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# Defects Appearing in the Surfacing Layers of Abrasion Resistant

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## Abstract

The surfacing technologies are used for constitution of protection layer against wear and is destined for obtaining coating with high hardness. Among many weldings methods currently used to obtain the hard surface layer one of the most effective way of hardfacing is using flux cored arc welding. This additional material gives more possibilities to make expected hard surface layer.
Chemical composition, property and economic factors obtained in flux cored wire are much richer in comparison to these obtained with other additional materials. This is the reason why flux cored wires give possibilities of application this kind of material for improving surface in different sectors of industry.
In the present paper the imperfection in the layers was used for hardfacing process in different situations to show the possible application in the surface layer. The work presents studies of imperfection of the welds, contains the picture of microstructures, macrostructures and shows the results of checking by visual and penetrant testing methods.

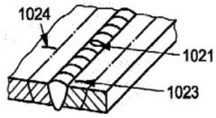
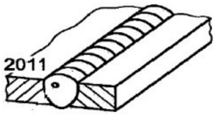
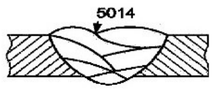
**Keywords:** Imperfection, Surfacing, Metallography, Hardfacing, Quality

## 1. Introduction

This paper is dedicated to the problem of imperfection of the wear-resistant surfaced plates, which are used for impact loading and transporting elements and in many different sectors of industry. Advance in materials engineering and surfacing technology has resulted in new materials and techniques of applying layers and improving surfaces that provide completely new opportunities for application in the different sectors in the industry. One of the most common techniques to increase the hardness of last layer is self-shielded flux-cored wire welding. [1-17]

Application of modern surface layer material can`t guarantee that obtained layers will be free of welding imperfection. Norm PN EN ISO 6520 includes classification of welding imperfection and divides it into 6groups: crack, cavieties, solid inclusions, lack of fusion and penetration, imperfection sharpe and dimension, miscellaneous imperfection. It also describes the mark of welding imperfection according the following scheme: ISO 6520-1-no, where marking number is the number of imperfection. The examples of the main groups are presented in Table 1.[18]
In this case of identification of imperfection the acceptable level must be defined according norm PN EN ISO 5817 (Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections). Were three acceptable levels can be found: from the highest B, through the medium C, to the lowest D.
Visual testing is conducted according to norm PN-EN ISO 17637 (Non-destructive testing of welds. Visual testing of fusion-welded joints) using general rules according to norm PN-EN ISO 17635. [19-21]

Table 1.
Group of imperfection

| Group | Describtion | Number of imperfection | Sample |
|---|---|---|---|
| 100 | Crack | 102 |  |
| 200 | Cavities | 2011 |  |
| 300 | Solid inclusion | 301 |  |
| 400 | Lack of fusion and penetration | 4012 |  |
| 500 | Imperfecta sharpe and dimension | 5014 |  |
| 600 | Miscellaneous imperfection | 600 | - |

The important question in welding surfacing technologies is correct determination of parameters that affect the quality and properties of the deposited layers. Changes in parameters setting chance to obtain deposit layers with different hardness, microstructure and without imperfection. [1-3, 11-15]
The main goal of the present research is examining microstructure defects and different imperfection of hardfacing layers made with semi automatic and automatic technologies.

## 2. Experimental procedure

Non-alloy structural steel of designation S235JR for general purpose was selected as parent material for hardfacing layers. The thickness of deposited steel plate was from 10 to 12 mm, but sometimes in the industry it is possible to find the base plate from 3 mm thickness. Self shielded cored wire with hardness over 60HRC were selected from hardfacing with chromium carbides $Cr_7C_3$. This materials are designed to work in conditions of abrasive wear metal-to-mineral.

The samples were cut with water jet to avoid changes in material structure and properties. Metallographic specimens were etched in a reagent with the following chemical composition of 80 ml $C_2H_5OH$, 10 g $FeCl_2$, 10 ml HCl. Prepared samples were investigated with microscope for determination of microstructure the obtained deposits.
Some of specimen to describe the imperfection on the surface were tested visually.

