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Submerged Arc Welding Fluxes - A Review

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Abstract: ***Submerged arc welding, because of its inherent benefits such as higher metal deposition rate, good strength of the joint and good surface appearance, is extensively used in the fabrication of pressure vessels, pipe lines and off-shore structures. Welding flux constitutes nearly half of the cost in SAW process. Over the years, development of better welding flux compositions in terms of mechanical properties and productivity, which are economically cost effective too, has caught the eye of many researchers. In the present paper research work carried out by various researchers in the field of welding flux development has been reviewed.***

Keywords: Welding flux, submerged arc welding, recycling of flux, hard facing.

1. Introduction

The submerged arc welding process, in which the weld and arc zone are submerged by a layer of flux, is the most efficient fusion welding process in plate and structural work such as shipbuilding, bridge building, and pressure vessel fabrication, assuming the work pieces can be properly positioned and the equipment accurately guided (Kah *et al., 2012*). Submerged Arc Welding (SAW) is preferred over other methods because of its inherent qualities such as ease of control of process variables, high quality, deep penetration, smooth finish, capability to weld thicker sections and prevention of atmospheric contamination of the weld pool (Hould Croft*, 1989*). In Submerged Arc Welding the arc is concealed by a blanket of granular and fusible flux. The source of heat for SAW is obtained from the arc generated between a bare solid metal (or cored) in the form of a consumable wire or strip electrode and the workpiece. The arc is maintained in a cavity of molten flux or slag that refines the weld metal and protects it from atmospheric contamination. Various submerged arc welding parameters affect the quality of the welding such as welding current, voltage, speed etc.

American Welding Society also defines the flux as "A material used to prevent, dissolve or facilitate removal of oxides and other undesirable substances" (Louise, *1981*). Welding flux in submerged arc welding performs several functions such as Flux removes the impurities from the molten metal. A gaseous envelope developed by the decomposition of the ingredients of the flux covers the molten weld pool, thereby protecting it from atmospheric contact. During cooling, the slag formed on the top of the weld metal acts as a protective cover against contamination by the atmosphere. It provides alloy addition to the weld metal. Helps to start and maintain the arc. Helps to deoxidise and refine the weld metal. Helps to control the weld bead profile and reduce the weld spatter. Helps to control viscosity of the slag so that vertical and overhead welding is made possible. Arc voltage and current intensity, thermal energy and mode of metal transfer are controlled by the flux. (Louise, *1981*).Each chemical constituent element of a flux has been found by other investigators to influence the quality of the weld, even perhaps increasing the strength of the resulting welds (Acheboet *al, 2008*). (Boniszewski, *1979)* recognized that there are several flux/coatings compositions. The composition selected depends on its utility. Achebo et al, *(2009)* observed that various manufacturers have produced different flux compositions depending on the weld strengths they intend to achieve; this being the criterion for developing their own unique flux compositions. Quintana *et al, (2005)* suggested that rapid deployment of engineering materials is hampered because arc welding technology has not been able to keep pace with the development of these new materials. Welding flux design is one of the key areas of arc welding technology that require improvement because the weld-metal quality, productivity of the welding process and economical weld production depend largely on the flux formulation. Operational characteristics such as arc initiation and stability, minimum spatter, positional welding, high deposition rate, penetration and bead morphology are influenced by the welding flux formulation (Pandey *et al, 1994*; Kanjilal *et al, 2007*). The quality of weld-metal is often evaluated by many characteristics such as chemical composition, mechanical properties, bead profile and microstructure. Studies have shown that these characteristics are influenced by the welding flux formulation; therefore it is important to select the right type of welding flux ingredients and choose the appropriate proportions of the various flux ingredients to attain a good weld-metal quality (Pandey *et al, 1994*; Paniaguaet *al, 2009*).

Since, the development of the SAW process, there has been attempts by technologists and researchers to increase its productivity and to decrease the welding cost. The cost of the flux is a major part of the total welding cost for the SAW process. Flux constitutes half of the total welding cost in submerged arc welding. It has been estimated that, in general, one kg of flux is consumed for every kg of weld metal deposited. Flux consumption increases with an increase in arc voltage. (Dalgobindet *al, 2010*).

2. Literature Review

DEVELOPMENT OF SUBMERGED ARC WELDING FLUX: A brief review on development of submerged arc welding fluxes has been provided for the (1) methods for development of fluxes (2) fresh fluxes constituents for optimization, (3) recycling of fluxes and (4) hard facing.

