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REPAIR WELDING PROCEDURE AND TECHNO-ECONOMIC ANALYSIS OF BURNER PIPE

REPARATURNO ZAVARIVANJE CEVI GORIONIKA SA TEHNO-EKONOMSKOM ANALIZOM

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Ključne reči
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- analiza mikrostrukture
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- prsline
- legura X12NiCrSi35-16

Abstract

The selection of the electrode for repair welding is one of the activities needed before repairing machine parts. In this case, damages that have occurred in a burner pipe welded joint during manufacture or previous repair welding have resulted in the need to replace the previously used electrodes with more suitable ones for the exploitation conditions to which the burner is subjected. For this purpose, 2 specimens welded with 2 different electrodes (Castolin and 6825 and PIVA 25/20 B) are cut from the pipes and tested. Micro- and macro-analyses of these specimens are performed, along with hardness testing. It is concluded that the Castolin 6825 electrode is better suited for burner pipe repair welding. Following this, the test repair welding of the burner pipe is performed. In addition to penetrant tests of the welded pipe, a short overview of the techno-economic analysis of the repaired pipe is given, including the ratio of repair price to the price of manufacturing a new burner.

Izvod

Izbor dodatnog materijala reparaturnog zavarivanja predstavlja jednu od aktivnosti koju je potrebno uraditi pre reparature mašinskog dela. U ovom konkretnom slučaju oštećenja cevi gorionika, koja su se pojavila na zavarenim spojevima tokom ranijih izrada cevi ili reparaturnih zavarivanja nametnuli su potrebu za promenom do tada korišćenih elektroda i upotrebu druge, adekvatnije elektrode, primerene radnim uslovima kojima je gorionik izložen. U tu svrhu, ispitivana su 2 uzorka uzetih sa cevi, koji su zavareni sa 2 različite elektrode (Castolin 6825 i PIVA 25/20 B), odnosno, urađena su ispitivanja tvrdoće, makro- i mikroanaliza izrađenih uzoraka. Analizom se došlo do zaključka da je Castolin-ova 6825 elektroda pogodnija za reparaciju cevi gorionika, i za tu svrhu urađeno je probno zavarivanje cevi. Pored ispitivanja penetrantima probno zavarene cevi, dat je i kratak osvrt na tehno-ekonomsku reparaciju cevi i odnos cene reparacije i izrade novog gorionika.

INTRODUCTION

Maintenance and repair represent different types of operations but have many common attributes. Both require individuals possessing a broad knowledge of welding and materials. Repair and its activities involve the salvaging of broken, worn out, or inoperable parts for continued use /1/. Welding is a process that requires considerable attention during all of its stages: design, technology development, performing of the process itself, welded joint control and sending the part back into service. Deviations from any of these stages may lead to the occurrence of defects in welded joints, /1-4/.

Damaged equipment in industrial facilities may be welded with or without dismantling. The process chosen for repair welding depends on several factors, such as the choice of filler metal for welding. The electrode or filler metal chemistry and mechanical properties must be determined during the planning of maintenance and repair procedure. The cause of fracture can be influenced by the selection of electrode or filler metal used for the repair procedure.

In this paper, a selection of the electrode for the repair welding of burner pipes in the ‘Hladna Valjaonica’ facility, belonging to Steelworks Smederevo, is made. Conditions under which the burner pipe was working lead to the need for repair welding, whereas the nature of the damage resulted in the need to replace the electrodes that were used. In this case, two electrodes are tested, first of which is typically used in the repair welding of these pipes, whereas the second one had mechanical properties that needed to be determined. The justifiability of the burner pipe repair procedure is presented through a techno-economic analysis that indicated significant direct and indirect savings, resulting from its application.

BURNER PIPE: DESCRIPTION, EXPLOITATION CONDITIONS, BASE MATERIAL

The burner is used for heating during the continuous annealing of a cold rolled strip. Natural gas combustion takes place within the burner, wherein the chamber through which the strip passes is heated by the heat generated through ‘W’ burners (Fig. 1).

Due to high temperatures that can reach up to 850°C and ‘explosions’ that occur during gas ignition, cracks may occur in the input part of the ‘W’ burner. Some of the damage on the ‘W’ burners is shown in Fig. 2. Damages have occurred in the base material, however, locations most vulnerable to cracking were in the welded joints.