## 3. Results and discussion

In the process of testing hard surface layer many examples of welding imperfection in the specimen were found.
Imperfection has different influence on durability of these elements. Norm PN EN ISO 6520 doesn`t describe microscopic imperfection, however such imperfection occurred during the test. Is results in describing this imperfection in micro scale.

Figure 1-3 shows chromium carbides $Cr_7C_3$ in the structure of surfacing layer. In the figure 1 chromium carbides are visible on the top of surface layer, and in figure 2, in the middle, and in the figure 3 they can be seen over the fusion line.

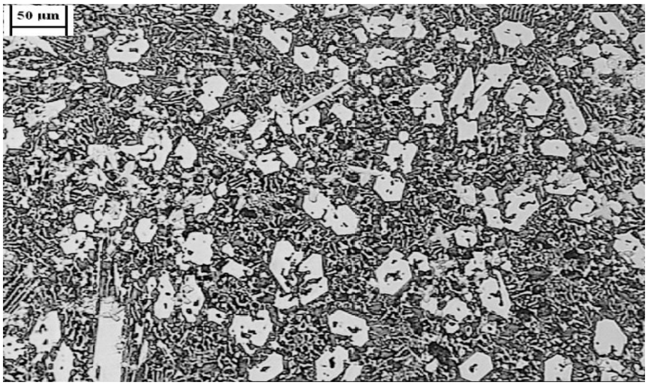


Fig. 1. Chromium carbides on the top of surface layer

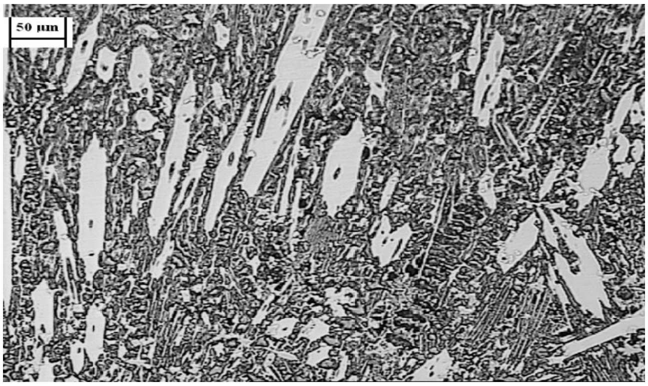


Fig. 2. Chromium carbides in the middle of surface layer

Fig. 3. Structure of material over the fusion line

Analysing figures from 1 to 3 the nature of change in chromium carbides dispersion can be found. The big particles of carbides go down over the fusion line, when changing the distance from fusion line to the face of welding the particle of chromium carbides are smaller.

Analysing the imperfection according PN EN ISO 6520-1 cavities over the fusion line can be found. (Fig.4)

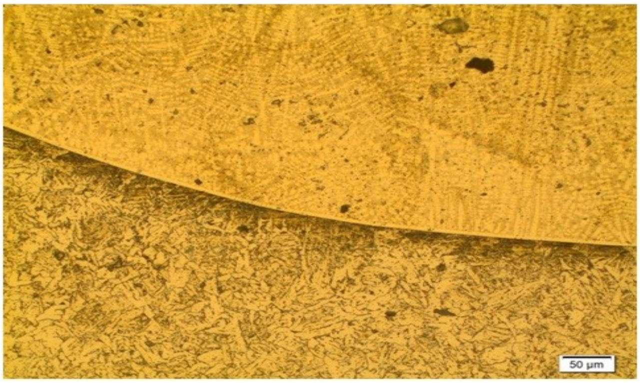


Fig. 4. Cavities over the fusion line

In the figure 5 the lack of fusion in micro scale can be seen, which was obtained by welding with oscillating layer due to the wrong automatic welding parameters.

