Can mankind survive without stainless steels?

Stainless steels have a large impact upon our lives but are they really indispensable? During the history of mankind stainless steels have only been available for approximately one hundred years, a period that is vanishingly small compared with the time man has existed on earth. Before we answer the rhetoric question in the title it is helpful to reflect upon the historical aspects of stainless steel development.

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Compared with many other metals and materials, stainless steels represent a relatively new class of materials. While the history of steelmaking as a whole spans about 3500 years, that of stainless steels only goes back about a century. Despite their short history, stainless steels have played a central role in our society since their introduction just before the First World War. In fact, it can be argued that they had a significant influence on the outcome of the war itself because of their use in the production of artificial gunpowder. Important attempts were already made during the 19th century to improve corrosion resistance in steel but the commercial breakthrough did not come until immediately before the First World War. Most people agree that Harry Brearley from Sheffield in the UK and Benno Strauß and Eduard Maurer from Krupp’s laboratory in Essen in Germany should be regarded as the inventors of stainless steels. It appears that they made their discoveries independently. Krupp’s first two patents were submitted at the end of 1912 and Brearley’s American patent was issued in 1916. The discovery of ‘stainlessness’ can be regarded as a perfect example of serendipity - at least in the case of Brearley, whose original intention was to find an alloyed steel of improved strength suitable for gun barrels. During his experiments he found that some of the experimental alloys resisted corrosion and, therefore, focussed his interest on this unforeseen property. He soon realised that stainless steels (the term coined by him) were ideal for cutlery. He took the initiative by persuading the production manager of the Sheffield cutler R.F. Mosley & Co. to start production. It became an immediate success and demand increased rapidly. One of the first applications of Krupp’s steels was in BASF’s chemical plants in Ludwigshafen, Germany. This turned out to be the onset of an industry that has revolutionised our civilization. By a happy coincidence, the newly developed austenitic stainless steel was found to be suitable for valves in the most corrosive part of the process, now termed the urea process. The urea industry, therefore, had a quick start. Its importance for feeding the increasing world population can hardly be overestimated. Furthermore, this was of benefit for the steel industry worldwide since the success of the process helped to pave the way for stainless steels.

The use of stainless steels today
Stainless steels are ubiquitous in society today. Early stainless steels were quite expensive and, therefore, only accessible to a minority of people who could afford them. However, new process metallurgical techniques emerged during the 1960’s. These techniques involve AOD (argon oxygen decarburization), VOD (vacuum oxygen decarburization) and CLU (a process developed in a collaboration between Creusot Loire and Uddeholm). The high carbon content, which had plagued the stainless steels in the first decades and sometimes had given them a bad reputation because of intergranular corrosion, could now be reduced at a much lower cost. As a result, high quality stainless steels became accessible to a large majority of people all over the world and led to a six-fold increase in stainless steel production from the early 1970’s up to the present. A dramatic improvement in the quality of life ensued.

Stainless steels for life
There are numerous examples of the use of stainless steels in our society and a complete list of applications is too extensive in this kind of presentation. We find applications in our homes (silver ware, cutlery, kitchen sinks, domestic appliances, refrigerators, razor blades), in cars (various types of springs such as seat belt retractors, catalytic converters, valves, spacer expanders etc.), in food handling (conveyor belts, dairy applications, storage tanks etc.) and in medical instruments (syringes, scalpels, dental reamers, surgical needles, implants etc.). The resistance to corrosion is of course an essential requirement but additional requirements are often imposed such as strength, formability, hardness and cleanliness. For instance, in addition to “stainlessness”, a kitchen knife also needs to be sharp and hard, a spring has to be mechanically strong to store sufficient elastic energy and a syringe used for injecting a medical substance in the human body must be compliant. Needless to say, surgical needles need to be tough enough to resist brittle fracture during e. g. an eye operation!

The above-mentioned examples are applications that enhance the quality of life but are they indeed necessary for our survival? Our ancestors lived for most of human history without access to stainless steels but we must remember that the world population before the advent of the stainless steels was below 1.5 billion people. A major concern today is how to produce sufficient food for our growing world population, which has now exceeded 7.3 billion people. Moreover, global warming, as a result of fossil fuel combustion and concomitant carbon dioxide emission, is already having a harmful effect on our climate and health and is a major threat to our civilization. How do we approach these problems? It so happens that stainless steels play a crucial role in our efforts to tackle these problems.

