Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2 (1): 25-29

jeteas.scholarlinkresearch.org

Development of Safety Fuse Plugs for Use in the Oil Industry

[2]Odior, A. O; [1]Oyawale, F. A and [3]Adeyemi, A.J

[1]Department of Industrial and Production Engineering, University of Ibadan, Nigeria.
[2]Department of Production Engineering, University of Benin, Nigeria.
[3]Department of Mechanical Engineering, Federal Polytechnic, Birnin Kebbi, Nigeria
Corresponding Author: Odior, A. O

Abstract
The safety plugs presently used on our equipment in the Nigerian industries are wholly imported. This research is aimed therefore at developing safety fuse plugs, using locally available materials that will compare favourably with the imported safety fuse plugs. Minerals from various mining sites in the country and laboratory samples were collected. Beneficiation processes were carried out on the samples using foundry equipments which included electric furnace, tongs, and crucibles. Impure and beneficiated samples were mixed at various eutectic compositions to determine the effective mix that would meet specific temperature blowouts. A comparative test was carried out on imported and the developed samples. It was observed that there was no significant difference in the performances using the χ^2 test at $p = 0.05$. It was also discovered that the presence of impurities also affected the composition of the alloy as reflected by the ANOVA conducted on the different samples produced.

Keywords: safety plugs, minerals, crucible, beneficiation processes, significant difference

INTRODUCTION

Fusible plugs are some of the safety devices used in some industries, particularly in the petroleum industry. They contain low melting alloy that melts at predetermined safe temperature, thereby preventing the build-up of excessive pressure in heated pressure vessels. These alloys have lower melting point than the individual components. The melting point is based on the percentage composition and is lowest at the eutectic point. The eutectic point is the temperature at which two alloyed metals are completely soluble in each other when in the liquid state but insoluble in each other when solid. Their very simple nature allows some confidence in their reliability and though there is no calibration or check available, the pneumatic part of the system does fail-safe. Safety devices are very vital to operations carried out in the petroleum industry. Though safety is the first consideration during any industrial operation, safety consideration in the petroleum industry is peculiar in the sense that while safety devices not only prevent accidents from occurring by acting as monitoring devices, they also initiate an action as a response to the event.

Safety in industry is the state of being certain that adverse effects will not be caused by some agent such as high pressure under defined conditions. Safety could be defined as relative freedom from danger, risk, or threat of harm, injury, or loss to personnel and/or property, whether caused deliberately or by accident. It is a state of being safe and the quality of averting injury, danger or loss. According to Hopkins (2010), risk management in necessary for safety and risk-management and rule-compliance are inter-related strategies for promoting safety in hazardous industries. They are co-existing and complementary, not contradictory. However risk-management offers very little guidance to end point decision-makers; they need rules to guide their decisions. Accordingly, it is important, even within a risk-management framework that risk-management be translated into rule-compliance for end point decision-makers, where possible, (Hopkins, 2010), Risk can be both negative and positive, but it tends to be the negative side that people focus on. This is because some things can be dangerous, such as putting their own or someone else's life at risk. Risks concern people as they think that they will have a negative effect on their future and it is defined as, (Apicella, 1998): Risk = (probability of an accident occurring) X (expected loss in case of accident). Keren, et al (2009), examined the relationship between level of safety climate and orientation toward safety in the decision making process and choice. They tried to answer the question of whether level of safety climate can predict safety-oriented decision making. In their study, they discovered that level of safety climate is not a significant predictor of the decision process; however, it was found to be a significant predictor of the selection of safer choices.
Accidents most often occur as a result of unsafe conditions of work (Adebiyi et al, 2007). These undesirable events may lead to human injury, damage to property, and loss of production hours, disease, permanent disability or death, (Duignan, 2003 and Burns, 2006). The consequences of accidents, in

some cases, are not borne only by those directly involved but extended to relatives, friends, employers and government, (Adebiyi et al, 2005).. Despite all established standards and legislations on safety, with sophisticated devices developed and researches carried, a perfectly safe condition for human and property is still an illusion, out (Adebiyi et al, 2005). The desire for safety is on the increase in the manufacturing industry. Apart from the cost due to downtime, loss of wages and equipment, hospitalisation, the tragedy associated with personal injury, disability and fatality is enormous. As far as fatalities are concerned, industrial accidents take the third place after vehicle and homicide, (Duignan, 2003).