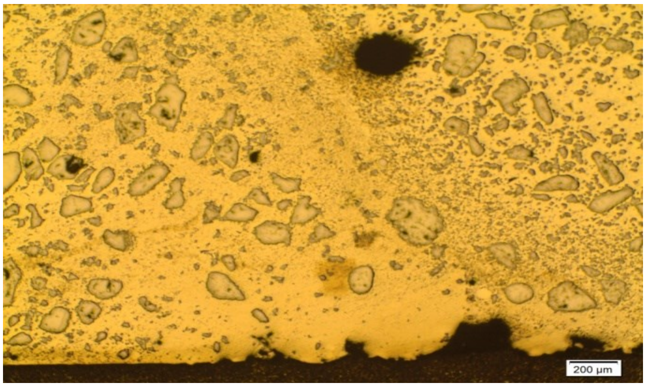


Fig. 5. Lack of fusion between the layer

To identify the imperfection in macro scale the scheme norm PN EN ISO 6520-1 was used. If the set of parameters isn`t correct many spatters can be found.

This kind of welding imperfection in some situations is accepted. (Fig.6).

Fig. 6. Spatter on the surface

If the distance between contact tip and end of the wire is wrong, there isn`t enough gas protection of welded metal. (fig. 7) In such a case the surface porosity can be found in micro scale in the single layer (fig. 8) or in wide layer (fig. 9)

Fig. 7. Surface porosity

Fig. 8. Gas pore in the single layer of the weld

Analysing the localization of porosity it is visible that in the single layer the imperfection are near fusion line (fig. 8), whereas in wide layer it can be seen on the top of layer (fig. 9).

Special attention should be paid to localization of the pores in the weld. In the case of single layer pores are located in the lower layers of the deposit due to the high rate of heat dissipation.

In the case of using wide layer of the width of 40 mm, pores are located on the top of the layer due to the larger volume of liquid weld pool.

Fig. 9. Gas pore in the wide layer the weld

Next imperfection indicated by protection process of surface are cracks. Stress cracks in welds made by straight stitch shown in figure 10. Cracks wide bead made by oscillating (with oscillation width 40 mm) are shown in figure 11.

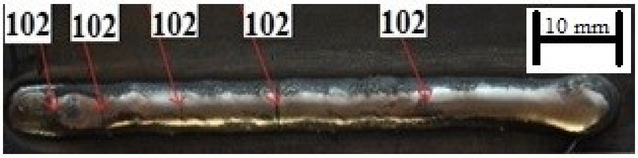



Fig. 10. Craks in the single bead with describe according to norm PN EN ISO 6520-1


Fig. 11. Craks in the wide bead

However, the use of a particular type of stitch carries the risk of deformation of elements.

Figure 12 shows examples of deformation of elements caused by the use of different widths of bead. In the figure of the bead the widths of 10 and 20 mm made on the base material S235JR with thickness of 10mm are presented.

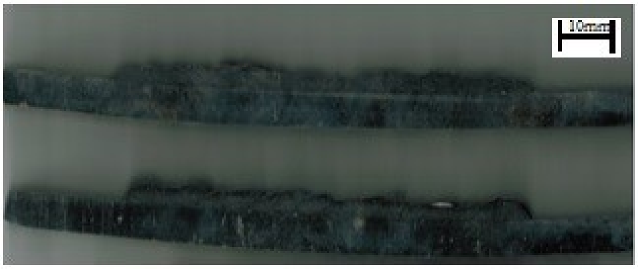


Fig. 12. Deformation

Analysing geometric discrepancies the easiest way to specify them is by performing metallographic section surface characteristic to welds made by semiautomatic methods. Figure 13 shows the inequalities face. Norm PN EN ISO 5817 allows this kind of imperfection but in limited range depending on the specific quality level in function of the thickness or value corresponding to 0.5; 1 or 2 mm.

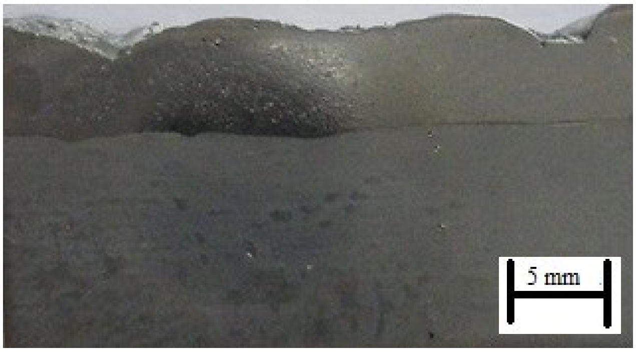



Fig. 13. Inequalities face

Character derived layers often necessitate bending elements. In this case these elements must be bent so that the deposited layer was stretched during the process and this leads to loosening of the deposit from the base material. Figure 14 shows the sample after the bending process on a mandrel with a diameter of 40 mm.


