

Analysis of non-sparking metallic materials for potentially explosive atmospheres

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Abstract. In few specific applications the explosive potential of environment in case of sparks presence is very high, like petroleum or natural gaseous media or even grain mills, and usage of non-sparking materials is extremely important. The damage produce by an explosion can be more expensive, 1000 times, than the cost of the metallic elements that can produce sparks. In case of working gears, that can produce sparks in time, is recommended the use of special metallic materials. The most used material for gears is steel and in this case can be replaced with a bronze with aluminum and beryllium to reduce the possibility of sparks production. In this article the obtaining of an aluminum bronze with beryllium is analyzed and is considered the possibility to use it as alloy for gears proposed for explosive environments.

1 Introduction

The necessity to reduce the frequency of explosion and instantaneous fires, at working place, is explained through humanitarions and economic considerations. The humanitarian considerations are obvious: explosions and fires can cause extremely serious injuries and deaths. Economic considerations emerge from studies on the real costs of accidents, which show that improved risk management (for health and safety) can significantly increase corporate profits [1, 2].

Avoiding a possible explosion became very significant for worker's protection because any detonations can jeopardize the life and sanity of employees due to the difficult to be controlled effects of flames and pressure, the presence of dangerous reaction compounds and the consuming of O₂ in the environment air breathed by workers. An explosion occurs when a fuel mixed with air (ie a sufficient amount of oxygen) reaches the explosive limits in the presence of an ignition source [3].

In the event of an explosion, workers are exposed to risks resulting from uncontrolled ignition and pressure phenomena, such as thermal radiation, flames, shock waves, the projection of debris as well as the presence of harmful reaction products and oxygen depletion. indispensable for breathing.

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This article presents the main solutions for non-sparking materials and the possibility of obtaining gears from these materials for various applications in potentially explosive environments. Many materials are presented as a solution for possible explosive environment use and in case of gears manufacturing is important to follow more factors: mechanical resistance, corrosion resistance, capacity not to produce hot sparks and final price. In our case we manage to identify a possible best solution for non-sparking metallic materials which should be tested for industrial applications.

2 Non-sparking materials

Electric and mechanic sparks represent the main source of ignition in different situations in machinery and production warehouses. To shrink the formation of sparks, the systems usually are made of non-sparking materials metallic or not metallic if the applications requires. A characteristic for all non-Fe alloys applied in environments with explosive potential present a high thermal conductivity.

Cu-Al materials, Stainless materials, Ag-base materials, Al and galvanized steel are few opportunities of materials that did not make sparks or they have cold sparks. Beside less chances to produce sparks these alloys are also more corrosion resistant permitting a longer activity in different gaseous or liquid environments. Because of their smaller strength compare to steels periodically inspections of the non-sparking elements must be realized to determine from the begging the damage degree of the material. Nowadays these inspections can be easily realized using supervision cameras with proper recognition software.

For different applications were no specific strength is required non-metallic materials are usually applied in systems that work in possible explosion environments. These materials are based on plastics, wood, thermos-plastic polymers, leather, etc.

Although the characteristics and properties to whom it is due the formation and growth of sparks are not really known there are few metallic materials supposed to be non-sparking materials. These materials are based on binary systems Cu-Zn, Cu-Sn, Cu-Ni, Cu-Al, Cu-Be and Ti-based alloys also ternary systems of their combinations. This materials present lower mechanical characteristics that Fe-C materials but can replace them in many applications. Off course that strength of this materials is at smaller values but with proper geometrical design and deformation processes can successfully replace steels or cast irons. Al-based materials also fall under this standard, but to date no confirmatory evidence is available that aluminum is a non-sparking material [2]. To assure that a material is so named non-sparking is not enough to use a soft alloy. If is considered that spark appearance procedure is connected to removal of parts of the materials during mechanical contact than ductility of the material must be considered more than his mechanical elongation strength. Aluminum remains again a qualified candidate for inclusion on the list of non-sparking materials.