Most implemented injury prevention measures required gymnasium and pool staff or users to change their behaviours. Awareness of safety standards is very necessary to all concerned. Identified factors influencing safety in were classified into three types: internal (e.g. training, culture); external (e.g. weather, demographic change); and governance (e.g. insurance, industry standards). (Finch, et. al., 2009). Some of the main actions of safety plugs include the release of extinguishant, isolation and venting of the particular equipment, cutting off power supply to stop the process flow or depressurising the equipment in order to eliminate fuel so as to stop further ignition. Safety fuse plugs find wide applications in developing countries like Nigeria because of the simple technology involved in their operation. Despite the importance, the abundance of mineral ores used for their production and wide usage of the safety fuse plugs in Nigeria, they are not produced locally. Production of these safety fuse plugs from locally available substitutes will eliminate importation thus creating job opportunities in the country while strengthening the economy. This work is aimed at identifying locally available minerals that may be used for the local manufacture of safety plugs for our consumption.

MATERIALS AND METHODS

The safety plugs were manufactured using locally sourced materials which include: bismuth ore, lead and tin. These materials were obtained from the northern part of Nigeria. The equipment used include: electric furnace, digital scale, tong, thermometer, glass crucibles, stirrer, test tubes and green sand. Three samples were locally developed for each of the two plugs and they are: Impure sample, pure sample and degassed sample. The impure sample consists of unbeneficiated material mix, the pure sample consists of beneficiated material mix while the degassed consists of pure samples with zinc chloride from dry cell battery added to eliminate gaseous impurities from the alloy. See Figure 1 for the safety plug manufactured. The produced samples of the safety plug were used in the instrumentation laboratory of an oil company in other to investigate their melting temperatures. The duration in the furnace (soaking period) was also altered to check their behaviour. The results from our investigation are presented in the Tables.

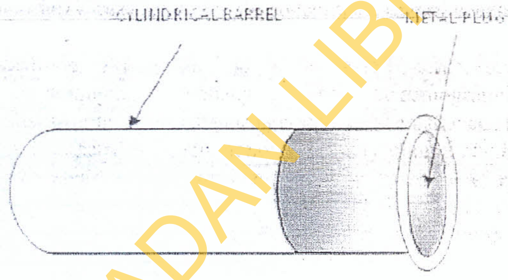

Fig.1: Safety Fuse Plug

Plug Number One (Bismuth and Tin (138^{0}C))

Plug number one was made from locally sourced material: bismuth ore and tin. Experimental investigations were conducted using the locally produced plug and Tables 1- 3 show results obtained using the following codes:

Y ----- Sample completely melted
PY---- Sample partially melted
PPY---Sample did not flow but drop of melt noticed on it
NS-----Sample did not melt but slid in the crucible
N-------Sample did not melt
N-------Sample did not melt nor slid

Table 1: Plug Number One was Left in the Furnace for 5 minutes

Temperature	138 - 140	158 - 160	178 - 180	198 - 200	218 - 220	228 - 230	238 - 240	248 - 250	268 - 270
Standard	N	N	N	N	PPY	PY	PY	Y	Y
Pure	N	N	N	N	PPY	PY	PY	Y	Y
Impure	N	N	N	N	N	PPY	PPY	Y	Y
Degassed	N	N	N	N	N	N	N	PY	Y

Table 2: Plug Number One was Left in the Furnace for 10 minutes

Temperature	138-140	162-164	166-167	170-172	180-182	212-215
Standard	N	N	PPY	PY	Y	Y
Pure	N	N	PPY	PY	Y	Y
Impure	N	N	N	N	N	Y
Degassed	N	N	N	N	NS	Y

Table 3: Plug Number One was Left in the Furnace for 20 minutes

Temperature	138-140	158-160	163-165	166-167	170-172	178-180
Standard	N	N	N	PY	Y	Y
Pure	N	N	N	PY	Y	Y
Impure	N	N	N	N	PPY	Y
Degassed	N	N	N	N	PPY	Y

Plug Number Two – Bismuth and Lead (124^{0}C)
Plug number one was made from locally sourced material: bismuth ore and tin. Experimental investigations were conducted using the locally produced plug and Tables 4-6 show results obtained using the following codes:

Y ----- Sample completely melted
PY---- Sample partially melted
PPY---Sample did not flow but drop of melt noticed on it
NS-----Sample did not melt but slid in the crucible
N-------Sample did not melt
N-------Sample did not melt nor slid

Table 4: Plug Number Two was Left in the Furnace for 5 minutes

Temperature	123 - 125	128 - 130	166 - 168	178 - 180	188 - 199	205 - 208	209 - 211	218 - 220	226 - 228	233 - 235
Standard	N	N	NS	PPY	PY	Y	Y	Y	Y	Y
Pure	N	N	N	PPY	PY	Y	Y	Y	Y	Y
Impure	N	N	N	NS	PPY	Y	Y	Y	Y	Y
Degassed	N	N	N	N	N	N	PY	PY	PY	Y

