

Nitrogenous Porosity and Ways to Prevent it Under Conditions of Arc Surfacing in a Nitrogen-containing Atmosphere

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Abstract. Pores coming to the surface can cause a violation of the tightness of the valve when the valve is closed, as well as be a focus of erosive destruction, especially in conditions of high-speed flows of the medium. Pores also contribute to the corrosive destruction of metals, since under the influence of certain aggressive media, they increase in size and cause a breach of the tightness of the gate. In the presence of carbon dioxide, nitrogen absorption by the weld pool metal increases and the tendency of the deposited metal to form pores decreases. The introduction of carbon dioxide of at least 30% to nitrogen makes it possible to obtain a dense deposited metal due to its better absorption of nitrogen. A significant factor reducing the formation of pores from nitrogen in the deposited metal 10X17H8X5G2T is the content of ferrotitanium in the charge of the PP-AN 133 powder wire. The titanium content in the deposited metal should be within 0.2...0.4%. A further increase in the concentration of titanium leads to a deterioration in the formation of the deposited metal and to an increase in the amount of slag on the surface of the deposited layer.

Keywords: pores, nitride-forming elements, surfacing, nitrogenous porosity, deposited metal, pipe fittings.

Introduction

One of the most important conditions for the stable operation of the valve of pipe fittings is to obtain a dense, pore-free deposited metal on the sealing surfaces.

Pores coming to the surface can cause a violation of the tightness of the valve when the valve is closed, as well as be a focus of erosive destruction, especially in conditions of high-speed flows of the medium. Pores also contribute to the corrosive destruction of metals, since under the influence of certain aggressive media, they increase in size and cause a breach of the tightness of the gate. Various kinds of abrasive particles can be introduced into the pores, which are the source of the formation of scratches on the rubbing surfaces and their premature wear. Pores are not allowed at all on the rubbing surfaces of pipe fittings of conditional passages up to DN 80 mm, and a very limited number of pores are allowed on conditional passages over DN 80 mm [1].

Therefore, the research and development of technology for surfacing friction surfaces of fittings in nitrogen and nitrogen-containing gas mixtures to identify patterns of pore formation and their prevention in the deposited metal is one of the main objectives of the study.

Prevention of nitrogenous porosity. An effective means of preventing or inhibiting the release of gas from the melt and the formation of gas bubbles and

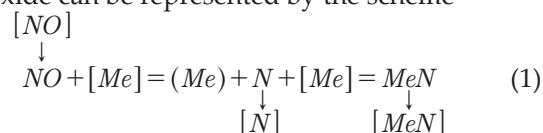
pores is to increase its solubility in the molten metal. This makes it possible to reduce the supersaturation of the metal, i.e. to have a minimum difference between the amount of dissolved nitrogen in the welding bath and its equilibrium concentration and, thus, to reduce or completely eliminate the release of gas from the liquid metal bath.

V.V. Podgaetsky [2] found that three main factors are required to reduce nitrogenous porosity:

1. Limiting the dissolution of nitrogen in a liquid electrode metal and a metal bath to a value less than the limit of the solubility of nitrogen in a liquid metal.
2. Increasing the solubility of nitrogen in a solid metal.
3. Nitrogen binding in the weld metal into persistent nitrides.

These three directions complement each other and require a specific approach in the development and application of various surfacing materials and surfacing technology.

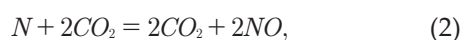
To increase the solubility of nitrogen in the deposited metal, the presence of nitrogen oxide on the surface of the welding bath contributes. Then the mechanism of nitrogen dissolution in the presence of nitric oxide can be represented by the scheme



Nitric oxide is adsorbed at the surface of the weld pool and then reduced by iron or other elements. The reduced nitrogen is dissolved in the metal in the form of atoms or nitrides.

At the same time, the absence of nitric oxide affects the process of nitrogen dissolution. It occurs mainly in the arc column at the end of the electrode, where there is a large concentration of active atomic nitrogen. This is proved by the fact that with an increase in the residence time of molten metal droplets at the end of the electrode, with a decrease in welding current and an increase in arc voltage, the nitrogen content in the metal increases markedly.

