HAZARDS FROM FRICTIONAL SPARKS OF CERTAIN LIGHT ALLOYS

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LIGHT metal and their alloys have some attractive features e.g., lightness and strength which have led to their widespread use in various fields. A drawback which certain of these alloys suffer from and which is not generally known, is their propensity to give frictional sparks. This propensity has been the cause of serious explosions in mines[1] and needs to be highlighted in a forum of this nature where metallurgists have gathered to discuss all the aspects concerning light alloys.

The hazard arises only when the sparks are produced in a flammable gas/air mixture such as occurs sometimes in a mine and in other locations where any flammable gas or vapour may be present continuously for any length of time. It is only certain light alloys which give rise to frictional sparks of an incendive nature and it is with these that we are concerned in this brief review.

Many examples may be cited of the application of light alloys in mines but one or two will serve the purpose to illustrate the hazard. Hand-held drill casings weighing up to 40 lb are often made of light alloy and it is not difficult to imagine such a tool slipping from the hands of its operator and falling on to a piece of rusty steel below. Or, a light alloy part of a rotating machine may hit accidentally the rusty casing at high peripheral speeds. Even a glancing manual blow with a hammer on an aluminium-painted rusty steel structure can produce a dangerous spark[2,3,4]. The first instance given represents an example of low-speed impact, and the others high-speed impact. Rubbing friction, at low speeds but under heavy loading conditions, can also engender frictional sparks of a dangerous nature. Articles such as lighting fittings, methanometer and anemometer casings, sylvesters, shovels, jacks, roof bars, props and certain parts in them, beams and channels could be and have been made with advantage from light alloys but any or all of these, under suitable conditions, may prove to be the igniting source from sparks generated by friction from them. It is obvious that spark production may occur under widely different conditions; experiments have accordingly been designed to simulate them in the laboratory. This is important because a light alloy tested in a particular way may not ignite gas but the same alloy, when tested in a different way, may produce sparks which are incendive.

The three chief methods[5] of testing light alloys have been: (1) the Drop test[6] in which sparking by impact is caused when one material strikes another, either in free fall or by hammer blows, (2) the Frictional Smear test in which the softer light alloy leaves a smear on rusty steel or other hard surface and is subsequently struck a sliding or grazing blow and (3) the Rubbing friction test which simulates the conditions obtaining when moving parts of a power-driven machine are fouled by a stationary object or surface. Pure light metals and the softer alloys, generally speaking, appear to produce incendive sparks under the Smear test conditions, while the harder alloys of light metals yield dangerous sparks under the other test conditions. In all the tests, a critical gas mixture known to be ignited readily by frictional sparks surrounds the point of impact or friction, and an explosion results when incendive sparking occurs in it.

It may be thought that it would be possible to say by mere visual examination whether or no certain sparks are dangerous. This is not easy[1]. For instance it is known that the discrete sparks flying through an inflammable atmosphere—particularly of methane and air—are dangerous[7,8,9,10] unless they are arrested and brought to rest. The discrete sparks from light alloys are, however, dangerous (in such atmospheres) even in flight; the material of the spark is undergoing rapid oxidation and a higher temperature is produced[9]. Sparks which are condensed, compact and which appear as a bright flash are believed to be a cloud of the eroded metal burning in air and are usually still more dangerous. It is never safe therefore to rely on the appearance of a spark to assume its incendivity—it is necessary to subject the alloy to all the tests and to any others that may need to be devised to reproduce the conditions in actual use.

In the foregoing observations, rusty iron has often been mentioned in connection with the generation of the incendive frictional sparks, and there is a reason for this. It is now generally[10,11] agreed that a "thermite" type of reaction is involved, and an oxygen-carrier in the form of rust, red lead, ammonium

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nitrate, nitro-cellulose lacquer, etc. plays a part in the process. It would appear that at the moment of impact of a light alloy on a rusty steel surface (or when a light hammer blow is struck on the smear produced by a soft light alloy), an intimate mixture of the light alloy and the rust (oxide) is formed instantaneously and begins to react by the frictional heat. The heat of combustion of this "thermite" mixture is sufficient to ignite any fine particles of the light alloy that may have been eroded on impact and that may be present as a cloud round the point of impact. Alternatively, the heat produced is sufficient to raise any eroded particle to incandescence and send it flying as a continuously self-oxidising discrete spark into the flammable gas. An interesting theory[12] (which incidentally would explain certain observed effects of humidity or moisture) attributes the ignition of firedamp primarily to an ignition of hydrogen which is believed to be produced locally by decomposition of water or moisture associated with the rust or the atmosphere.

A comparison has been made between the energy of a single electric spark required to cause ignition of a gas and that of the minimum energy required in a frictional spark. From experiments to determine the minimum size of a burning particle of magnesium required to cause ignition in a methane-air mixture, it has been established[10] that a particle weighing not more than one half of a micro-gramme and having an energy equal to only ten times that dissipated in a single electric spark is sufficient to cause an ignition. In other words, the energy is only of the order of 10 millijoules or perhaps less! The energies involved in the tests on frictional sparking propensity are, of course, very much larger.