Table 5: Plug Number Two was Left in the Furnace for 10 minutes

Temperature	123-125	128-130	160-162	166-168	172-174	175-177	182-185
Standard	N	N	NS	PY	Y	Y	Y
Pure	N	N	NS	PY	Y	Y	Y
Impure	N	N	N	PY	PY	Y	Y
Degassed	N	N	N	NS	PPY	PY	Y

Table 6: Plug Number Two was Left in the Furnace for 20 minutes

Temperature	123-125	128-130	150-152	158-160	164-166	173-175	182-185
Standard	N	N	N	Y	Y	Y	Y
Pure	N	N	NS	Y	Y	Y	Y
Impure	N	N	N	N	PY	Y	Y
Degassed	N	N	N	N	NS	Y	Y

PERFORMANCE EVALUATION

The Analysis of Variance was used to study simultaneously the differences among the means of several composites obtained for each of the produced sample plugs with standard ones.

Table 7: Analysis of Variance For Plug One: (Bismuth and Tin)

	Standard	Pure	Impure	Degassed
Complete	6	6	4	4
Partial	4	4	0	1
Dropping	2	2	3	1
No melt	10	9	14	17

Table 8: Analysis of Variance for Plug Two: (Bismuth and Lead)

	Standard	Pure	Impure	Degassed
Complete	12	12	9	5
Partial	2	2	3	4
Dropping	1	1	1	1
No melt	10	9	11	16

It is seen from Tables 7 and 8 that there was no significant difference among the two pure safety plugs and the standard ones. However, there was significant difference among the samples of impure and degassed plugs and the standard ones.

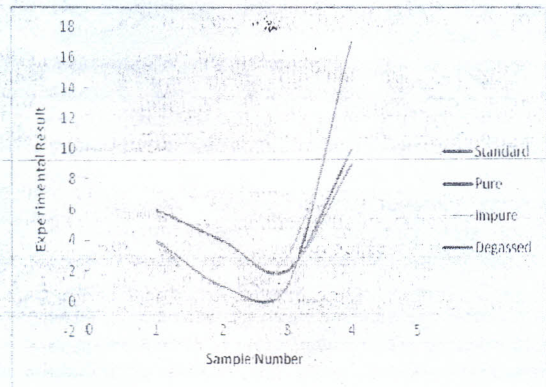

Fig. 1: The Result for Safety Plug Number One

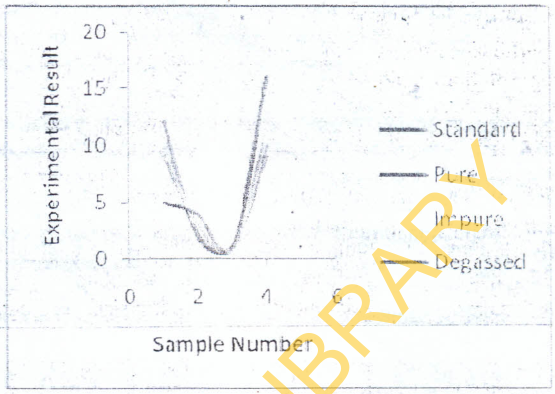

Fig. 2: The Result for Safety Plug Number Two

The results of the reactions during the performance evaluation using a steam apparatus for Plug One are presented in Table 9, while the results for plug Two are presented in Table 10.

Temperature was the input factor while the pressure was the control factor.

Table 9: Temperature and Pressure Relationship for Plug One

Pressure (bar)	Temperature (°C)						
1	70 (stable)	100 (stable)	140 (stable)	180 (stable)	200 (stable)	220 (soften)	240 (eject)
2	70 (stable)	100 (stable)	140 (stable)	180 (stable)	210 (eject)		
3.5	70 (stable)	100 (stable)	140 (stable)	160 (eject)			

Table 10: Temperature and Pressure Relationship for Plug Two

Pressure (bar)	Temperature(°C)				
1	70 (stable)	100 (stable)	140 (stable)	180 (stable)	205 (eject)
2	70 (stable)	100 (stable)	150 (eject)		
2.5	70 (stable)	100 (stable)	130 (eject)		

