Materials beyond Steel for a New Future from the New Normal

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Materials beyond Steel for a New Future from the New Normal

The advances in human civilization are based on the use of materials. Take it from the Stone Age to the Modern Era of the silicon age, materials have played a vital role in our lives. However, let us look back to the history of material usage. The one material still encompassing all spheres of our surroundings is an alloy of iron (Fe) and carbon (C), called steel. It is ubiquitous, look around, from a petty pin to cutlery, from a static structural member in construction to fast running trains, from ancient 'wootz steel' to modern-day armors, everything is made of steel. What makes steel so special? The extent of C alloying (< 2 wt.%) with Fe, yields different phases and their proportion can be controlled using various thermomechanical processes to achieve the desired set of properties like strength-ductility, toughness-hardness, conductivity-thermal expansion, etc. Today, we have well-established steel-making techniques, from extraction to casting, welding to forming, and even recycling. Moreover, the availability and the cost of producing steel make it indispensable to our lives. Off let our lives have been significantly impacted by the Covid19 pandemic. A new normal has been set in every aspects of our lives. Will this new normal affect the use of steel in our lives? Can we replace steels? Can we go beyond steel?

To answer the above questions, we need to find new materials with major properties or even better properties than steel; if we cannot, then we need to improve steels' properties. Today, let us look at materials that have already been employed in a few applications where steel was used, e.g., fiber-reinforced polymers in automotive sectors, graphene in bulletproof shields, metallic foams in submarines, and filters, superalloys as turbines blades, etc. These examples demonstrate that we need materials that replace steels from mundane to strategic applications. Reflecting on a new normal, we need to rely on and develop materials indigenously. India has major resources of bauxite (Al ore), magnesite (Mg ore), chromite (Fe-Cr ore), copper-ores, manganese ores, graphite, zinc, tungsten, gypsum, mica, fluorspar, gold, and diamond. Thus, our strategy must focus on developing materials/alloys from these resources to be self-adequate.

To replace steels that are used for applications from room-temperature to 500 °C, our attention must focus on the development of high-strength Al- and Mg- alloys. We have an abundance of bauxite ore. Thus, the extraction of Al and development of Al-alloys must be one of our priorities. Many Al-alloys have a high strength to weight ratio with yield strength reaching 500 MPa. Till now, 1xxxx to 8xxx alloys have been used, but in the upcoming future 9xxx alloy development must be considered. Recently, the metallic foam of Al starts using in the world arms, tanks. We know that Al- alloys have high oxidation resistance. Thus Al- foams or sandwiched structures can replace steels majorly in automobile industries and specific applications where dampening and strength are required.[1] Coming to Mg-alloys, they form the lightest structural materials. Due to their high specific strength, machinability, they find wide structural applications like automotive, aerospace, industrial, and commercial applications. Mg alloyed with rare earth elements demonstrate excellent mechanical properties.

We have a scarcity of these rare earth elements. Developing "rare earth free" Mg alloys must be encouraged. Plausibly, if these lightweight alloys successfully replace steel, they will bring down the carbon footprint.[2]

Now for applications pertaining to 500 – 900 °C, Cu- and Ni- alloys can be considered. We have a good amount of copper ores. According to Indian Mineral Yearbook 2015, we have 189 million tonnes of Ni ores. The Cu-alloys find their usage in advanced propulsion tanks, while Ni-alloys are extensively used for military or strategic applications. Thus, reducing the cost of extraction and eco-recycling of these non-ferrous alloys will mark steel's replacement [3].

Let us give thoughts on some unconventional materials. For human civilization, carbon and carbon-based material play a very important role in our daily life. In fact, without carbon materials, our life is impossible on the earth. From recent studies, graphene is considered one of the wonderful achievements in science and technology. It obtain in different forms like graphene nanoribbons, nanosheets, nanoplates, and 3D graphene[4]. Using graphene, we can make a single layer and multilayer carbon nanotube (CNT). CNT has excellent electrical, thermal, mechanical, and biomedical properties. Carbon is brittle, but CNT is ductile with an elastic limit of 18%. It has good tensile strength. CNTs are approximately 200 times stronger and six times lighter than steel. These useful properties of CNTs and other variants of graphene are exploited to make composites with metals, ceramics, and polymers.[5] Recently, carbon dioxide is successfully converted to graphene. If this technique is commercialized, it will reduce global warming, which is a much-needed step.[6]

A new material Fiber-reinforced polymer is a composite polymer that starts using in the engineering structure such as aerospace to spacecraft, boats to submarines, offshore platforms and automobiles, civil infrastructures such as buildings and bridges. The recent development of the new advanced form of the fiber-reinforced polymer attracts our attention because of its high strength, light in weight, long-lasting, high performance, withstanding corrosive ocean environment, etc.[7]. Some major automobile industries like Tata Motors are already using it in vehicle components. To some extent, it is surely replacing steel in the automobiles sectors.

In my opinion, steel cannot be replaced fully for the next century. Thus, we need to make steel better. Incorporating effective structural or design changes can reduce steel usage. The recent alloy design ideas as in complex-concentrated alloys and microstructure tailoring can enhance present-day steel properties. Newer technologies such as additive manufacturing can be beneficial to design components with the desired set of properties. Also, we need to reinvent our older wisdom where we created rust-less wonder ‘the Iron Pillar’ and marvelous ‘Damascus sword’.[8] Finally, we need to move towards sustainable metallurgy of steel to sustain for years to come after the new normal.

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