The presence of nitrogen oxide allows additional absorption of nitrogen by the metal on the surface of the welding bath, where the temperature is lower than at the ends of the electrode and where there is no active atomic nitrogen.



Under the conditions of arc surfacing in nitrogen in the presence of carbon dioxide and the product of its dissociation – oxygen, nitric oxide is formed by the following reactions:



Thus, the presence of carbon dioxide in a mixture with nitrogen contributes to a better absorption of nitrogen by the deposited metal and at the same time reduces the amount of nitrogen released to the metal surface during the crystallization of the weld pool.

Formation of nitrides. The affinity of any element to nitrogen can be characterized by the value of the free energy of the formation of the corresponding nitride. The higher the thermodynamic strength and the greater the activity of the nitride-forming element, the lower the pressure at which the nitride phase is formed (Table 1). The table shows that the most thermodynamically strong nitrides are Ti, Zr, Ce.

Depending on the presence of alloying elements in the melt having different affinities to nitrogen, the nitrogen activity coefficient also changes. The coefficient of nitrogen activity in the melt with alloying elements $f_N(Me-j)$ is determined from the ratio [2].

$$f_N(Me-j) = \frac{[N]_{Me}}{[N]_{Me-j}}. \quad (6)$$

where $[N]_{Me}$ – nitrogen concentration based on the alloy;

$[N]_{Me-j}$ – the concentration of nitrogen in an alloy with alloying elements.

At constant P and T , if the alloying element increases the nitrogen activity coefficient, then the solubility decreases, and vice versa.

By introducing nitride-forming elements Ti, Al, Zr, Nb, V, Mo, porosity caused by nitrogen can be prevented. The formation of nitrides prevents the

Table 1 – Values of enthalpy of nitride formation [3]

Element	Nitride	H ⁰ , kcal/mol
Al	AlN	-76,5
Si	Si ₃ N ₄	-44,0
Ti	TiN	-80,5
Zr	ZrN	-87,5
Nb	NbN	-42,0
Cr	Cr ₂ N CrN	-58,6 -25,6
Mo	Mo ₂ N	-28,2
Fe	Fe ₄ N Fe ₂ N	-16,6 -1,1
Co	Co ₃ N	-2,7
Ni	Ni ₃ N	+2,0
Ce	CeN	-78,0
W	W ₂ N	17,0

release of nitrogen in the free state. Nitride-forming elements bind nitrogen in the liquid metal into persistent nitrides and, thus, prevent the nucleation of gas bubbles.

To determine the optimal amount of Ti required for the introduction of PP-AN133 powder wire into the charge, which excludes the formation of pores in the deposited metal, and also ensures the satisfactory formation of the deposited roller, several variants of 10X17N8X5G2T type powder wires with different ferrotitanium content in the charge were studied.

Surfacing was carried out on plates made of steel 20 with a size of 200 × 100 × 16 mm from one to five layers in a protective atmosphere of CO₂, N₂, CO₂ + N₂. The scheme of the installation for the study is shown in figure 1.

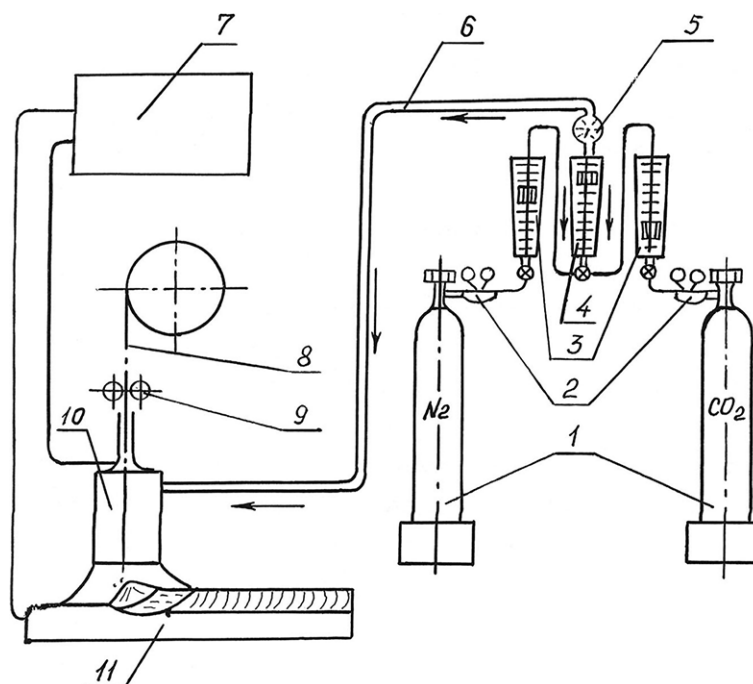
The nitrogen content in the mixture was 30, 50, 70%. Surfacing mode: welding current – 200...220 A; arc voltage – 26 V; V_H = 20.5 m/h.

