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Why Dhu al-Qarnayn Dam is Impenetrable? A Chemical and Physical Study

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ABSTRACT: Original Paper

By development of human scientific abilities, more miracle aspects and wonders of the Qur'an have been recognized. Stating the story of Dhu al-Qarnayn and constructing of dam, verses (Q.18:83-98) 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 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 be based on the knowledge of common craftsmen of that time, but it must have been based on superhuman wisdom.

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

KEYWORDS: Dhu al-Qarnayn's dam; Miracle of the Qur'an; Copper; Iron.

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1. Introduction

The Statue of Liberty, on a 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. The engineers decided to make her skin out of thin copper sheets and attach them onto a metal iron frame.

As another application of copper-iron structure, the Swedish nuclear fuel waste is today stored in Clab, a central interim storage facility serving as a final repository where it was stored 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, Dhu al-Qarnayn's dam is one of the famous ancient structures made out of copper-iron metals. As mentioned in holy Qur'an, this dam is a durable protective wall, separating two areas on earth.

Dhu al-Qarnayn, attested in the Qur'an (Q.18:83-98), traveled a long way of east and west and erected a dam between two mountains that separated between mankind and Gog and Magog (Ya'jūj and Ma'jūj) (Cook 2005)..

Verses (Q.18:96-97) show that Dhu al-Qarnayn built a dam impenetrable to Gog and Magog, *"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 had special abilities (Q.21:96), but the mentioned dam was so strong that they were not able to make a hole in it.

The 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'"* (Q.18:98). So not only they could not to destroy it, but also it cannot be corroded easily in different weather and environmental conditions.

The development of human abilities further demonstrates the miracle aspects of the Holy Qur'an. 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?

The story of Dhu al-Qarnayn and studying of his dam constructions can be regarded as a high technology in safety industry, impenetrability and consolidation of iron through coating its surface with copper.

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

2. Problem Statement

One of the miracle aspects of the Qur'an is its scientific miracle. We imagine the miracle as revealing of some formerly unknown point in science. *"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"* (Q.11:49). So, some subjects in Qur'an, 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).

Dhu al-Qarnayn's dam also can be considered as a miraculous aspect of the holy Qur'an. 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"* (Q.18:84).

This story is purely through inspiration and the people were not aware of it: *"and they ask you, [O Muhammad], about Dhu al-Qarnayn. Say, I will recite to you about him a report."* (Q.18:83).

The peoples he helped them were unaware of such advanced technology, because they asked him for help: *"They said: "O Dhu al-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?"* (Q.18:94). Also, as will be mentioned below, historical studies indicate that such advanced technology in alloying could not be based on the knowledge of craftsmen of the time, and some copper alloys were accidental and perhaps not even distinguished from copper.

So, we are looking for some points and hints about Dhu al-Qarnayn's dam which could be understood as modern science. The verses (Q.18:83-98) are related to the dam, its structure and some of its properties. We are thus looking for some valuable scientific and technologic point and profound thinking about the dam.

3. Result and Discussion

The powerful Gog and Magog could not penetrate Dhu al-Qarnayn's dam. But why did they not destroy it by any known tool? From What material was it built and what were 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 agents and factors can be classified in two parts – 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, the compound from which it was produced as well as its chemical and physical properties need to be clarified and thus the method of constructing the structure be discussed. As mentioned above, 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 the pure iron and copper structure. Studying the phase diagram of copper-Iron (Cu-Fe) reveals that the $Cu^{70}Fe^{30}$ alloy is simply available and rapid solidification of this alloy may cause some dendrite like microstructures, which are clearly visible with optical microscopes (Chen et al. 2007; Figure 2). Many aspects of the phases of separation, nucleation, solidification and microstructure evolution in boundary condition and contacting edge between copper and iron were not known at the time.