Submerged Arc Welding Flux Design Methods

The conventional approach to welding flux development is by experimental optimization. The extensive and expensive trial and error experimentation was needed because it is often difficult to know a priori how the flux ingredients interact to determine the operational characteristics of the flux and the final performance of the welded structure. For development of welding fluxes by hit and trial methods, many investigators tried to understand the role of each flux ingredients on the weld-metal properties and operational characteristics of the process by varying only the individual flux ingredient in a given flux system (Farias *et al., 2004*; Du Plessis *et al.* 2007).Kanjilal *et al., (2004*) observed that this approach by its very nature failed to take into account the simultaneous variation of the flux ingredients as well as their interaction effects. Assessment of flux ingredient interaction has been recognized as increasingly important in welding flux design where it may be necessary to determine the combined synergetic and antagonistic effects of many flux ingredients (Kanjilal *et al., 2004, 2006, 2007*).Factorial design, which has been widely used in other areas of arc welding technology, is inadequate for welding flux formulation because flux properties depend on the relative proportions of the flux ingredients (Anderson *et al, 2002*).Ren *et al, (2010)* used a design of experiment method (DoE) known as uniform design (UD) to develop a new agglomerated flux for high speed and multi-arc SAW. In the UD, the only thing to be considered is the uniform dispersion of the experimental points in the experimental space. Although the UD method has advanced the traditional experimental optimization, the result may be suboptimal or at best near optimal. Kanjilal *et al, (2004, 2005, 2007a, 2007b)* used another form of DoE technique known as the extreme vertices design (XVERTD) proposed by McLean and Anderson *(1966).* In the XVERTD technique, the constraints on the q flux ingredients define the experimental region, which is usually a (q – 1) dimensional simplex. The extreme vertices of the simplex, the centroids of each of the faces and the centroid of the entire simplex are determined and used as the experimental points or treatment combinations. Kanjilal and his co-investigators used their experimental data to develop prediction models for the measured responses such as weld-metal composition, mechanical properties, microstructure and element transfer characteristics of the flux. Standard mixture designs such as simplex-lattice and simplex-centroid will have limited applications in welding flux research because flux ingredients usually vary between a lower bound greater than 0 and an upper bound lesser than (100%). Extreme Vertices Designs are most appropriate when the researcher is interested in the effect of flux ingredients proportions on the responses.(Mclean and Anderson, *1966*; Snee and Marquardt, *1974*; Ding *et al, 1999*; Adeyeye *et al, 2008*).Development of models should not be limited to process factors because studies have shown that flux formulation plays a prominent role in the productivity of the welding process and the quality of the welded structure (Du Plessis *et al, 2006, 2007*).