The tendency of the deposited metal to form pores, depending on the composition of the protective atmosphere and surfacing modes, was assessed by color flaw detection according to OST 5.9537-80, sensitivity class 2 and radiographs obtained by X-ray transmission of the deposited samples with the RUP 150/300 X-ray apparatus according to OST 5.9095-77 on the RT-1 film.

Results

The results of the experiments (Table 2, Figure 3) revealed a significant influence of the titanium content on the tendency of the deposited metal to form pores, depending on the composition of the protective atmosphere.

With a FeTi content of 0.5%, pores appear already in the first layer. The surfacing of subsequent layers increases the tendency to pore formation. With an increase in the percentage of nitrogen in the protective



1 – gas cylinders; 2 – post reducers; 3 – rotameters RS-3; 4 – rotameter RS – 3A; 5 – pressure gauge;
6 – protective atmosphere supply hose; 7 – welding rectifier; 8 – surfacing wire;
9 – wire feeding mechanism; 10 – gas-electric burner; 11 – surfaced the plate

Figure 1 – Scheme of the surfacing plant for technological research

Table 2 – Titanium content in the deposited metal depending on the composition of the protective atmosphere (three-layer surfacing)

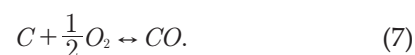
Protective atmosphere, %	Ferrotitane content in the wire, %							
	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0
	Titanium content in the deposited metal, %							
CO ₂	0,04	0,08	0,12	0,13	0,16	0,18	0,25	0,28
70CO ₂ + 30N ₂	0,04	0,09	0,13	0,13	0,17	0,20	0,26	0,29
50N ₂ + 50CO ₂	0,05	0,10	0,13	0,14	0,18	0,20	0,26	0,30
30CO ₂ + 70N ₂	0,05	0,10	0,14	0,15	0,18	0,21	0,26	0,31
N ₂	0,06	0,11	0,14	0,16	0,19	0,21	0,27	0,31

mixture, the number of pores in the deposited metal also increases. The largest number of pores, depending on the ferrotitane content in the surfacing wire, was obtained by surfacing in pure nitrogen. This can be explained by a decrease in the solubility of nitrogen in the deposited metal due to the absence of an oxidizer in the protective atmosphere, which is consistent with the works [4, 5].

With an increase in the ferrotitane content in the powder wire charge, the titanium content in the deposited metal increases. At the same time, its tendency to pore formation also decreases in multilayer surfacing.

On the other hand, the addition of carbon dioxide to nitrogen as a protective atmosphere enhances the boiling of the welding bath in its high-temperature

region due to the formation of carbon monoxide



In this case, the resulting carbon monoxide is removed from the welding bath and promotes the release of supersaturated nitrogen from the liquid metal to the surface.

It should be emphasized that the pores are mainly formed at the end of the deposited roller. This phenomenon, apparently, can be explained by the presence of «bubble boiling» of the welding bath due to the supersaturation of the surface layers with nitrogen.