Fig. 14. Sample after the bending process

During the test surface it is possible to identify both the same discontinuity in the material and the severity of the imperfection at the surface of the element.

The view of the sample after testing penetration is shown in figure 15.

Part of the imperfections were revealed during the work or during the trial process. In figure 15 the subsequent stages of exploring the internal imperfections can be observed. They were made while abrasive wear erosion trial process using blast machine with the following working parameters: pressure 0,6 MPa and the use of abrasive sharp edge type G20.

In this test, the consumption was determined at different depths measured from the face and using the information shown in figures 1-3. The process of erosion wear method is very invasive in the material and therefore each time after a short period (about 60 seconds) of operation of stream erosion the samples were assessed visually. In the case of the situation shown in figure 15a there was a discovery of internal imperfections. In the further step (fig.15b) the deposited layer was worn till interrupting the test (fig.15c) which disclosed a base material layer and a lot of internal imperfections in the weld pad.

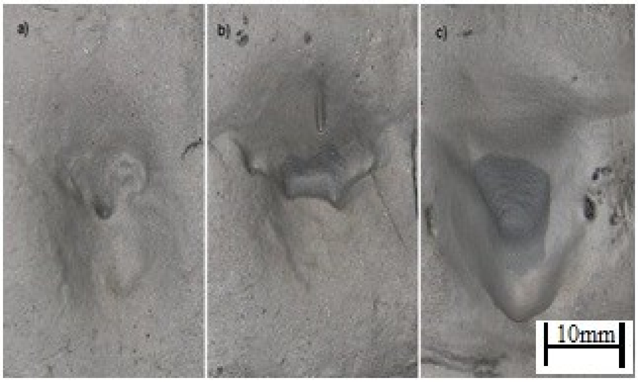


Fig. 15. Phases erosive wear abrasive welds

Surfaces protected has full and uniform coverage. Figure 16 shows the effect of incorrectly selected parameters of the process, whereby the inequalities of the face are obtained.

Fig. 16. Face inequalities by automatic welding.

Structure and properties of crystallizing weld overlays show significant differences due to variable parameters which directly resulted in the amount of welding technique.

## 4. Conclusions

The application of cored wires allows to obtain welds of high hardness and diverse size of hard phases. The selection of appropriate parameters of the process protection of surface allows to obtain welds with the desired properties.

This process and their parameters are important to find a good protection against wear.

Research on imperfection of weld would allow to determine relevant technological factors and their influence on the properties of these welds.

One of the biggest problems of surface protection against wear is to obtain the highest hardness in the first layer without having to do second or third layer. In order to mix the additional material is minimized by changing the parameters, for example: current, welding speed, modifications distance between tip and stick electrodes, or increase the speed of heat dissipation. As a result these changes can lead to the formation lack of fusion.

Porosity and gas pores are locked inside the workpiece as a result of the growing rate of cooling. This can be determined on the basis of information collected from the analysis of samples taken by simple and with oscillations layer.

For samples made with oscillating gas pores are localized in the upper layer of the weld, and in the case of beads made without oscillation -in the lower region of the weld just above the fusion line. This proves that the conditions of the heat and the type of heat source affect the location of this type of imperfection.

Layer of high hardness above 60 HRC can be regular cracks. These imperfections are cracks relaxing.

The location of cracks depending on the direction of the erosion can be significant from the point of view of the user.

It is observed that the direction of the cracks coincides with the direction of moving the material erosion.

Occurs the creation of self pair of friction. The emerging from factor of erosion that enters into the gaps and cracks creates the perfect vapor rubbing.

## References

[1] Bęczkowski, R. & Gucwa, M. (2015). Qualifying of hardfacing surfacing layers operating under conditions of the cement industry, *Welding Technology Review*. 87(9), 43-46.

[2] Bęczkowski, R. & Gucwa, M. (2014). The impact of the current settings to change the size of the geometric cross-section welds. *Welding Technology Review*. 86, 72-76.

