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# The Influence a Type of Welding Material on Parameters of a Solid Parts Welding Fumes

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***Abstract*** **-** Medical studies show, that welding fumes is the common reason of professional illness of welders. Usual in manufacture controlled level of concentration of particles in air of workplace on , but concentration just it is one of parameters, more important composition, main compound, shape size and structure of solid particles welding fumes. In this paper presented how all this parameters depend on type of electrode coating in condition hand arc welding, in paper presented relationship between composition and shape of typical solid particles welding fumes.

***Keywords*****:** Welding, Coated electrodes, Labor protection, Solid component of welding fumes.

## 1. Introduction

Welding is technical process characterized by clear rules about quality of weld joint and high level of health hazard. Mechanical strength of weld joint is provided by correct choice of type of electrode, but type of electrode never describe how welding process with this electrode will influence on health of welder. Many studies show that the dangers for health factor in welding process is welding fumes and especial solid particles, because they can stay lung in long time and influence as cumulative effect.

The solid particles welding fumes consists from compounds based on elements O, Na, Si, K, Ca, Fe, Mg, Ti, Ni, Cu, S, Cl, Mn. Source of welding fumes are weldable metal, metal of electrode and components of electrode coating (Bereznaja et al., 2013). The variety of types electrode coatings provides variety of solid particles welding fumes. Some studies describe dependence just between composition of coating and welding fumes (Ignatova A.M., Ignatov M.N., 2012). However, the most modern studies describe results (Kuznecov D.A., Simonovich A.L. et al., 2012), which show that composition of solid particles welding fumes doesn't contain full information about real nature of solid particles welding fumes, more important parameters is compounds in composition, shape and size of particles (Ignatova A.M., Ignatov M.N., 2012).

The goal of our study is search links between characteristics of shape, size and composition of typical solid particles of welding fumes, which were produced by different type coating of electrodes in process hand arc welding.

## 2. Order of Studies

In this article we will use data from our earlier survey in that publication we described methods which was used for collecting particles on workplace (Ignatova A.M., 2009) . We had researched welding fumes produced by the arc welding process using different welding materials (different electrode coating: rutil ESAB OK 53.70, OK 46.00, basic Kobe Steel LB 52U, cellulosic Kjellberg-Finsterwalde Prima Blue, acid MP-3M ТУ 1272-303-00187211-2002).

The order of study of characteristics solid particles welding fumes include 4 stages: a study of shape and size particles by X-ray microscopy, a study of composition by X-ray microprobe analysis, a calculate

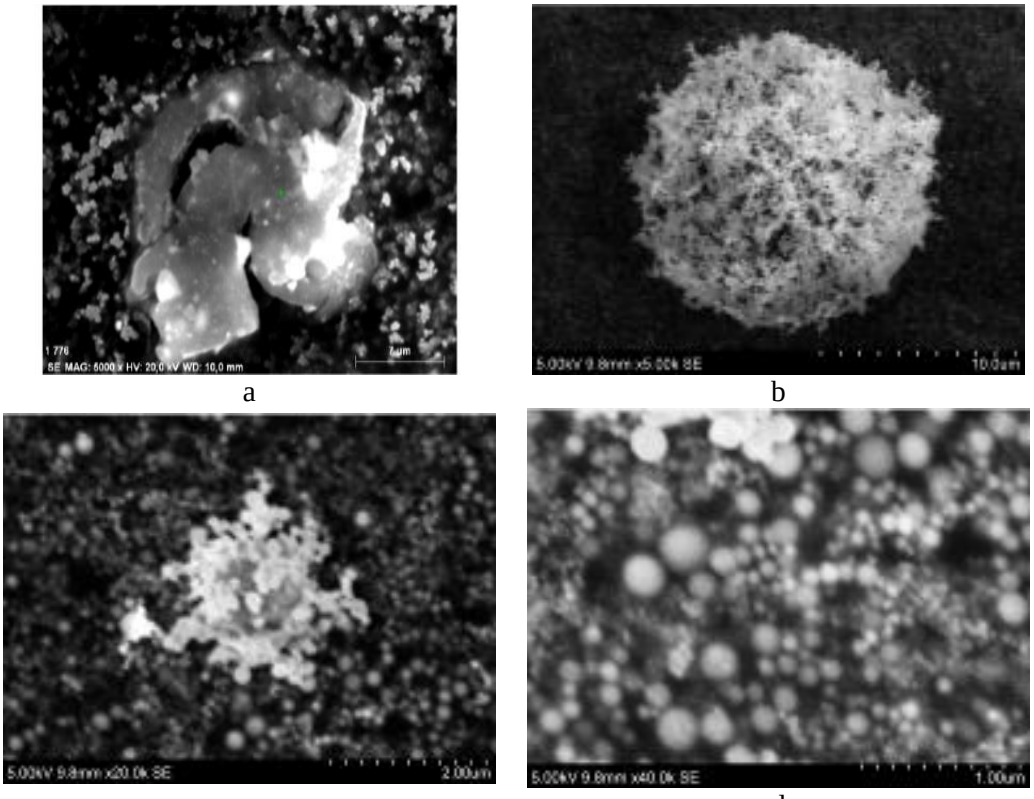
of real compounds in composition of particles and a study of fractional composition by especial equipment Zetasizer Nano, Malvern.