Damages, as mentioned in the introduction, resulted in the need for repairing the damaged pipe parts. The repairs involved cutting off from the damaged part of the pipe and replacing it with a new pipe. The base material used for the burner is stainless steel nickel alloy X12NiCrSi35-16, of chemical composition as shown in Table 1, whereas its microstructure can be seen in Fig. 3. Base metal microstructure is austenitic with spheroidal pearlite. A significant presence of carbides is observed in the base material structure.

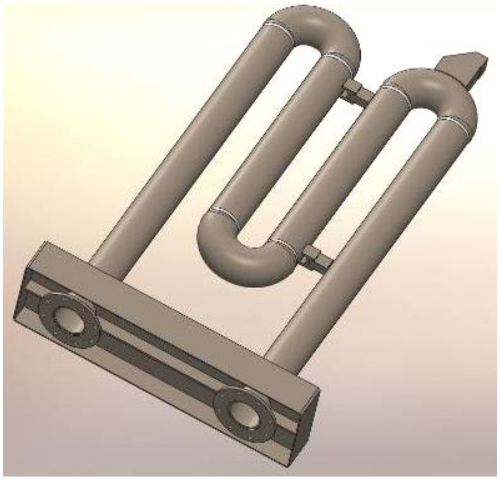

Figure 1. Model ‘W’ burner.

Figure 2. ‘W’ burner pipe input damage.

Table 1. Chemical composition of the burner pipe base material, /5/.

Element	C	Si	Mn	P	S	Cr	Ni	Cu	Al
Percentage [%]	0.270	2.583	2.057	0.029	0.024	21.01	31.84	0.063	0.045
Element	Mo	Ti	As	V	Nb	Sn	Pb	W	Co
Percentage [%]	0.079	0.058	0.015	0.023	0.409	0.153	0.004	0.123	0.365

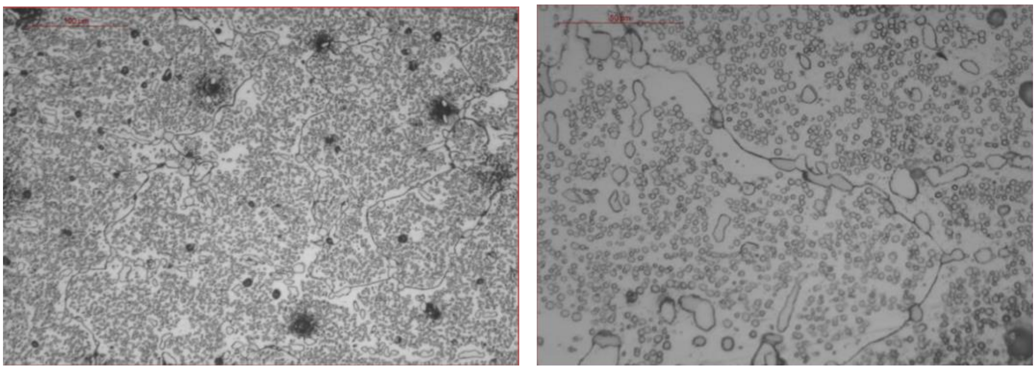

Figure 3. Burner pipe base material microstructure.

FILLER METAL FOR REPAIR WELDING

Welding procedure specification and filler metal selection need to be made before the welding process takes place. For the purpose of repairing burner pipes, manual arc welding procedure is selected, which also influences the choice of filler metals. Filler metal quality, as well as the performing of welding activities affect the quality of the welded joint. Filler metal selection must be approached responsibly while taking into account the specification of this material and electrodes, as well as the purpose of the electrodes for specific types of steels. The selection of filler metal also requires adequate treatment and storing of such materials for the purpose of avoiding defects that could occur due to the presence of impurities or humidity, /6-9/.

During the previous repair welding of burner pipes, electrodes containing 25% Cr and 20% Ni (in further text, electrodes type 25/20), i.e. electrodes PIVA 25/20 and INOX 25/20 B were used. Experience has shown that, for most welded joints, cracks will typically occur due to conditions under which the pipes are working (high temperatures and its cyclic change) which lead to crack initiation, most commonly encountered in the weld metal. Cases of burner pipes in which cracks occur along the welded joint length are shown in Fig. 4, as a very rare case in practice.