DISCUSSION

The thermal properties of the developed sample safety plugs were similar, however, the presence of impurities affected the performance of some of the developed plugs. Some impurities were found in the raw materials used in our safety plugs manufacture due to the fact that the materials were obtained locally from the northern part of Nigeria. Some of the common impurities found in the raw materials include silica sand, iron, decayed leaves, sulphur and other impurities resulting from the local processing and beneficiation of the raw materials. The impurities in the plugs increased the melting point of the plugs. As could be observed from the tables, those that were not beneficiated and those that were degassed had higher melting points. This was due to a change in the effective composition of the eutectic alloy. Magnesium and zinc electrolytes used for degassing improved the physical appearance of the plugs but increased their melting point. The analysis of variance carried out showed that the difference was significant. The time spent in the furnace also affected the behaviour of the plugs as they melted at lower temperatures when retained at those temperatures for longer periods. Such temperatures were however close to their melting temperatures. The temperature at which the safety fuse plugs melted reduced with increase in pressure and the time spent before melting also reduced with increase in pressure.

CONCLUSION

Safety fuse plugs were successfully developed and manufactured using locally sourced minerals available in Nigeria. The materials were locally sourced from Northern part of the country and they comprised of beneficiated ores obtained from the field. The developed sample safety plugs were similar in appearance and performance to the standard plugs used in industry. These plugs compared favourably with the standard safety plugs being used in the petroleum industries.

REFERENCES

Adebiyi, K.A, Charles-Owaba, E.O., Waheed, M.A. (2007) "Safety performance evaluation models: a review", Disaster Prevention and Management, Vol. 16 Iss: 2, pp.178 – 187

Adebiyi, K.A.; Jekayinfa, S.O.; Charles-Owaba, E.O. (2005). Appraisal of Safety Practices in Agro-Allied Industries in South-Western Nigeria. Journal of Disaster Prevention and Management: 14(1): 80-88.

Apicella C. L. (1998). Testosterone and financial risk preferences. Evolution and Human Behavior. Vol 29. Issue 6. 384-390

Burns, C. M. (2006). Towards Proactive Monitoring in the Petrochemical Industry.Journal of *Safety Science* 44: 27-36.

Douglas G. N. (1959). Safety practices in Industry. Journal of Chemical Education. 36 (8) 377- 383

Duignan, T. (2003). "Good health and safety is good business", Engineering Technology,. July/August, pp. 12-13. Encarta, Encarta Encyclopedias .

Finch, C. Donaldson, A. Mahoney, M. and Otago, L. (2009). The safety policies and practices of community multi-purpose recreation facilities. Journal of Safety Science. Vol. 47, pp 1346-1250.

Hopkins A. (2010). Risk-Management and Rule-Compliance: Decision-Making in Hazardous Industries. Journal of Safety Science. Vol. 49, No. 2, pp 110-120

Keren, N., Mills, T. R., Freeman, S. A. and Shelley, M. C. (2009), 'Can Level of Safety Climate Predict Level of Orientation toward Safety in a Decision Making Task?', *Safety Science*. :47:1312-1323.

Oligomers, PhD dissertation, National University "Lvivska Polytechnika", Ukraine.

Rodriguez, F., Cohen, C., Ober, C., and Archer, L.A., 2003. Principles of polymer systems (5th ed). New York: Tayor and Francis.

Velten U., Shelden R. A., Caseri W. R., Suter U. W., Li Y.Z, 1999. Polymerization of Styrene with Peroxide Initiator Ionically Bound to High Surface Area Mica, Macromolecules. 32 (11) 3590-3597.

Velten U., Tossati S., Shelden R.A., Caseri W.R., Suter U.W., Hermann R., Müller M, 1999. Graft Polymerization of Styrene on Mica. Formation and Behavior of Molecular Droplets and Thin Films, Langmuir, 15(20) 6940-6945.

Voronov, S. V. Tokarev, K. Oduola and Yu. Lastukhin. 2000. Polyperoxidic Surfactants for Interface Modification and Compatibilization of Polymer Colloidal Systems. 1. Synthesis and Characterization. J. Applied Polym. Sci, 76, 1228-1239

Wager, Charlene M., Haddleton, David M., Bon, Stefan A.F., 2004. A simple method to convert *atom transfer radical polymerization (ATRP)* initiators into reversible addition fragmentation chain-*transfer* (RAFT) mediators. European Polymer Journal, 40, 641.

Waysberger, A. Proskauer E., Riddik J., Tups E., 1958. Organic solvents (Moscow Publishers, Russian translation).

Yu, Qiang; Xu, Sijia; Zhang, Hongwen; Ding, Yonghong; Zhu, Shiping. 2009. Comparison of reaction kinetics and gelation behaviors in atom transfer, reversible addition–fragmentation chain transfer and conventional free radical copolymerization of oligo(ethylene glycol) methyl ether methacrylate, Polymer, 50(15) 3488-3494.