## 3. Results and Discussion

AOur study showed, that for different welding materials corresponds different types fumes particles, but the particles of specific type have similar properties (as composition and shape) without influence the type of welding material. It's mean that, for example, particle by type «sphere with a fibrous surface» is always have shape of sphere and contains ferrous oxide and particle of this type will be similar for rutile and basic welding materials. Every type of particle have individual set of main components, but it doesn't mean that the composition of particles include only oxides of this elements. In our studies we take in consideration what the composition of particle include complex mineral compound which can be different depending on conditions (acid or base). We add data about hazard level every compound to this information and presenting as scheme, of course the data should be clarified.

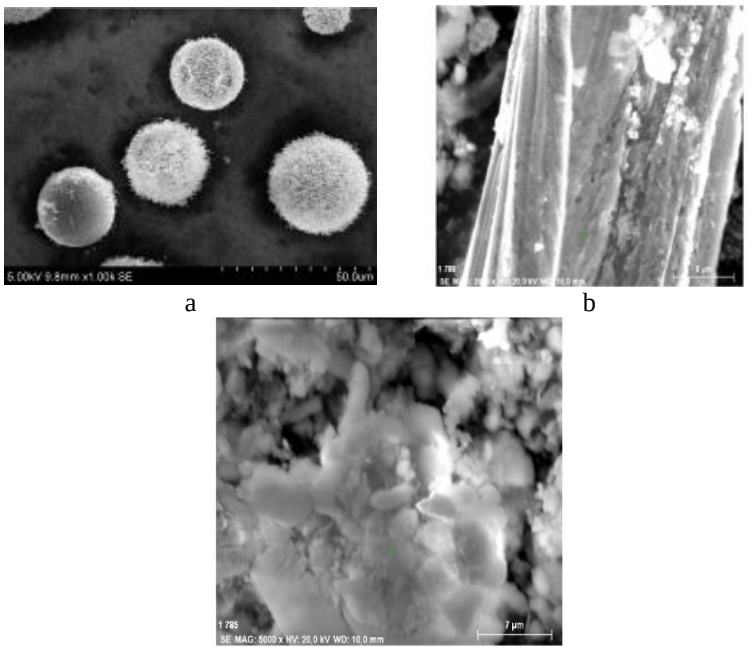
We noticed which type of particles corresponds for each type of electrode coating:

- The typical solid particles welding fumes for basic electrode coating (fig. 1) are agglomerates, spherical with fiber surface, cluster and chain-shaped;
- The typical solid particles welding fumes for rutile electrode coating (fig. 2) are spherical with smooth surface, fibrous and chain-shaped;
- The typical solid particles welding fumes for cellulosic electrode coating (fig. 3) are agglomerates, spherical with fiber and smooth surfaces;
- The typical solid particles welding fumes for acid electrode coating (fig. 4) are spherical with fiber and smooth surfaces particles.