Figure 4. Cracks along the welded joint length in burner pipes.

Table. 2 Chemical composition of electrodes PIVA 25/20 B and Castolin 6825 /9, 10/.

Electrode \ (%)	C	Si	Mn	P	S	Cr	Ni	Cu	Mo	Nb+Ta	Fe
Castolin 6825 (catalogue)	0.01	0.2	0.69	0.005	0.002	20.95	63.52	0,01	9.2	3.4	1.84
PIVA 25/20 B (catalogue)	0.12	1.0	2.5	/	/	25	20	/	/	/	/

For the purpose of analysing the selection of filler metal for burner pipe repair welding, a parallel testing of welded joints is performed, wherein these joints are welded using 25% Cr and 20% Ni electrodes and Castolin 6825 electrodes. The pipes are welded using the two materials and specimens are taken from locations 1 and 2 (Fig. 5). These specimens are subjected to hardness tests, along with macro and microstructural analyses. Chemical compositions of electrodes used are shown in Table 2.

Figure 5. Location 1 (welded with Castolin 6825 electrode) and location 2 (welded with PIVA 25/20 B electrode) in pipes.

PIVA 25/20 B is an austenitic-base electrode meant for welding water-resistant steels and steel casts, as well as for fireproof ferrite chrome steels, /9/. During the welding, a smooth weld is obtained, with easily removable slag. It is fireproof up to 1200°C and has guaranteed toughness as low as -196°C. Castolin 6825 electrode is a manual electrode used for joining nickel alloys, duplex, and super austenitic stainless steels, 9% nickel steels and dissimilar combinations with carbon steels, /10/. It has excellent resistance to stress corrosion cracking, pitting, crevice and intergranular corrosion. It also has very high dilution tolerance with nickel and ferrous alloys, and it is characterized with superior positional weldability and service temperatures from cryogenic to 980°C, /10/.

Welding of pipes from which specimens are taken from is performed using manual arc welding procedure (MAW), same as in the case of pipes in exploitation. Shown in Fig. 6 are macro appearances of specimens welded using Castolin 6825 electrode (6a) and PIVA 25/20 B (6b), along with the models of welded specimens with measured hardness values in all welded joint zones. Welds are corroded using an alcohol solution of nitric and hydrochloric acid. Figure 6c shows measured hardness values of specimens in Brinell units for Castolin 6825, whereas the hardness of specimens made with PIVA 25/20 B electrode is shown in Fig. 6d.

From the results presented here, it can be seen that the measured hardness of the welded joint made using the Castolin electrode was higher than PIVA 25/20 B specimens. It should be noted that a crack had occurred in the specimen welded with PIVA 25/20 B, as can be seen in Fig. 6b.

Microscopic investigation of tested specimens at locations 1 and 2 in the pipe determined that both specimens are pure in terms of non-metallic inclusions. Large carbides are observed in the base material of both specimens in their non-corroded state. In the case of specimen from location 2 (PIVA 25/20), micro-cracks are noticed in the weld zone, with lengths ranging from 2 to 3.5 mm. As previously mentioned, the microstructure of the base material is austenitic with spheroidal pearlite and separate large carbides. Microstructure of the specimen welded using Castolin 6825 electrode is shown in Fig. 7, whereas the microstructure of PIVA 25/20 B specimen is shown in Fig. 8. Figure 9 shows micro-cracks in the weld of specimen 2.