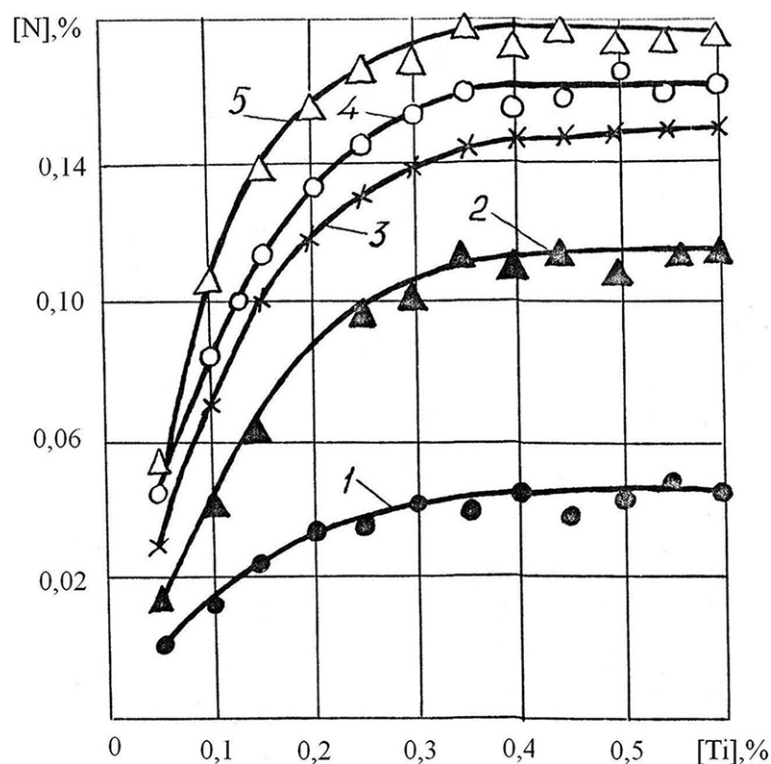
However, with an increase in the ferrotitane content in the charge of PP-AN133 powder wire, the den-

sity of the deposited metal increases (Figure 2). With a ferrotitanium content in the range of 3.5...4.0%, the absence of pores was recorded even in the five-layer surfacing in the studied protective atmospheres at an arc voltage of over 28 V.

Titanium, as a strong nitride-forming agent, increases the solubility of nitrogen in the deposited metal, reduces its release during the crystallization of the welding bath. Titanium still in liquid metal increases the time interval before the «bubble boiling»

begins. At the same time, the crystallization of the welding bath has time to occur even before its possible boiling.

With an increase in the arc voltage, the tendency of the deposited metal to pore formation increases (Figure 3), since the solubility of nitrogen in the metal increases. Therefore, the surfacing must be carried out at the minimum allowable arc voltage, ensuring satisfactory formation of the deposited roller. It should be noted that the titanium content in the deposited



1 – CO₂; 2 – 30%N₂ + 70%CO₂; 3 – 50%N₂ + 50%CO₂; 4 – 70%N₂ + 30%CO₂; 5 – 100%N₂

Figure 2 – The effect of titanium on the solubility of nitrogen in the deposited metal (PP-AN133, 3-layer surfacing)

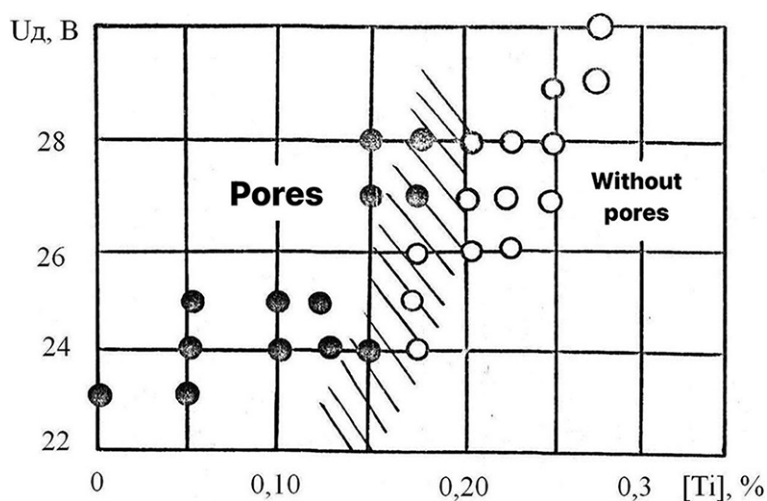


Figure 3 – The effect of the titanium content in the deposited metal, on reducing the tendency to pore formation in it (4-layer surfacing)

metal of more than 0.4% practically does not change the solubility of nitrogen in the deposited metal, but at the same time the technological properties of the wire deteriorate, the arc burns less steadily, there is an increase in slag formation and the separability of the slag crust becomes difficult.