The light metals, aluminium, magnesium, titanium and cerium, are all capable of giving incendive sparks. Of the alloys, those based on magnesium are more dangerous than the aluminium-based ones, the susceptibility to sparking increasing with magnesium content. Thus a 50% probability of ignition at an energy level of 390 ft lb has been established for cast aluminium alloy LM6 which contains no magnesium, about 12% silicon and the balance aluminium, while for the same probability of ignition the energy level is only 89 ft lb for "Elektron" alloy containing between 92 and 93 per cent magnesium[13]. Other things remaining the same, the susceptibility to sparking also appears to be related to the hardness, susceptibility increasing with hardness.

Attempts have been made[11] to produce alloys free from hazard by adding: (1) anti-frictional materials such as polytetrafluoro-ethylene and molybdenum disulfide, (2) metals of lower melting point such as tin and lead and (3) anti-oxidants which would act as inhibitors of the "thermite" type reaction. So far, such attempts have met with little success. Efforts[11] to find coatings which will reduce the sparking hazard have met with somewhat better success. Coatings of polythene, epoxy resin, moulded rubber or neoprene, solder, stove enamel, paint, soft sprays of zinc or lead, etc. have been tried. While the protection resulting varies in degree from coating to coating, one must remember that such protection lasts only as long as the coating is intact.

To summarise, where there is danger of flammable atmospheres the advantage accruing from the use of light alloys has to be weighed against their propensity to generate incendive frictional sparks—which are particularly dangerous with certain light alloys. The metallurgist is thus faced with a challenge if light metals are to find unqualified use in hazardous locations. To meet this challenge, he has probably to find an alloying addition which not merely confers the desired engineering properties but also serves to eliminate the production of incendive sparks.

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DISCUSSIONS

Mr. G. S. Warrier, Alcan Asia Ltd., Calcutta: The question as to what fire hazards arise by the use of light alloys in collieries which give out explosive gases has been raised in the paper. I believe that this problem was investigated in some detail by the National Coal Board in the United Kingdom about 3 or 4 years ago following an explosion when a hand drill having a magnesium alloy casing fell on a rusty steel roof support. The results of the investigation showed, I believe, that the explosion was mainly due to certain aluminium/magnesium alloys, and that may also be in a measure due to the rusty steel and the reaction between aluminium/magnesium alloy and the steel.

The author has also referred to the common casting alloy of aluminium/silicon, LM6, and has mentioned that these alloys may also give rise to frictional hazards. I do not think that the investigation found the alloy to be dangerous. Many mines in the U.K. use aluminium roof supports and other aluminium applications and the advantage is that aluminium does not rust. Hence the answer to avoid hazards of sparking may equally lie in the more extensive use of aluminium and less steel. I may add that aluminium alloys are being used to a much greater extent in Germany than in the U.K. in coal mines, including those having explosive gases but no ban on the use of aluminium/magnesium alloys has been imposed in Germany. Hence the question as to what extent the possibility of sparking exists cannot be said to have been really determined. Many metals and alloys can give rise to sparking under certain conditions of which, I believe, moisture may be one contributing factor. I wonder whether all aspects of sparking hazards have been thoroughly investigated.

Dr. G. N. Badami (Author) : Mr. Warrier has opined that the explosions may be "in a measure" due to rusty steel. We have already made it clear in our review that the hazard arises out of a thermite type of reaction and that rusty steel or any suitable oxygen-carrier is essential. Regarding his contention that LM6 alloy has not been found to be dangerous, we must beg to differ. The latest evidence available indicates that all alloys based on aluminium and having more than half their atoms aluminium must be considered hazardous. Only those alloys which contain less than one-third atomic proportion of aluminium may be looked upon as having their incendivity reduced but at such low aluminium content, the alloy has already lost the main property for which it is being chosen viz. lightness.

Mr. Warrier is right in claiming that light alloys continue to be used in Germany. The question here is related to the level of hazard acceptable in any particular industry in any particular country and the National bodies can and do sometimes differ in their evaluation of a hazard and practice based on the evaluation. It is, however, true to say that frictional sparking hazard of light alloys is being gradually realised and there is increasing awareness of the problem and of the need to solve it.

The role of moisture has been briefly touched upon but it is perhaps right to say that moisture is not always essential.

Regarding Mr. Warrier's suggestion to use less steel and more aluminium, we would only like to say that it is not a practical suggestion. We do not think it will ever be possible to replace steel with light alloys entirely for the properties of hardness and ductility (which are so desirable from the mechanical engineering point of view) are the very properties which together increase incendivity at any particular aluminium content level. It may also be added that research into development of light-weight steel sections for roof support bars, etc. is proceeding apace in the United Kingdom. The object is to replace light alloys which have been withdrawn from use following the many accidents attributed to them.