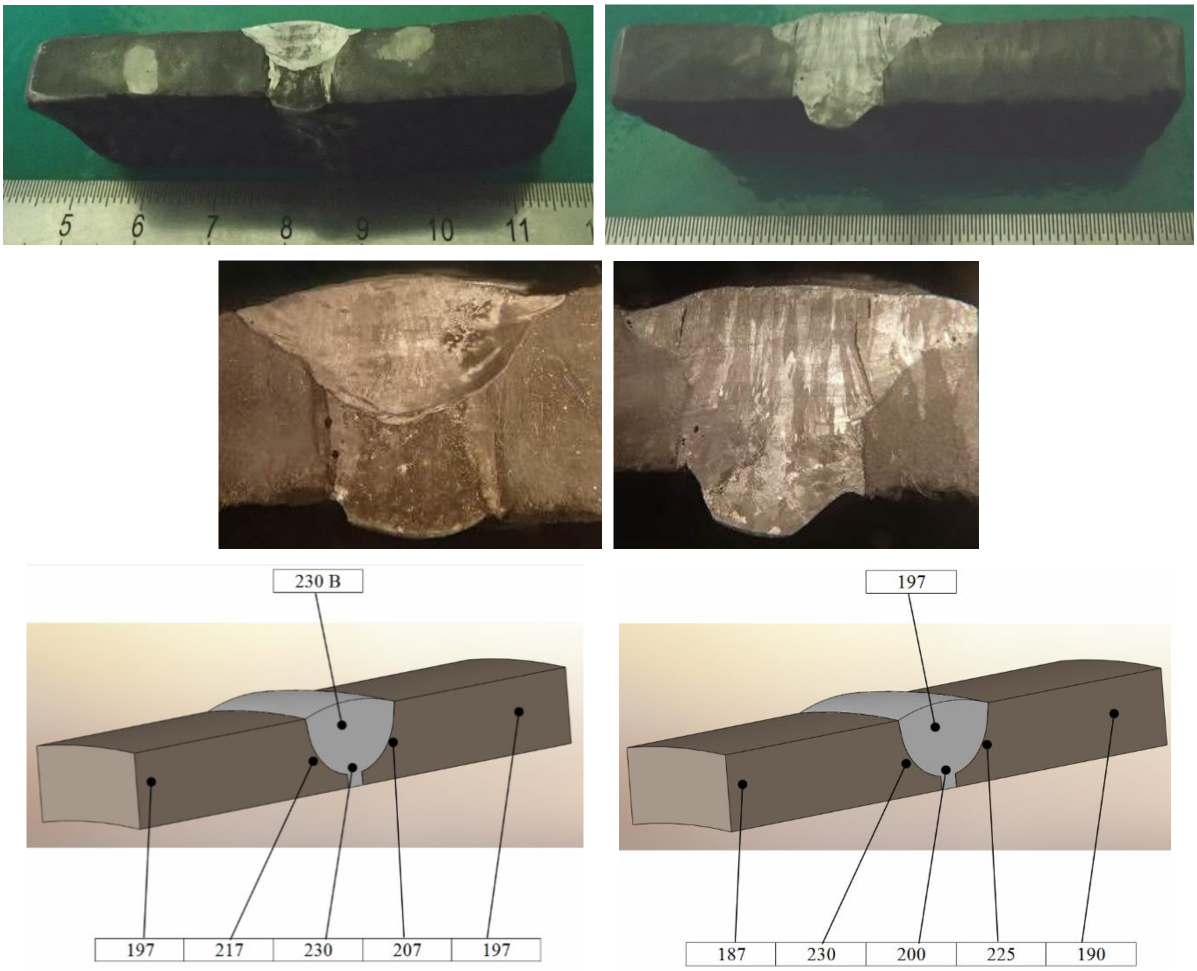

Figure 6. Macrographs of welded joints: a) Castolin 6825; b) PIVA 25/20 B; and measured hardness c) Castolin 6825; d) PIVA 25/20 B.

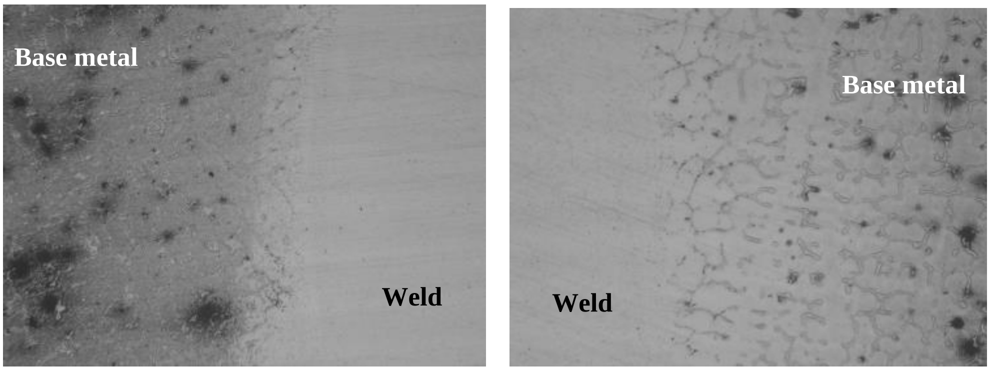

Figure 7. Microstructure of the Castolin 6825 specimen (corroded using an alcohol solution of nitric and hydrochloric acid).