Nickel metal and in the form of Monel, during the spark test, generate a wavy orange stripe of sparks with low volume and claim that they could become a non-sparking material but these characteristics are not fully justified. In a process of creating the spark, the ignition of gas, aeronautic gas supply, paraffin and pre-heated oil was analyzed due to a spark ignition by the firing of different materials over the "stone". The materials applied were Al, Ti Mg, Cr-Mo steel and stainless steel. All materials, bating Al, can spark an explosive environment. The experimental tests were proposed to spark a 7% CH₄-air combination to analyze the heat and top of the area of the initial material necessary for sparking. The area of 3x2 mm x mm is necessary to spark a gaseous combination at a T of 1300 Celsius degree (°C), in the same time the requested area is reduced to 2x1.5 mm square at a temperature of 1550 °C. Lowering the source temperature below 1100 ° C requires an area of 2x10 mm² or more [4, 5].

For brass and bronzes (Cu-base alloys) case their non-sparking inclinations are taken in consideration, a different important characteristic is an impressive thermal conductivity (Cu, 401 W/mK), and Ti (14.98 W/mK) did not fulfill this property and Al (199.8 W/mK) is a good candidate by this point of view. Cu and Cu-based alloys have a good chemical composition and structure distribution and most of the times single-phase materials. Usually these materials are not transforming through heat treatments and the main properties can be modified through cold or hot plastic deformation. Anyway using Be (beryllium) as accompanying elements between 0.6 to 3%, Cu-alloys present a hardening of the materials by formation of precipitates. Even that Be alloying is usually till a 3% higher limit in materials the working through different methods of them can insert contamination elements in the atmosphere. The OSHA - Occupational Health and Safety Administration has set a limit of 1.95 g/m³ of Be in the atmosphere of the warehouse work for an activity time of 7-10h, because Be is appreciate as dangerous for peoples [6-8].

Cu-alloys with high percentages of Be can provoke metallic fume disease and the contact for a long time with this kind of environments can give headaches and dizziness. Analyzing different metallic materials Cu-Zn alloys seems like not dangerous materials, even the characterization of spark ability was not clearly highlighted.

3 Explosive hazardous environments

The need to reduce the frequency of explosions and instant fires in the workplace is explained by both humanitarian and economic considerations. Humanitarian considerations are obvious: explosions and fires can cause extremely serious injuries and deaths. Economic considerations emerge from studies on the real costs of accidents, which show that improved risk management (for health and safety) can significantly increase corporate profits. Explosion protection is of particular importance for safety as explosions endanger the life and health of workers due to the uncontrolled effects of flames and pressure, the presence of harmful reaction products and the consumption of oxygen in the ambient air breathed by workers. An explosion occurs when a fuel mixed with air (ie a sufficient amount of oxygen) reaches the explosive limits in the presence of an ignition source.

The following, table 1, are several examples of potentially explosive situations in various industrial environments [9].

Table 1 Potential explosive examples from different sectors

	Sector	Example of explosion risk
	Chemical industry	The chemical industry uses numerous processes for the transformation and processing of gaseous, liquid and solid combustible substances. These processes can generate explosive mixtures.
	Landfills and civil engineering	Landfills can produce flammable gases. In order to prevent them from being emitted in an uncontrolled manner and to ignite, far-reaching technical measures are needed. Flammable gases from various sources can accumulate in tunnels, basements, etc., which are poorly ventilated.

	Energy producers	Possible ignition powders / gaseous combinations that can appear in transport industry, preparation or drying of coal in the form of lumps (these materials are explosive free in combination with atmospheric air).
	H ₂ O purge brands	A source of possible ignition atmosphere is presented by fermentation compounds set free pending waste-water purge
	Gaseous compounds distribution	Explosive gas/air mixtures may form in the event of natural gas leaks.
	Wood processing	Wood processing creates wood dust that can be explosive or form dangerous mixtures
	Painting workshops	Excess spray paint that forms in the paint booths during surface varnishing with the spray gun as well as removed solvent vapors can generate explosive media.