[3] Gucwa, M. & Bęczkowski, R. (2014). The effect of heat input on the geometric properties of welded joints. *Archives of Foundry Engineering*. 14(spec.1), 127-130.

[4] Gucwa, M. & Winczek, J. (2015). The properties of high chromium hardfacings made with using pulsed arc. *Archives of Foundry Engineering*. 15(spec.1), 37-40.

[5] Winczek, J. (2003). The temperature field in steel side link-of stripper bucket during oscillation rebuilding. *Archives of Foundry*. 3(10), 267-272.

[6] Bober, M. & Tabota, K. (2015). Study significance of the impact of the basic parameters of plasma surfacing on the geometry of the weld overlays. *Welding Technology Review*. 87, 24-28.

[7] Buytoz, S. & Yildirim, M.M. (2010). Microstructure and abrasive wear properties of $M(Cr,Fe)_7C_3$ carbides reinforced high-chromium carbon coating produced by gas tungsten arc weldign (GTAW) process. *Archives of Foundry Engineering*. 10(spec.1), 279-286.

[8] Szajnar, J., Wróbel, P. & Wróbel, T. (2010). Multi-layers castings. *Archives of Foundry Engineering*. 10(1), 181-186.

[9] Fraś, E., Olejnik, E., Janas, A. & Kolbus, A. (2010). The morphology of TiC carbides produced in surface layers of carbon steel castings. *Archives of Foundry Engineering*. 10(4), 39-42.

[10] Suchoń, J., Strudnicki, A. & Przybył, M. (2010). Stereology of carbide phase in modified hypereutectic chromium cast iron. *Archives of Foundry Engineering*. 10(2), 169-174.

[11] Zikin, A., Hussainova, I., Katsich, C., Badisch, E. & Tomastik, C. (2012). Advanced chromium carbide-based

hardfacings. *Surface & Coatings Technology*. 206, 4270-4278. DOI: 10.1016/j.surfcoat.2012.04.039.

[12] Veinthal, R., Sergejev, F., Zikin, A., Tarbe, R. & Hornung, J. (2013). Abrasive impact wear and surface fatigue wear behaviour of Fe–Cr–C PTA overlays. *Wear*. 301, 102-108. DOI:10.1016/j.wear.2013.01.077.

[13] Lai, H.H., Hsieh, C.C., Lin, C.M. & Weite, Wu. (2014). Effect of oscillating traverse welding on microstructure evolution and characteristic of hypoeutectic hardfacing alloy. *Surface & Coatings Technology*. 239**,** 233-239. DOI: 10.1016/j/surfcoat.2013.11.048.

[14] Qi, X., Jia, Z., Yang, Q. & Yang, Y. (2011). Effects of vanadium additive on structure property and tribological performance of high chromium cast iron hardfacing metal. *Surface & Coatings Technology*. 205, 5510-5514. DOI: 10.1016/j/surfcoat.2011.06.027.

[15] Zhou, Y.F., Yang, Y.L., Jiang, Y.W., Yang, J., Ren, X.J. & Yang, Q.X. (2012). Fe–24 wt.%Cr–4.1 wt.%C hardfacing alloy: Microstructure and carbide refinement mechanisms with ceria additive. *Materials Charakterization*. 72, 77-86, DOI: 10.1016/j.matchar.2012.07.004.

[16] Klimpel, A. (2000). *Cladding and thermal spraying – technologies*. Warsaw: WNT. (in Polish).

[17] Klimpel, A., Dobrzański, L.A. & Janicki, D. (2015). A study of worn wear plates of fan blades of steel mill fumes suction system. *Journal of Materials Processing Technology*. 164-165, 1062-1067. DOI:10.1016/j.jmatprotec.2005.02.219.

[18] PN-EN ISO 6520-1:2009 Welding and allied processes. Classification of geometric imperfections in metallic materials. Part 1: Fusion welding.

[19] PN-EN ISO 5817:2014-05 Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections.

[20] PN-EN ISO 17635:2011 Non-destructive testing of welds. General rules for metallic materials.

[21] PN-EN ISO 17637:2011 Non-destructive testing of welds. Visual testing of fusion-welded joints.