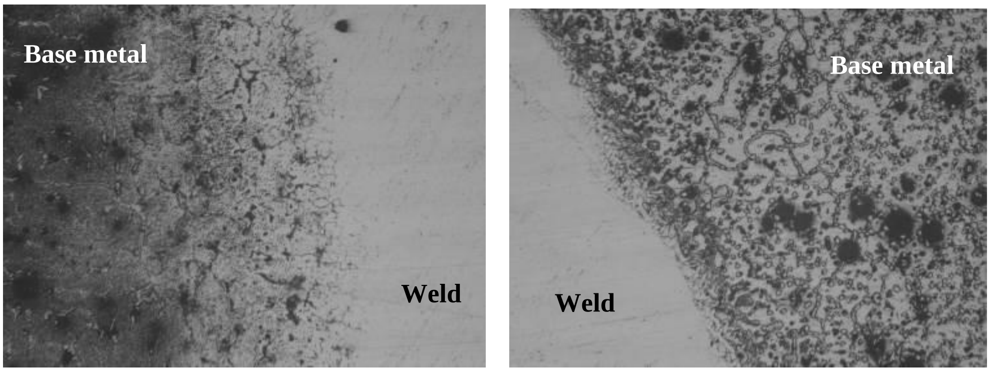

Figure 8. Microstructure of the PIVA 25/20 B specimen.

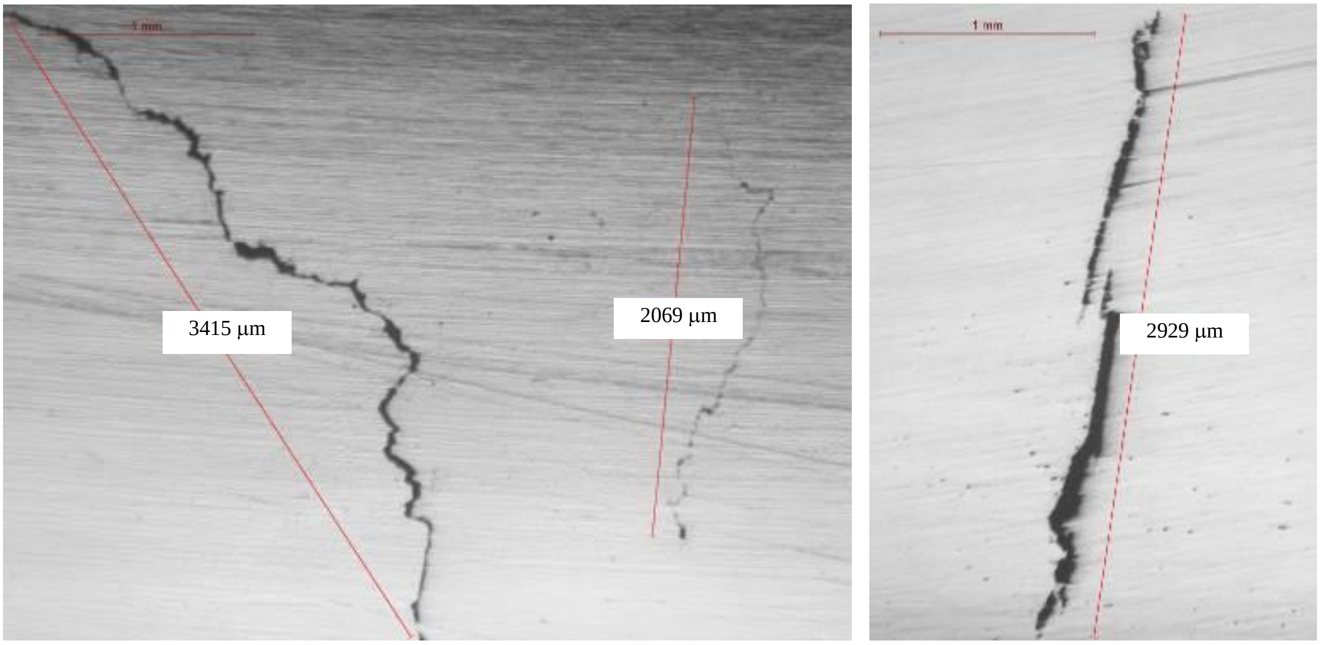

Figure 9. Appearance of micro-cracks in specimen 2 weld (PIVA 25/20 B).