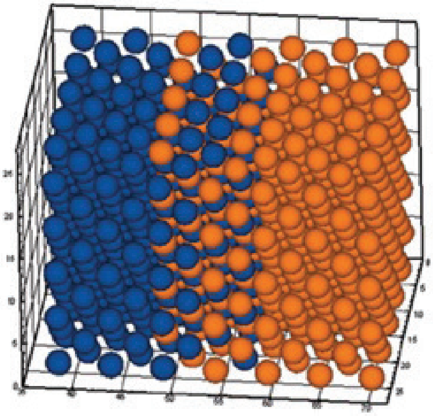

Figure 1. When iron heated, atoms of the molten copper are doped into the context of the iron and some iron atoms are solved in the molten copper.

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 the pure layer of copper, as the farthest layer contacting with the environment are the consequences of heating. Dhu al-Qarnayn thus applied the bulk undercooling techniques for Fe-Cu alloys.

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

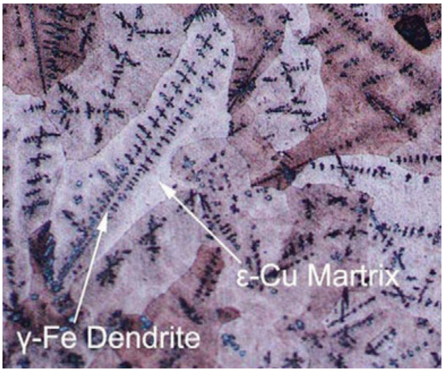

Figure 2. Rapid solidification of copper-iron alloy causes some Fe dendrite like structures in the context of copper.

Before investigating the properties of the structure, it must be emphasized that such advanced technology in alloying could not be based on the knowledge of the craftsmen at the time. Because the composition of the early brass and "bronze" objects are highly variable and the Zinc or Tin contents were lower than the copper alloys produced by cementation. These may be 'natural alloys' manufactured by smelting zinc or tin rich ores in the production process. 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 the post-medieval period, because the zinc or tin vapor which reacted with copper were not recognized as metals (Thornton 2007; Ruette 1995). In historical records the word 'brass' can mean any 'bronze' alloy or copper and it may have had an even less precise definition than the modern one.

3.2. Chemical Corrosion Is Kinetically Unsuitable

Durability and stability are important factors in metal structures that should ensure a long life. Both of these are strongly dependent on 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 the oxygen melted in moisture. The iron protected by semi-stable metal, such as copper, is thermodynamically and kinetically durable in a 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 it is completely subject to probable events. As mentioned above in verse (Q.18:98), Dhu al-Qarnayn's dam is well durable and stable, so it had to be physically or chemically protected against the oxidative agent.

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

On the other hand, as it will be explained below, the chemical electron transfer is also kinetically an unsuitable reaction. When metallic materials are put into a corrosive environment, they tend to have chemical reactions with the air and/or water. Corrosion is a natural process that converts a refined metal into more chemically-stable forms 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. It is thus the gradual destruction of metals by chemical and/ or electrochemical reaction by their environment. Because corrosion is a diffusion-controlled process, it occurs on a surface exposed to an oxidant. Reducing the exposed surface, such passivation or plating with other stable materials can increase materials corrosion resistance (Mufīdī 1998).

Resistance of all grade of copper to atmospheric corrosion is good due to its relatively high positive electrode potentials. Copper corrosion, therefore, occurs at negligible rates in the air and achieves a higher resistance as it develops the adherent protective coatings, initiated with cuprous oxide (Cu^2O). Then, after a few years, it converts to cupric oxide (CuO; Skoog et al. 2003). Also due to high electrical conductivity of metals such a copper, silver and gold, they can act as a destabilizing perturbing potential field (tunneling effect) on the adsorbing oxidizing species and consequently reduce their corrosion activity (Moghaddasi & Zahedi 2017).

Therefore, in the iron coated 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 and thus make it durable and stable against corrosive agents.

3.3. Why Is the Mechanical Penetration of This Structure So Hard?

The mechanical properties of metals determine the range of usefulness of the metal and establish the ability that can be expected from them. It represents how metals will respond to external forces. 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).

Material strength is mainly 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.

Since it does not show all the properties, other parameters, such as ductility, is also reported. Ductility is the property which allows 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, lack of ductility causes brittleness or 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. These parameters refer to the local behavior of materials in external forces and do not 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 the extent to which 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.