Conclusion

Thus, a significant factor reducing the formation of pores from nitrogen in the deposited metal 10X17H8X5G2T is the content of ferrotitane in the

charge of the PP-AN 133 powder wire. At the same time, the titanium content in the deposited metal should be within 0.2...0.4%. A further increase in the concentration of titanium leads to a deterioration in the formation of the deposited metal and to an increase in the amount of slag on the surface of the deposited layer. The introduction of carbon dioxide of at least 30% to nitrogen makes it possible to obtain a dense deposited metal due to its better absorption of nitrogen.

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Азотты кеуектілік және азот құрамды атмосферада доғалы балқытып қаптастыру жағдайында оны ескерту тәсілдері

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Аңдатпа. Беткейге түсетін тесіктер қақпа жабылған кезде клапанның тығыздығының бұзылуына әкелуі мүмкін, сонымен қатар, әсіресе жоғары жылдамдықты орта ағындар жағдайында эрозия зақымдалуының ошағы болуы мүмкін. Кеуектер металдардың коррозияға ұшырауына да ықпал етеді, өйткені белгілі бір агрессивті ортаның әсерінен олардың мөлшері ұлғаяды және ысырманың тығыздығын бұзады. Көмірқышқыл газының қатысуымен дәнекерлеу ваннасының металымен азоттың сіңуі жоғарылайды және балқытылған металдың кеуек түзуге бейімділігі төмендейді. Азотқа кем дегенде 30% көмірқышқыл газын енгізу азотты жақсы сіңіру арқылы тығыз балқытылған металды алуға мүмкіндік береді. 10X17H8C5Г2Т балқытылған металда азоттан кеуектердің түзілуін төмендететін маңызды фактор ПП-АН 133 ұнтақ сымның шихтасындағы ферротитанның мөлшері. Балқытылған металдағы титанның мөлшері 0,2...0,4% аралығында болуы керек. Титан концентрациясының одан әрі артуы балқытылған металдың түзілуінің нашарлауына және балқытылған қабаттың бетіндегі қож мөлшерінің көбеюіне әкеледі.

Кілт сөздер: кеуектер, нитрид түзуші элементтер, балқыту, азотты кеуектілік, балқытылған металл, құбыр арматурасы.

Азотистая пористость и способы ее предупреждения в условиях дуговой наплавки в азотсодержащей атмосфере¹***ТӨРЕХАНОВА Марал Төреханқызы**, старший преподаватель, *maraltt_1985@mail.ru*,¹**КАБДУЛЛИНА Динара Сайлаубековна**, старший преподаватель, *aldiy2009@mail.ru*,¹НАО «Восточно-Казахстанский технический университет имени Д. Серикбаева», Казахстан, Усть-Каменогорск, ул. А.К. Протозанова, 69,

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Аннотация. Поры, выходящие на поверхность, могут вызвать нарушение герметичности арматуры при закрытом затворе, а также явиться очагом эрозионных разрушений, в особенности в условиях скоростных потоков среды. Поры содействуют и коррозионному разрушению металлов, так как под действием определенных агрессивных сред они, увеличиваясь в размерах, вызывают нарушение герметичности затвора. В присутствии углекислого газа повышается поглощение азота металлом сварочной ванны и снижается склонность наплавленного металла к образованию пор. Введение углекислого газа не менее 30% к азоту позволяет получать плотный наплавленный металл за счет лучшего поглощения им азота. Существенным фактором, снижающим образование пор от азота в наплавленном металле 10X17H8C5Г2Т, является содержание ферротитана в шихте порошковой проволоки ПП-АН 133. Содержание титана в наплавленном металле должно быть в пределах 0,2...0,4%. Дальнейшее увеличение концентрации титана приводит к ухудшению формирования наплавленного металла и к увеличению количества шлака на поверхности наплавленного слоя.

Ключевые слова: поры, нитридообразующие элементы, наплавка, азотистая пористость, наплавленный металл, трубопроводная арматура.

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