TEST REPAIR WELDING OF BURNER PIPES

Previous results show that the weld made using electrode Castolin 6825 has better properties compared to the weld made with PIVA 25/20 B electrode. Microstructural analysis reveals a large number of cracks in the 25/20 specimen, unlike the Castolin one, which did not contain any noticeable defects in the welded joint. Due to the above mentioned facts, the conclusion is that the Castolin 6825 electrode should be used for burner pipe repair welding. For this purpose, a test welding of a single burner pipe is performed.

Welding current is 70 A, whereas voltage ranged from 20 to 22 V. The weld is made with frequent interruptions, i.e. the entire welded joint is made of short welds in order to avoid overheating of the material to temperatures above 100°C (similar to grey casts). Burner welding is performed in the ‘wall’ position (vertical position) without swaying the electrode. The appearance of the test welded burner pipe (welded joint) is shown in Fig. 10 (left). The weld is tested using penetrants, and no defects are detected, Fig. 10, right.

TECHNO-ECONOMIC ANALYSIS

The price of producing a new machine part dictates and determines the justifiability of repair /4, 8, 11-14/. Shown in Table 3 is the overview of repair costs for burner pipes, and when compared to the cost of manufacturing a new one, slightly above 10 000 EUR, it confirms the actual economic justifiability of burner pipe repairs. It can be seen from Table 3 that the total cost of repair is around 235 EUR, about 40 times lower compared to the manufacturing cost of a new burner. In addition to these direct savings, the use of this repair welding procedure also provides indirect savings, in the sense of waiting for the new part to be delivered, which would lead to downtimes within the facility, and could result in costs several thousand times higher than direct costs.


Figure 10. Welded pipe (left); penetrant testing of the pipe (right).

Table 3. An overview of burner pipe repair costs.

Cost element	Sum of total planned costs [EUR]
Filler metal cost [130 EUR/kg], total for two welded joints	113.5
Welding activities	45
Penetrant test costs	8.5
Base material costs	50
Miscellaneous costs (tools, consumables, grinding plate, depreciation costs)	10% of total cost
Total sum	~235 EUR

CONCLUSION

Selection of filler metal represents an important step in the algorithm of operations involved in repair welding. Direct comparison of properties and characteristics of welded joints made with different electrodes represents the best approach to selecting of adequate filler metals. In addition, selection of electrodes is affected by both the exploitation conditions to which the repaired part is subjected and its base material.

Electrode type 25/20, used so far, did not represent the best solution for repairing of burner pipes, thus the process of finding a better suited electrode is undertaken. Direct comparison of macro- and microstructures, as well as measured hardness values for the two tested specimens taken from pipes welded using 25/20 and Castolin 6825 electrodes determined that the Castolin electrode is the better choice. This is further confirmed by the fact that a large number of micro-cracks is observed in the weld metal itself, in the case of PIVA 25/20 B electrode. Following this, test welding of burner pipes is performed, and the subsequent penetrant test did not reveal any defects on the pipes. The pipe is released into exploitation and its behaviour is being monitored.

It is interesting to notice that pipes from which the specimens are taken, as well as the pipe later put into exploitation (welded by Castolin 6825 electrode of diameter 3.25 mm) are welded with a current of 70 A, whereas the temperature during the welding did not exceed 100°C. This electrode is meant to work at temperatures up to 1100°C.

The techno-economic analysis shows savings achieved by repairing the pipe. Direct savings are reflected in the fact that the price of a new burner is about 40 times higher than repair cost. Indirect savings resulting from facility downtime, further emphasize the significance of an adequate and high-quality repair welding of any and all machine parts.

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