FRESH WELDING FLUXES: The physicochemical properties of the fluxes such as the size mix, bulk density, flowability, hygroscopic nature, melting point, melting range, surface tension, viscosity, current carrying capacity, welding speed, and electrical conductivity affect welding behavior of fluxes significantly. To make a strong joint in submerged arc welding the above characteristics of the flux should be considered and for this a scientific methodology is to be adopted for designing the fluxes (Khan *et al, 2013*). The molten flux should be sufficiently viscous for proper coverage of weld pool, to attain the desired viscosity of coating and the flux must have a low enough viscosity to dissolve the gases entrapped between the molten flux and metal (Butler *et al, 1967*). It has been reported that the viscosity of a basic flux is decreased when CaO, MnO, Fe_2O_3, CaF_2 content is increased. The viscosity of fluxes increases by the presence of corundum and SiO_2 which are present in most of the fluxes (Singh *et al, 2013*). The flux consumption remains a function of process parameters and directly influences the productivity of the process (Arora *et al, 2009*). Flux consumption increases with the increase in open circuit voltage and very small increases with increase in current. Welding speed has negative effect on flux consumption. Flux consumption decreases acutely with the increase in nozzle to plate distance (Krishnkant*et al, 2012*, Kumar et al, 2011). The weld metal oxygen content decreases with increasing arcing time, eventually becomes constant in what is assumed to be a quasi-equilibrium state. (Hirohisa *et al, 2013*). A submerged arc flux with good usability characteristics is composed of granules whose size enables them to flow freely during flux feeding. (Jackson, C. E. *1982*) stated that freely flowing granules can be attained by the sequence of melting, chilling and grinding, or by agglomeration. The more popular but expensive potassium silicate binder can be replaced by the more readily available sodium silicate but for it to perform effectively, it must be enriched with potassium carbonate (Nwigbo*et al, 2012*). Chai *et al, (1981)* developed a theory for predicting slag-metal equilibrium during submerged arc welding with fused neutral fluxes. The proposed theory was capable of predicting the gain or loss of Mn and Si over a wide range of flux electrode-base plate compositions. Chai and Eagar *(1982),* it was shown that CaF_2 would reduce the amount of oxygen in the weld metal, but the effect might be due to dilution of the metal oxide rather than due to a direct chemical reaction. The effect of CaF_2 in reducing the level of weld metal oxidation was dependent upon the stability of the metal oxide. Bennet*et al,(1966)* reported that SiO_2 and MnO in the flux would influence the levels of Si and Mn in the weld metal, influencing the impact strength of the weldment Weld hardness and wear resistance are dependent on the chemical composition of the weld wire and flux (Gulençet*et al, 2003*). Farias et al, (2004) concluded that the replacement of quartz with Wollastonite in the coating increased slag basicity and decreased all weld metal silicon and oxygen contents. Ana *et al, (2005),* the presence of acicular ferrite was found to influence the yield and ultimate tensile strength of the weldment. The elongation and percentage of reduction of cross sectional area were affected by the inclusion volume percentage. The hardness decreases when the arc voltage and welding current are increased because of the change of the sizes grain boundary of microstructure (Mohamat*et al, 2012*). De-liang*et al, (2009*), The microstructures consisting of acicular ferrite can be obtained in weld metals using the wires with a low carbon content and appropriate contents of Mn, Mo, Ti-B, Cu & Ni, resulting in the high low-temperature impact toughness of weld metals.

Ana et al, (2009), observed that the increase in titanium content in fluxes improves the toughness and ductility of the welds. The sizes grain boundary of microstructure changes from bigger to smaller size when the welding speeds increase (Mohamat*et al, 2012*). Indacocheae*t al (1983)* reported that the penetration increases with the increase in slag viscosity and interfacial tension. An increase in viscosity, arc stability, surface tension between the flux and liquid metal, and a decrease in surface tension between the flux and the base metal all result in deeper penetration (Schwemmer*et al, 1979*).Penetration increases significantly with current, decreases with welding speed and remains unaffected by open circuit voltage & nozzle to plate distance (Choudhary*et al, 2011*; Mohamat*et al, 2012)*.

RECYCLING OF FLUX: Beck *et al, (1996)* proposed that if processed properly and according to code requirements, recycled slag could be reliably used as a substitute to fresh flux. They further emphasized a saving up to 50% of the total cost of purchased flux by recycling the slag. Devis*et al,(1982)* established that fused calcium silicate flux, which has fully reacted during manufacturing, produces no change on reheating. Such a flux contains no readily oxidizable material and can be recycled. A few researchers have also explored the possibility of using a mixture of fresh flux and slag. Livshits*et al,(1960)*has shown the possibilities of using pulverized slag crust mixed with iron filings for hard facing applications. They additionally confirmed that this process is efficient and cost-effective. Moi*et al,(2001)* and Pal *et al,(2001)* found that of mixture containing up to 20% fused slag in fresh flux produces no change in weld metal chemistry. Milichenko *et al,(1960)*.have proposed a new method for preparing alloying fluxes for hard facing by enriching the flux with ferro-alloys. Their *(1983)* has proposed empirical equations for computing the alloy content of the weld metal. In spite of the fact that from the available literature of Pandey *et al,(2005),* it was found that slag is being recycled by some companies but they are professional recyclers and have not disclosed the methodology, may be due to commercial reasons. Pandey *et al,(2006)* found that an acceptable bead geometry can be achieved using recycled slag and have claimed a saving of 68.6% using recycled slag. Most recently Kaveh*et al,(2008)* have developed a methodology of recycling of slag obtained from the application of powder in submerged arc welding used in low carbon steel. Their research highlights finding a method for recycling such wastes by making use of phases assessment systems (X-ray diffractometery XRD), chemical composition assessment systems (X-ray fluorescence XRF), phases type and form assessment system (Scanning electro microscope SEM), and carbon and sulphur value assessment system (Strolein system) and by using separation, formulation, and ceramic sintering.

