overcome the high tensile strength of iron, high ductility of copper and the high toughness of Cu-Fe alloy. The high thermal and temperature resistance are the evidence for more structural power.
These original scientific issues, indicate that the Holy Quran cannot have been originated from knowledge of that time, but must base on superhuman wisdom. Qurans verses also indicate that this story is purely through inspiration and the people were not aware of it. And the peoples he helped them, as confirmed in the historical studies, did not know such grade of technology, because they asked him for help.

However, Quran reports the event that are approved by science, but it is possible, such Dhul-Qarnayn story, to be used in development of science. The verses clearly stated how the dam must be built, same as the precise prediction of its properties. Therefore, for development the modern science, pondering the verses can let us to have more excellent idea for science progression. Consequently, the miracle of the Quran is not merely in the report, but as well in anticipations.

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**Figure captions:**

**Figure 1.** When iron heated, atoms of the molten copper are doped into the context of the iron and some irons atom are solved in the molten copper.
**Figure 2.** Rapid solidification of copper-iron alloy causes some Fe dendrite-like structures in the context of copper.

**Figure 3.** Relative high strength (iron), High ductility (copper) and high toughness (copper-iron alloy). As depicted, the area under the stress strain curve represent the toughness.
**Figure 4.** Heat affected zone area. When an area of metal is subjected to temperature increase, thermal energy flows to around.

Such gradient of temperature merely depends on thermal conductivity of metals.
Figure 5. Thermal behavior of heat affected zone in iron, copper and copper-iron system. Iron has a higher “temperature resistance” than copper whereas the copper has higher “thermal flow resistance”. The copper-iron system is highly efficient in both “thermal resistant” and “thermal flow resistant”.