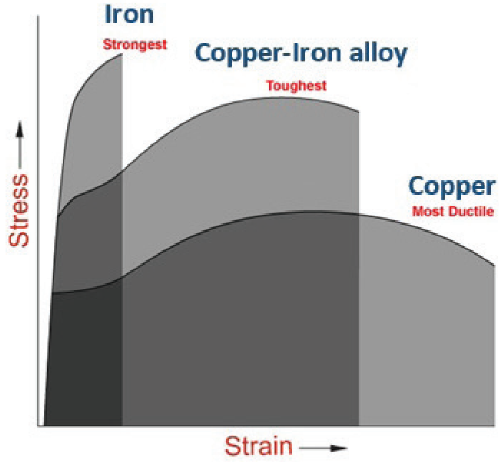

Figure 3. Relative high strength (iron), High ductility (copper) and high toughness (copper-iron alloy). As depicted, the area under the stress strain curve represent the toughness.

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

Therefor Dhu al-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. As mentioned above, the microstructure dendrite like structure of iron among the copper-iron alloy can highly increase these phenomenal properties.

3.4. Why Is Thermally Penetrating This Structure So Hard?

Considering the thermal properties of metals, a wide variety of properties and phenomena come to mind. Thermal properties are the metal properties related to thermal conductivity. In other words, these are the properties exhibited by a material when the heat is passed through it.

Thermal properties of metals determine the manner of their reactions when they are 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. The melting point, 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.

If the whole system is not subjected to temperature increase, such a thermal cutting, the efficiency of thermal source is mainly related to the thermal conductivity of metal, since the thermal flow from the heat affected zone to the surroundings demand a stronger heat source in order to compensate the 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 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.

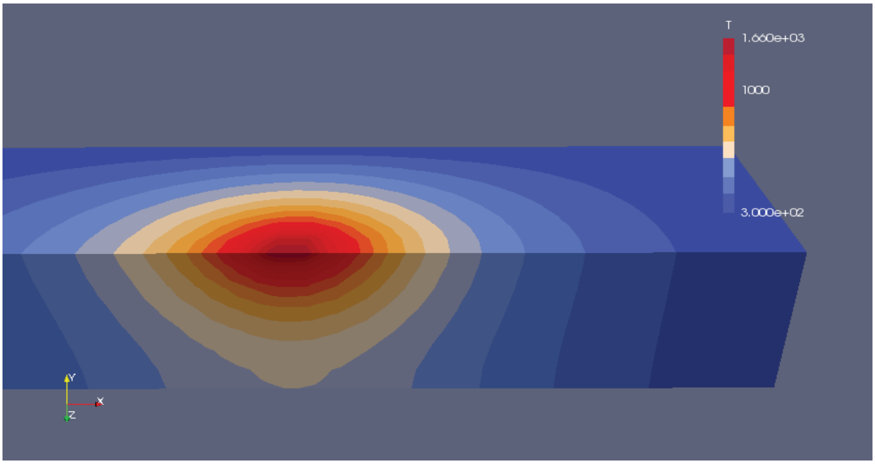

Figure 4. Heat affected zone area. When an area of metal is subjected to temperature increase, thermal energy flows to around.

Such gradient of temperature merely depends on thermal conductivity of metals.

Melting a piece of metal in an isolated condition and in contact with the environment will result in a different output power of the source. Compared to copper, iron has to pass a 'higher temperature resistance,' whereas copper needs 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, Dhu al-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 which is related to its different layers.