The role of stainless steels in fuel cells
A substantial percentage of carbon dioxide emission comes from

Figure 1. A fuel cell car for testing purposes put at disposal by Hyundai. The test driver is the author of this article.
automobiles driven by conventional combustion engines (60% in the US). Fuel cell vehicles (see Figure 1) offer a means of reducing the carbon dioxide emission since they emit only water and heat with no tail-pipe pollutants. Electricity is generated in a fuel cell in which hydrogen gas is allowed to react with the anode whereby hydrogen is dissociated into protons and electrons. While the protons pass through an electrolyte the electrons are allowed to pass through an outer circuit thus providing an electric current. The electrons and protons recombine at the cathode and form water vapour together with oxygen from the surrounding air. To generate sufficient electric current several cells are connected in series. Typically 400 such cells are used in the stack of a fuel cell vehicle. A fuel cell car is regarded as a zero emission vehicle. Whether such a car is “green” or not is entirely dependent upon the means by which the hydrogen is produced, i.e. to what extent the electricity used to produce hydrogen from water by electrolysis is “green”. In other words, the environmental responsibility is left to the producer of hydrogen gas. Provided that the problems associated with hydrogen production can be solved satisfactorily, the fuel cells show very promising results as an environmentally friendly way of producing electric power. An interesting fact about fuel cells in this context is that stainless steels play a very important role in the form of thin steel sheets separating each cell in the stack. Alternative materials exist, such as graphite, but stainless steel is to be preferred in large scale production according to Sandvik, which is actively participating in the development of fuel cells. In total 100 m² of surface coated stainless steel (preferentially 316 type austenitic stainless steel) of 0.1 mm thickness is required. Type 316 stainless steels is considered to be suitable for this particular application since it is resistant to corrosion under these conditions, chromium and iron ions contaminating the cell being the main concern. The potential volumes of stainless steel are enormous!

Figure 2. Modern agriculture – and the growing human population – is heavily dependent upon the efficient production of urea fertilizer, an important application of stainless steels and particularly duplexes.
makes use of DP28W (developed together with Sumitomo). Stamicarbon uses the duplex grade Safurex, which was tailor-made for this process in a collaboration with Sandvik. The high resistance to corrosion of these alloys makes it possible to reduce the addition of oxygen, which reduces the risk of forming explosive compounds. In addition, costly standstills are minimised. Briefly speaking, special stainless steels are essential in the production of urea and, consequently, the production of food. Considering the fact that urea increases the yield by a factor of 3-4 implies that the global food production without urea would not be enough to sustain the present world population. A likely scenario is that lack of artificial fertilizers, caused by for instance energy shortage, would lead to a worldwide famine.

Concluding remarks
During most of human history there has been no access to stainless steels. In evolutionary terms they were launched yesterday. Despite this, we have quickly appreciated their advantages and developed a society in which we have become dependent on them. We no longer accept a rusting razor blade. We no longer accept a stained kitchen sink or casserole. We no longer accept a tarnished conveyor belt used to produce medical pills or biscuits. We no longer accept corrosion taking place in syringes, pace maker wires or medical implants. All are examples of applications where stainless steels contribute to cleanliness, improved hygiene and a better quality of life. Although it is an impossible task to estimate how many lives are saved it is evident that the impact on the health of the world population is considerable. We just have to imagine the vast number of syringes used annually (a conservative estimate is 3 billion) to realise that cleanliness in medical care prevents transmission of infections and saves lives (see Figure 3).

Regarding the use of stainless steel in the urea process the situation is more critical as it is related to the most essential of human problems, namely how to produce food and avoid starvation. High efficiency of the process in combination with safety requires high pressure and high temperature in the stripper, which is the most critical part of the urea plant. Super duplex stainless steel is unrivalled in this application. There are other means of producing urea than the prevailing one, but they are all less efficient. Stainless steels have reduced poverty and contributed significantly to the growth of the world population from about 2 billion (a population of 2 billion people was reached in 1927) to more than 7 billion during the last century. They have become accessible to a large majority of people and contributed to a much higher quality of life than would otherwise have been possible. Moreover, this is accomplished with a material, which shows promising performance in fuel cells, is aesthetically appealing, is suitable for decoration and art, and is 100% recyclable. Stainless steels have revolutionised our daily life and are without doubt essential in our society. Are stainless steels really necessary for the survival of mankind? Would we be totally wiped out in the absence of stainless steels? No, but among several consequences there will be a substantially smaller world population than today. Allow me to raise a final question: Would we be willing to accept the consequences?

Figure 3. Stainless steels are essential for their contribution to cleanliness, improved hygiene and a better quality of life in the pharmaceutical industry.

About the author
After receiving a PhD in Physics from University of Gothenburg in 1979, Jan-Olof Nilsson has spent 35 years at the R&D Centre of Sandvik Materials Technology in Sandviken. During this time he has also held a position as an adjunct professor of Physics for 9 years at Chalmers University of Technology in Gothenburg. He has published some 150 scientific papers within Physical Metallurgy in reviewed journals. Since the beginning of May 2014 he runs his own consultancy in Materials Technology (JON Materials Consulting) with the emphasis on Stainless Steels. He can be reached by email under the address: janolof.jedviknilsson@gmail.com