HARDFACING: YimlazBayhan*(2005),* observed that the wear rate of the hardfaced surface depends both on hardness and chemical composition of the materials used. They also observed that the wear rate decreases with increasing carbon(C) and manganese (Mn) proportion in the chemical composition of the material used. Kemal*et al, (2007)* concluded that the wear resistance of the austenitic manganese steel, showed a higher work-hardening capacity and a better wear resistance under low speed impact velocity. Xinhong Wang *et al, (2007)* showed that the wear resistance of the materials depends upon their hardness, therefore with increasing graphite content in the coating of the electrode, the hardness of the hardfacing layers increases. Selvi*et al, (2008)* said that carbon and chromium content decreases wear and improvers the microstructure. Mehmet *(2009)* suggested that hardness increase with boron content.

3. Conclusion

After going through the research work carried out in the field of welding flux development it has been concluded that the welding flux can be designed by using statistical and design of experiment methods such as mixture designs etc. instead of lengthy trial and error methods. Various researchers have used different methods and different ingredients for improving the quality of flux and optimizing its properties, thus there is a vast scope for research work in the field of development of high performance and cost effective fluxes.

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References

[1] Adeyeye AD and Oyawale FA. (2008) Mixture Experiments and their Applications in Welding Flux Design. Journal of the Brazilian Society of Mechanical Sciences and Engineering. 30(4):319-326.

[2] Ana, M., Paniagua, M., Victor, M., Lopez, H., Maribel, L. and Saucedo, M. (2005) “Influence of the Chemical Composition of Flux on the Microstructure and Tensile Properties of Submerged-Arc Welds”. Journal of Materials Processing Technology, 169: 346-351.

[3] Ana, M., Paniagua, M., Victor, M. Lopez, H., Hector, J., Dorantes, R., Paulino, E., Diazb., E. and Diaz, V. (2009) “Effect of TiO_2-containing fluxes on the mechanical properties and microstructure in submerged-arc weld steels”. Material Characterization, 60(1):36-39.

[4] Beck, H.P. and Jackson, R.A.,June,(1996) “Recycling SAW Slag Proves Reliable and Repeatable” Welding Journal, , 51-54.

[5] Bennet, A. P. and Stanley, P. J. (1966) “Fluxes for the SAW of QT 35 Steel”. British Welding Journal, 13: 59-66.

[6] Boniszewski T, (1979) “Manual Metal Arc Welding”. Metallurgist and Materials Technologist, Vol.11 No.10. P.567-574.

[7] C. E. Jackson, (1982) “Submerged-arc welding, fluxes and relations among process variables,” in Metals Hand Book, pp. 73–77.

[8] Choudhary D K, Jindal S and N.P.Mehta, (2011) “To study the effect of welding parameters on weld bead geometry in SAW welding process”.