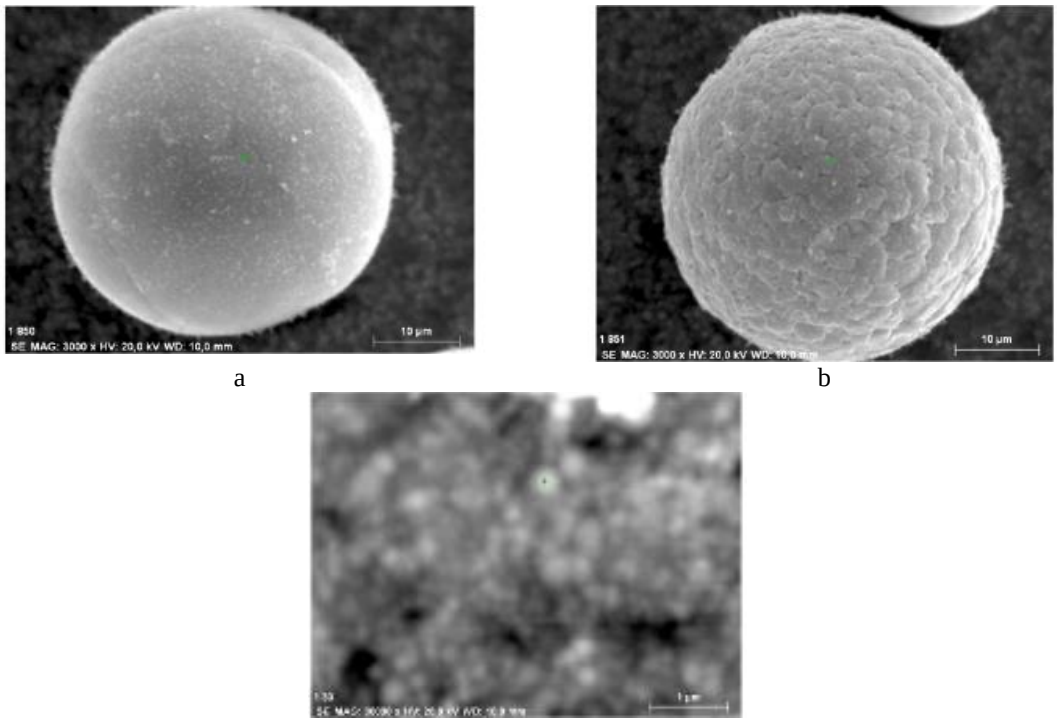
a b c d

Fig. 1. The solid particles of welding fumes formed by hand arc welding with electrode with basic coating LB – 52U: a – agglomerate, b – spherical particle with fiber surface, c – cluster, d – chain-shaped.



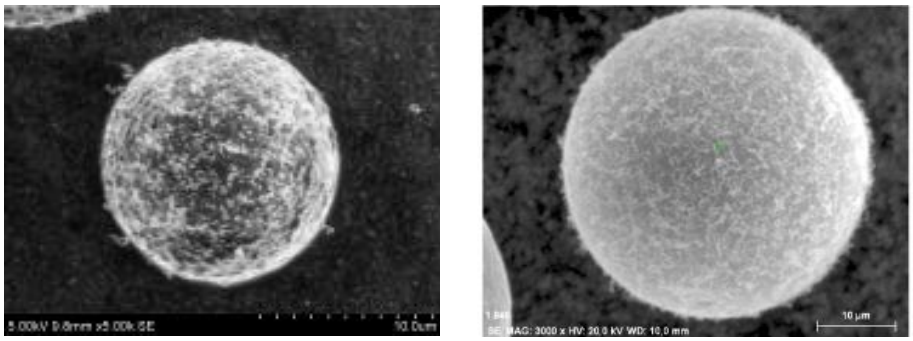
a b c

Fig. 2. The solid particles of welding fumes formed by hand arc welding with electrode with rutile coating OK 46.00: a – spherical particle with smooth, b – fibrous particle, c – chain-shaped particles.



a b c

Fig. 3. The solid particles of welding fumes formed by hand arc welding with electrode with Cellulosic coating PRIMA BLUE: a – spherical particle with smooth, b – spherical particle with fiber surface, c – agglomerate.



a b

Fig. 4. The solid particles of welding fumes formed by hand arc welding with electrode with acid coating MP – 3M: a – spherical particle with smooth, b – spherical particle with fiber surface

The data of X-ray microprobe analysis show that particles of one type have similar composition independent of type electrode coating (table 1).