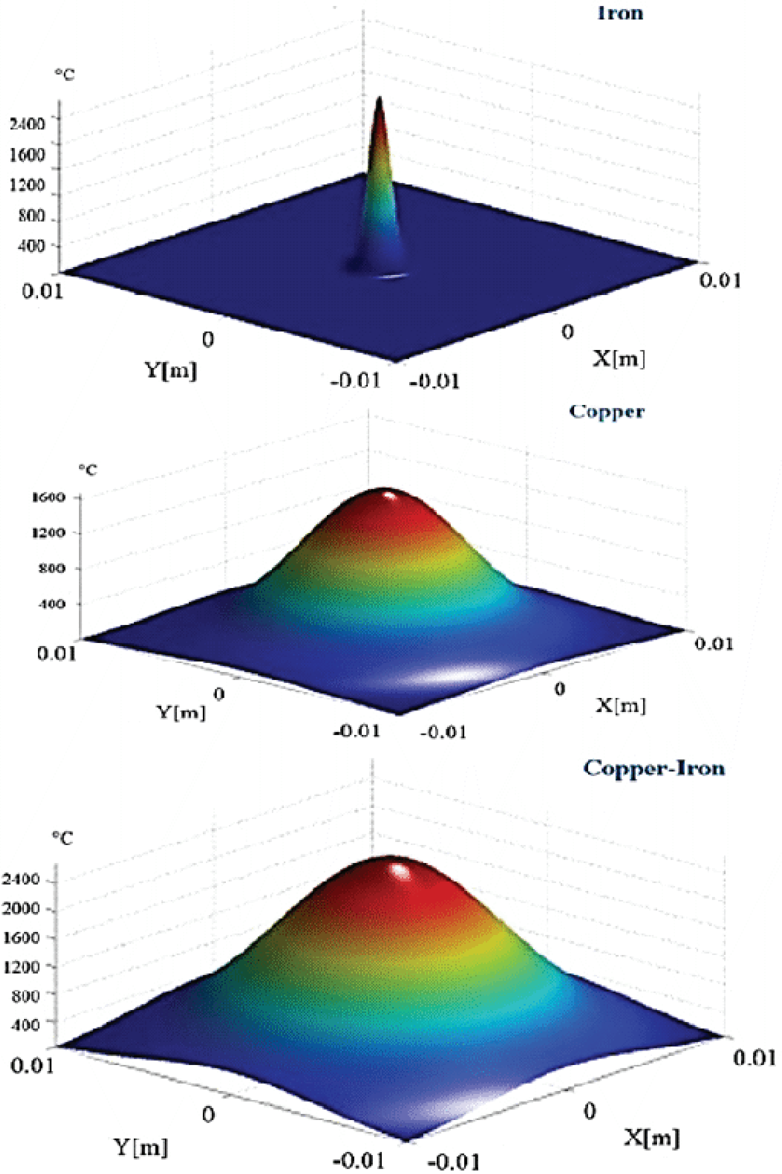

Figure 5. Thermal behavior of heat affected zone in, iron, copper and copper-iron system.

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'.

4. Conclusion

The Qur'an is the book of guidance that leads people to prosperity. Although it is not a scientific book, but it has raised various scientific issues. The people at the time of revelation of the holy Qur'an did not have any scientific knowledge of some issues mentioned in it. It was after the passage of centuries that such issues were proved by scientific advances.

Dhu al-Qarnayn's dam can be considered as a miraculous aspect of the holy Qur'an. As it may be understood from the verses, the instruction and the precise expected properties for the mentioned structure reveals the non-accidental process familiarity with which would require advances 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 and its phenomenal thermal and mechanical properties were unknown at that time. Consequently, carrying out such endeavor would require extensive knowledge in modern sciences like chemistry, physics and metallurgy.

As mentioned above, the construction method in verses confirms that he made a multi-structural three-layer dam. Such structure is durable and stable against most chemically destructive agents. Also, it has the optimum mechanical and thermal properties. Therefore, 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 serves as evidence for more structural power.

These original scientific issues indicate that the Holy Qur'an could not have originated from the knowledge of that time, but it must be based on superhuman wisdom. The verses of the Qur'an also indicate that the origin of the story is divine revelation, something of which people had not been aware. The peoples seeking help from Dhu al-Qarnayn, as confirmed in historical records, had not been in possession of such advanced technology.

However, the reports of the Qur'an were later proved by science and as it is the case in the story of Dhu al-Qarnayn, the holy Qur'an can be used in the development of science. The verses clearly show the manner of construction of the dam as well as the precise prediction of its properties. Therefore, for development the modern science, reflecting on the verses may lead us to have a better understanding of advancement in science. Consequently, the miracle of the Qur'an is not merely in the report, but it lies as well in anticipations.

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