[9] Chai, C.S. and Eagar, T.W. (1981) "Slag-Metal Equilibrium during Submerged Arc Welding". Metallurgical Transactions B, 12(B), September: 539-547.
[10] Chai, C. S. and Eagar, T. W. (1982) "Slag-Metal Reactions in Binary CaF_2- Metal Oxide Welding Fluxes". Welding Research Supplement, July: 229s-232s
[11] DalgobindMahto, Anjani Kumar (2010), "Novel Method of Productivity Improvement and Waste Reduction Through Recycling of Submerged Arc Welding Slag", Jordan Journal of Mechanical and Industrial Engineering, Pages 451 – 466.
[12] Davis, M.L.E. and Bailey, N. (2010), "Properties of Submerged Arc Welding Fluxes.-A Fundamental Study" Metal Construction, Vol. 14, No. 4, 1982. 202 – 209. Jordan Journal of Mechanical and Industrial Engineering. All rights reserved - Volume 4, Number 4 (ISSN 1995-6665) 465.
[13] De-liang Ren, Fu-ren Xiao, Peng Tian, Xu Wang and Bo Liao (2009), "Effects of welding wire composition and welding process on the weld metal toughness of submerged arc welded pipeline steel", International Journal of Minerals, Metallurgy and Materials Vol.16: 65-70.
[14] Ding, Jian-Tong., Yan, Pei-Yu., Liu, shu-Lin., and Zhu, Jin-Quan., (1999) "Extreme Vertices Design of Concrete with Combined Mineral Admixtures",Cement and Concrete Research, Vol. 29, Issue 6, pp. 957-960.
[15] Du Plessis, J. and Du Toit, M., (2007), "Reducing diffusible Hydrogen Contents of Shielded Metal Arc Welds Through Addition of Flux-Oxidizing Ingredients", Journal of Materials Engineering and Performance.
[16] Du Plessis, J., Du Toit, M., and Pistorious, P.C., (2006), "Reducing the Diffusible Hydrogen Content of Shielded Metal Arc Welds by Means of Fluoride and Calcite Flux Additions", IIW Doc II-1590-06.
[17] Farias, J.P., Scotti, A., Balsamo, P.S. and Surian, E. (2004) "The Effect of Wollastonite on Operational Characteristics of AWS E6013 Electrodes", Journal of Brazilian Society of Mechanical Sciences and Engineering, 26(3): 317-322.
[18] Gulenç, B. and Kahraman, N. (2003) "Wear behavior of bulldozer rollers welded using a submerged arc welding process". Materials and Design, 24: 537-542.
[19] Hould Croft P.T. (1989), "Submerged Arc Welding, 2nd ed", England: Abington Publishing, Cambridge.
[20] Indacochea, J.E. and Olson, D.L. (1983) "Relationship of weld–metal microstructure and penetration to weld-metal oxygen control". Materials for energy systems, 5 (3): 139- 145.
[21] Quintana MA, DebRoy T, Vitek JM and Babu S.(2005)"Novel Optimization Methodology for Welding Process/Consumable Integration". Technical Report Submitted To The United States Department of Energy. Repot No DOE-ID14204-F1; Award No DE-FC36-011D14204.
[22] Pandey ND, Bharti A and Gupta SR, (1994). "Effect of Submerged Arc Welding Parameters and Fluxes on Element Transfer Behaviour and Weld Metal Chemistry". Journal of Materials Processing Technology; 40:195-211.
[23] Kanjilal P, Pal TK and Majumder SK, (2007). "Prediction of Element Transfer in Submerged Arc Welding". Welding Journal; 86(5):135s-146s.
[24] Paniagua-Mercado AM, López-Hirata VM, Dorantes-Rosales HJ, Estrada Diaz P and Diaz Valdez E, (2009). "Effect of TiO2 Containing Fluxes on the Mechanical Properties and Microstructure in Submerged Arc Weld Steels" Materials Characterization.; 60(1):36-39.
[25] Kah P and Martikainen J, (2012), "Current trends in welding processes and materials". Received: September 28, 2011Rev.Adv.Mater. Sci. 30 (2012) 189-200.
[26] Kanjilal, P., Majumder, S.K., and Pal, T.K., (2004), "Prediction of Submerged Arc Weld-Metal Composition from Flux Ingredients with the Help of Statistical Design of Mixture Experiment", Scandinavian Journal of Metallurgy, Vol. 33, pp. 146-159.
[27] Kanjilal, P., Majumdar, S.K. and Pal, T.K., (2005a), "Prediction of Acicular Ferrite from Flux Ingredients in Submerged Arc Weld Metal of C Mn Steel" ISIJ International, Vol.4, No. 6, pp. 876-885.
[28] Kanjilal, P., Pal, T.K. and Majumdar, S.K., (2005b), "Prediction of Mechanical Properties in Submerged Arc Weld Metal of C-Mn Steel" Materials and Manufacturing Processes, Vol. 22, pp. 114-127.
[29] Kanjilal, P., Pal, T.K. and Majumdar, S.K., (2006), "Combined Effect Of Flux And Welding Parameters On Chemical Composition And Mechanical Properties Of Submerged Arc Weld Metal", Journal Of Materials Processing Technology, Vol. 171, Issue 2, pp. 223-231.
[30] Kanjilal, P., Pal, T.K. and Majumdar, S.K., (2007a), "Prediction of Element Transfer in Submerged Arc Welding", Welding Journal, Vol.86, No. 5, pp.135s-148s.
[31] Kanjilal P, Pal TK and Majumdar SK.(2007b),"Prediction of Mechanical Properties in Submerged Arc Weld Metal of C-Mn Steel. Materials and Manufacturing Processes", 22(1):114-127.
[32] Kanjilal P, Pal TK and Majumder SK.(2007),"Prediction of Element Transfer in Submerged Arc Welding". Welding Journal; 86(5):135s-146s.
[33] Kaveh, A., Haghighati, A.H., and Mirzahosseini A.R.(2008), " Recycling the slag obtained from the Application of Powder in Submerged Arc Welding", Journal of Environmental Science and Technology, Vol.38,
[34] Kemal Yildizli ,MehmatEroglu, M BakiKaramis,(2007), "Microstructure and erosive wear behaviour of weld deposits of high manganese electrode" . Surface and Coating Technology, 201, 7166-7173.
[35] Krishankant, Sandeep Jindal &Shashi Kant Shekhar, (2012), "Determination of Flux Consumption in Submerged arc Welding by the Effect of Welding Parameters by Using R.S.M Techniques", Global Journal of researches in engineering Mechanical and mechanics engineering ,Volume 12 Issue 2 Version 1.0.
[36] Kumar Vinod, (2011), "Use of the Response surface Modeling in predication and control of flux consumption in submerged arc weld deposits", proceedings of the world congress on engineering& computer science,