Table 1. The composition of solid particles welding fumes depending from shape of particles.

| The type of particle / The element | | The agglomerate | The cluster | The spherical particles with fiber surface | The spherical particles with smooth surface | The fibrous particle | The chain-shaped particles |
|---|---|---|---|---|---|---|---|
| Composition, % | O | 50-70 | 50-70 | 60-70 | 60-70 | 60-70 | 50-70 |
| | Na | 10-18 | 1-3 | 2-4 | - | - | 1-3 |
| | Si | 1-5 | 5-16 | 15-20 | - | 0-1 | 5-10 |
| | K | 2-8 | 1-4 | 1-2 | - | - | 1-4 |
| | Ca | 1-6 | - | - | - | - | - |
| | Fe | 1-10 | 10-15 | 0-7 | 40-30 | 30-40 | 15-18 |
| | Mg | - | - | 1-3 | - | - | - |
| | Ti | 0-12 | - | 0-20 | - | 1-2 | - |
| | S | 1-4 | - | - | - | - | - |
| | Cl | 1-6 | - | - | - | - | - |
| | Mn | 0-3 | 0-3 | 0-4 | - | 0-1 | 3-5 |
| | Al | 1-4 | 5-13 | - | - | 0-1 | 5-8 |

The results of fraction composition (fig. 5) show, that the main part of all particles have size from 0,1 to 1,5 um, particles of 0,5 um is 86% from all mass welding fumes, 4% is particles 6 um, other 10% is particles bigger that 6 um.

The results of analytical calculation of compound in composition of solid particles of welding fumes show way of changing and transition compounds from electrode coating to welding fumes (table 2).

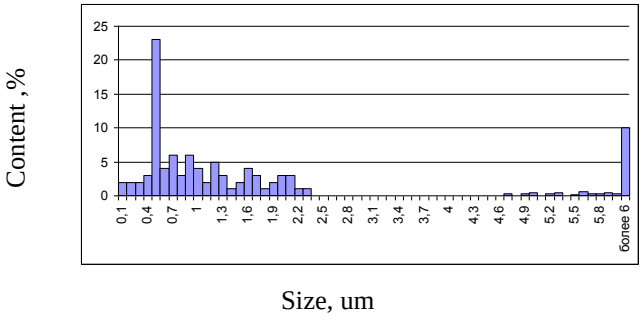



Fig. 5. The diagram of fractional composition of solid particles welding fumes

Table 2. The compounds, which contained main elements in welding electrodes coating and supposed compounds with this elements formed in solid particles of welding fumes.