If a hazardous explosive environment may form, explosion protection measures are required. First of all, an attempt must be made to avoid the formation of explosive media.

If the formation of hazardous explosive media can be avoided with certainty, no further action is required.

In many cases it is not possible to avoid explosive atmospheres or ignition sources at a sufficient level of safety. In such cases, measures must be taken to limit the effects of the explosions to an acceptable level.

Explosions can occur during fires. In some cases, the explosions are followed by fires. Sometimes only the explosion occurs.

In order to prevent, according to the provisions of art. 7 para. (3) of Law no. 319/2006 and ensuring protection against explosions, the employer must take technical and / or organizational measures appropriate to the nature of the operation, in order of priority and respecting the following basic principles [10]:

- a) analysis of the possible appearance of ignition to explosive environments; or
- b) if it is not possible to prevent the formation of explosion atmospheres the usage of non-sparking materials became necessary in order to avoid ignition possibility; and
- c) limiting the harmful effects of an explosion in order to ensure the health and safety of workers.

4 Accidents provoked by friction sparks

In many incidents in industry the main problem was the appearance and evolving of sparks through friction. Most of the times a complete analyze of the process of spark appearance was not been made. There are few factors to be considered like the degree of friction of two or more materials in contact, impact intensity and shock value and can become important and influential for the atmosphere where they work. Can be considered that gears, especially those with a high load presents high risks to start and spread sparks in contact

function. An industry with a high risk of explosion is that of natural gaseous production and transportation also of processing the fuels. An example, [6], mention a fire during the manipulation of equipment's for fuel preparation. The sparks were provoking in manual working on a metallic engine by a heavy tool also metallic. In the final report there were no suggestion to use non-sparking tools. The observations were done on the tool rate and main conclusions were concentrated on the equipment rate usage. A better solution can be the usage of a non-spark material with similar mechanical properties.

A different example dated in 1854, a caravan of horses sustain carriages start burning after the ignition of black dust from sparks made by horseshoes at the heavy contact with the road. In 1979, a huge gaseous pipe caught on fire because the friction sparks made during manual cleaning with producing sparks metallic tools. Most of the events shows that an important role in sparks production is the material state (dust, rust etc.) and the contact between different materials that work with different sollicitation. Wear and friction of metallic materials can provoke sparks that will lead to fire or explosion ignition.

5 Cold sparks and best practices to avoid explosions

Contrary to popular belief, the non-sparking process does not completely deny the creation of sparks. In some cases, such equipment may generate "cold sparks." In this case based on a reduced quantity of heat there are not capable to start a fire through CS₂ ignition. These sparks are considered safe for working environments. A spark to be dangerous must have a high temperature and to exist for a certain period of time in order to start the combustion of a flammable compound [11].

Adherence to best practices for explosion-proof equipment against sparks can ensure that their properties for not producing sparks are well maintained. A general conclusion is that such equipment will be placed in a different location than Fe-based materials. Moreover, the elements must be kept away from other substances and definitely not in straight contact to acetylene, because the existence of probability to create very volatile and dangerous materials. In any case very important is the airing process that can avert formation of dangerous compounds from 'clumping' or accumulating around sparking elements [6, 12].

6 Conclusions

The authors analyzed the non-sparking materials and those for gears in order to propose a new application of non-sparking material gear with applications in explosive environments. At the moment Cu-Al alloys, SS, Ag and Al are most used materials in non-sparking applications for environments with explosive potential. Our analyses conduct us in identification of a new possible alloys system to be: Cu –rest Al(8-12%wt) Be(0.5-3%wt)). This materials present proper mechanical properties in order to be applied for gear made and the possibility, which will be further investigated, to work without sparks in explosive environments.

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