[37] Livshits, L.G. and Shiryaev, A.I,(1960) , "A New Ceramic Flux for Hard Facing," Welding Production, 28-29.
[38] Louise, D. (1981), "An introduction to welding fluxes for mild and alloy steels". Cambridge: The Welding institute, 1-10.
[39] Mclean, R.A., and Anderson, V.L., (1966), "Extreme Vertices Design of Mixture Experiments", Technometrics, Vol. 8, pp. 447-456.
[40] MehmatEroglu,(2009) "Boride coatings on steel using shielded metal arc electrode: Microstructure and Hardness". Surface and Coating Technology, 203, 2229-2235.
[41] Milichenko, S.L. and Zuravlev, I.V,(1960).,"A Method Whereby Fused Welding Fluxes Can be Enriched with Ferro Alloys" Welding Production,74-75.
[42] MohamatSyarulAsraf, IbrahimaIzatulAini, Amalina Amir, Abdul Ghalib, (2012) " The Effect of Flux Core Arc Welding (FCAW) processes on different parameters", Procedia Engineering 1497 – 1501 , International Symposium on Robotics and Intelligent Sensors .
[43] Moi, S.C., Bandyopadbyay, A and Pal, P.K.(2001), "Submerged Arc Welding With a Mixture of Fresh Flux and Fused Slag," National Seminar on Advances in Materials and Processing, IIT, Roorkee.
[44] Nwigbo Solomon Chukwuka, Atuanya C.U, (2012) "Formulation of a Metal Arc Welding Flux with a Potash Enriched Sodium Silicate Binder", Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 3 (3): 974-501.
[45] Pal, P.K., Bandyopadbyay, A. and Bala, A.K.,(2001), "Some Aspects of Submerged Arc Welding with Mixture of Fresh Flux and Fused Slag," International Conference, Dhaka, Bangladesh,.
[46] Pandey S, Singh K and Mani A.(2005), "Effect of Recycled Slag on Weld Bead Geometry in Submerged Arc Welding" 14th ISME International Conference on mechanical Engineering in Knowledge Age, DCE, New Delhi.
[47] S Selvi, S.P Sankaran, R Srivatsavan, (2008) "Comparative study of hardfacing of valve seat ring using MMAW process". Journal of Materials Processing Technology 207, 356-362.
[48] Schwemmer D.D, Olson D.L, Williamson D.L (1979). "The relationship of weld penetration to the welding flux". Weld. Res. Suppl. 59(5):153-160.
[49] Singh K, Pandey S and Mani A., (2006)"Recycling of Submerged Arc Welding Slag," Australasian Welding Journal, Vol.51, ,34-38
[50] Singh Hari, Kumar Ajay, and Maheshwari Sachin, (2013) "XRD and DTA Analysis of Developed Agglomerated Fluxes for Submerged Arc Welding" Journal of Metallurgy, 8 pages.
[51] Snee, R.D.E., and Marquardt, D.W., (1974), "Extreme Vertices Designs for Linear Mixture Models", Technometrics, Vol. 16, No. 3, pp. 399-408.
[52] Their H.,April (1983) " IIW Documents XII 802-03", The Welding Institute, London,.
[53] XinhongWang , Fang Han, Xuemei Liu , Shiyao Qu, ZendaZou, (2007), "Microstructure and wear properties of the Fe-Ti-V-Mo-C hardfacing alloy". Wear, 265, 583-589.
[54] YimlazBayhan, (2005), "Reduction of wear via harfacing of chisel ploughshare". Tribology International, 39, 570-574.

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