| The element | The compounds of electrode coating | The compounds of solid particles of welding fumes | The type flux coating of electrode |
|---|---|---|---|
| Fe | $Fe_2Si$ | FeO | Basic |
| | FeMn | FeO | Basic |
| | $Fe_2O_3$ | FeO | Acid |
| | $FeCO_3$ | FeO, $Fe_2[SiO_4]$ | Basic |
| | $Ca_2(Mg,Fe,Al)_5(Al,Si)_8O_{22}(OH)_2$ | FeO, $Fe_2[SiO_4]$ | Rutile |
| Ti | $TiO_2$ | $FeTiO_3$, $TiO_2$ $CaTiO_3$ | Rutile, Cellulosic |
| O | Oxides, water, carbonates | All Oxides | Acid, Basic, Rutile, Cellulosic |
| F | $CaF_2$ | HF (gas) $KMg_3[Si_3AlO_{10}]\cdot[F,OH]$ | Basic, Rutile, Acid |
| C | $(C_6H_{10}O_5)_n$ | CO, $CO_2$ | Cellulosic |
| Na | NaCl | NaCl, | Basic |
| | $Na[AlSi_3O_8]$ | $Na_2O$, $Na(Al,Fe^{3+})Si_2O_6$ | Basic, Rutile |
| Mg | $CaMg(CO_3)_2$ | $CaMgSi_2O_6$, MgO | Basic, Cellulosic |
| | $Ca_2(Mg,Fe,Al)_5(Al,Si)_8O_{22}(OH)_2$ | $CaMgSi_2O_6$ | Rutile |
| Al | $Na[AlSi_3O_8]$ | $Al_2O_3$, $Al_4[Si_4O_{10}](OH)_8$ | Basic, Rutile |
| | (Ca, Na)[(Al, Si)$AlSi_2O_8$] | $Na(Al,Fe^{3+})Si_2O_6$ | Basic, Cellulosic |
| | $KAl_2(AlSi_3O_{10})(OH)_2$ | (Na,Ca,Mg)(Mg,Fe,Al)$Si_2O_6$, Al2O3, | Rutile |
| | $Al_2O_3*2SiO_2*2H_2O$ | (Na,Ca,Mg)(Mg,Fe,Al)$Si_2O_6$, Al2O3, | Rutile |
| Si | $Fe_2Si$ | $SiO_2$ | Basic |
| | SiO2 | β $SiO_2$ | Basic, Acid |
| | $Na[AlSi_3O_8]$ | $Na(Al,Fe^{3+})Si_2O_6$ | Basic, Acid |
| | $Al_2O_3*2SiO_2*2H_2O$ | β SiO2, $(Mg,Fe)_2Si_2O_6$ | Rutile |
| K | (Ca, Na)[(Al, Si)$AlSi_2O_8$] | KCl, $K_2O$ | Basic, Rutile |
| | $KAl_2(AlSi_3O_{10})(OH)_2$ | KCl, $K_2O$ | Rutile |
| | $K[AlSi_3O_8]$ | KCl, $K_2O$ | Basic, Rutile |
| Ca | $CaF_2$ | $CaSiO_3$ | Basic, Acid |
| | $CaCO_3$ | CaO | Basic |
| | $Ca[Al_2Si_2O_8]$ | CaO, | Basic, Rutile |
| | $CaMg(CO_3)_2$ | $CaMgSi_2O_6$ | Basic, Rutile |
| Mn | FeMn | MnO | Basic |
| | (Ca,Mn)$CO_3$ | MnO, $MnMgSi_2O_6$ | Rutile |
| | MnO | $MnMgSi_2O_6$ | Acid |
| Zn | $Zn_2[SiO_4]$ | SiO2, $CaZnSi_2O_6$ | Rutile |
| Cl | NaCl | NaCl, KCl | Basic |
| S | $FeS_2$ | SO2, SO3 (gas) $Fe_6S_7$ | Basic, Rutile |

Some elements proceed to oxides, but this oxides can be just first products, second products is the result chemical reaction to form complex mineral compounds. Some of complex mineral compounds have crystalline structure, but same have amorphous structure, they more active than crystalline compounds.

The spherical particles with fiber surface have different composition of a shell and a core, composition of surface is silicate and composition of core is iron oxide and some other metal (table 2). The spherical particles with smooth surface can have different relief, if particle have deep relief it is mean that it particle doesn't hollow, particles with smooth surface usually is hollow. The agglomerate is mixture clumping similar to sintered material. The cluster is mixture clumping spherical particles. The

chain-shaped particles have amorphous structure and high concentration of Mn. The fibrous particle formed as result aero dynamic and mechanical action from environment in process of welding [10-12].

Every type of particle have individual set of main components, but it don't mean that the composition of particles include only oxides of this elements. In our studies we take in consideration what the composition of particle include complex mineral compound which can be different depending on conditions (acid or base). We add data about hazard level every compound to this information and presenting as scheme, of course the data should be clarified (fig. 6).

In this scheme we give especial index for hazard level but it's not enough for new system of certification, for it we must add recommendation about choice welding material with different hazard's level depend on conditions of workplace. For example, for welding in open space we can use more hazard material then for welding in close space, because in open space volume of air stream is powerful and it's mean that this stream can clean atmosphere around workplace. In modern standards of safety on workplace there regulations of volume air necessary for cleaning atmosphere in close space. We offer add for sign hazard's level from fig. 6 number of volume of air which necessary for occupational safety from table 3.

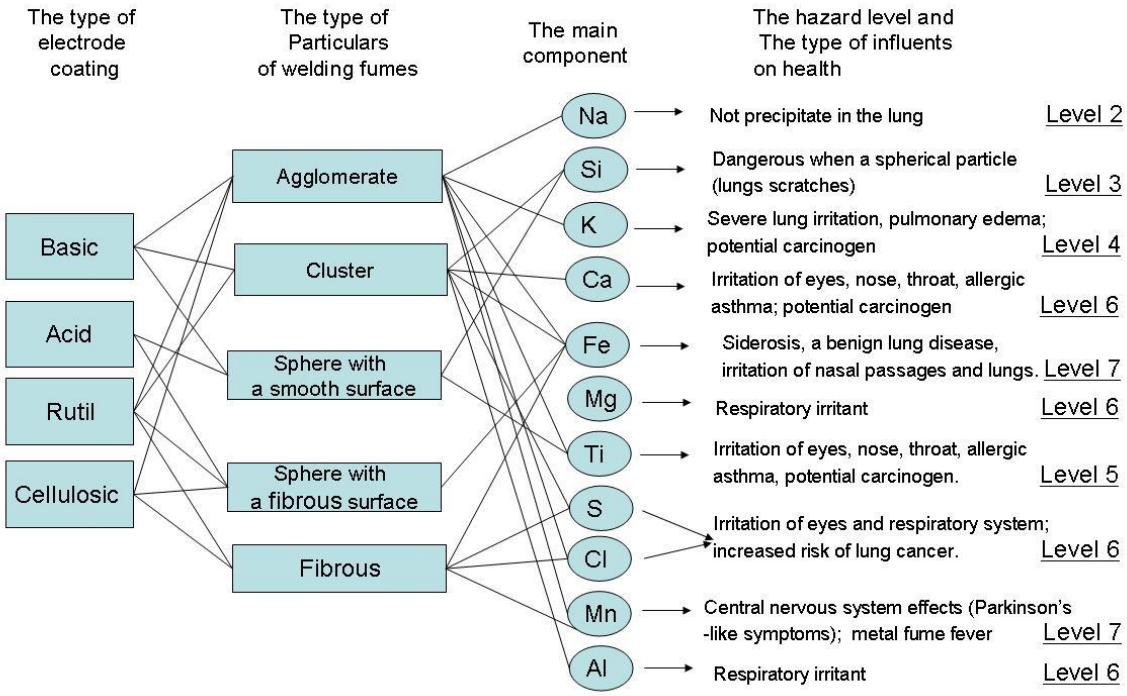



Fig. 6. Scheme of link between the hazard level and types of welding particles.

Table. 3. The number of volume of air which necessary for occupational safety for welding fumes with different hazard level.

| The hazard level | The number of volume of air, $m^3/h$ |
|---|---|
| 2 | 3000... 7500 |
| 3 | 7500... 15000 |
| 4 | 15000... 35000 |
| 5 | 35000... 60000 |
| 6 | 60000... 100000 |
| 7 | >100000 |

## 3. Conclusions

The results of our studies show that in process of hand arc welding with different type of electrode coating formed solid particles welding fumes with fraction, shape and composition, but all this parameters depend from type of particles. For each type of electrode compare individual set of typical particle;

The hazard level of welding fumes can be register and this parameter must take in consideration of welding materials. The hazard type of electrode can be sign as «index hazard level + number of volume air for cleaning workplace»;

The recomendations of technical documentations must take considerations from conditions of workplace and nanotoxicology recommendation about the hazard level of welding material;

The hazard type of welding materials must be write on technical drawing next after requirements of mechanical strength for increase quality of occupational safety, safety be provide always and even if it requires the design change (increase in the thickness of a welding union and other).

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