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REMEDY BY RECONDITIONING THE METAL PARTS DEFECTS FROM THE COMPONENT OF PUMPING AGGREGATES

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Abstract: Repair of defects in parts and subassemblies of pumping units is generally done by refurbishing. Reconditioning of parts is a component of maintenance work, includes the necessary measures to restore worn or damaged parts in working order. Through reconditioning, maintenance costs are reduced by 30–70%. The high share of spare parts and subassemblies, pumping units in the cost price of the repair of a pump, gives the reconditioning activity a special role in reducing costs. The share of spare parts in the cost of a repair is about 45–75%. Reconditioning technologies must be simple, and materials and energy consumption reduced. In this paper, the authors present some technological procedures for reconditioning cast iron and steel parts from the component of the pumping units and some proposals for improving the functional characteristics of the pumping units.
Keywords: pumping aggregates, metal parts, reconditioning, mechanical processing, welding loading, metallization

1. INTRODUCTION

The reconditioning activity comprises a succession of technological operations (mechanical processing, heat treatment, metal coatings, welding, etc.) whereby a worn part as a result of its operation or damaged, through damage is restored to the functional parameters of use. The opportunity to perform the refurbishments is done based on technical–economic analyzes and especially the cost of the refurbished part. For parts where the cost of reconditioning represents over 50–60% of that of the new part, reconditioning is not recommended.

The main stages of the repair activity are the disassembly of the parts of the pumping unit assembly, the sorting in order to identify the worn or damaged ones, the washing, finding and delimiting the wear or damage, establishing the reconditioning technology and performing the reconditioning operations [1].

The main reconditioning technologies are mechanical processing, metal coatings by welding layer loading, galvanic coatings, metallization, mechanical straightening (with bracelets, ribs, gussets, etc.), processing by plastic deformation (forging) and the use of compensators (complementary parts) [1,2].

Within the final adjustment operations of the reconditioned parts, mechanical processing, thermal treatments and dimensional and structural control are performed.

2. EXPERIMENTS

— Reconditioning by mechanical processing

It is recommended for worn parts such as shaft or shaft, where the wear is not advanced. By processing, the geometric form and the roughness of the surfaces are reproduced. Reconditioning by mechanical processing includes operations such as turning, milling, milling, grinding, etc. At advanced degrees of wear, it is recommended that the reconditioning of the part–counterpart assembly be carried out by increasing the part size and the corresponding reduction of the part size. In the shaft–type parts, wear is found mainly in spindles.

Mechanical machining is preceded by hot or cold straightening operations. Mechanical processing is also performed as final operations after metal coatings. The thickness of the layer to be removed has the following values:

≡ to the hard–chromed parts 0.05–0.15 mm;

≡ to the metallic parts 1–3 mm;

≡ to the parts loaded with welding 2–5 mm.

— **Welding layer loading**

The reconditioning can be performed by oxyacetylene welding (for castings, steel and non–ferrous parts) or by electric welding (for steel parts).

The technological process includes the identification of wear or damage, preparation of surfaces (removal of the oxide layer, degreasing of the worn area), peeling of the worn area, checking the chemical composition, preparing the mark for welding, tightening by screws the cracked portions, pre–heating the parts (pre–heating the components), made of non–alloy steel with thicknesses over 30 mm, 100–150°C, on pieces of low alloy steel with high carbon content, 150–350°C, on pieces of alloy steel, 150–350°C, on castings, 600–720°C), coating with welding layer, checking the quality of the deposited layer (porosity, cracks, adhesion, compactness, inclusions, oxides), annealing treatment, mechanical processing and thermal improvement treatment.

— **Welding in CO_2 atmosphere**

The CO_2 atmosphere protects the electric ring formed between the electrode and the part. It is necessary that the material which is lost by oxidation must be compensated with the additive material. Under these conditions, welding speeds of 0.5–1 m/min and productivity of 2–8 kg/h are achieved. Productivity can be increased by using a second electrode without being electrically powered. Table 1 shows the main technological parameters.

After the metal loading, the reconditioned parts are heat treated (annealing) and turned to preset dimensions. The roughness of the deposited layers depends on the quality of the workpiece surface preparation, the degreasing method used, the impurity content of the protective gas, the welding execution angle.

Table 1. Technological parameters for CO2 welding

Technological parameter	U.M.	Value
Current intensity	A	80–250–40 (small values correspond to the short arc)
Current density	A/mm²	100 – 800
Welding voltage	V	16 – 28 – 36
Welding speed	mm/min	200 – 600 – 1000
Advance wire	mm/s	0,0 – 17,2
Wire diameter	mm	1 – 2,4
Wire number	–	1 or 2
Productivity	Kg/h	1 – 8
Oxidation depth	mm	1 – 5
Gas pressure	MPa	0,2 – 0,3
Gas consumption	1/h	12 – 26

The electric arc is protected against oxygen and nitrogen and stabilized by the flow of metal powders.

The flow also has the role to compensate the alloying elements lost by oxidation, to introduce elements that give the layer deposited special properties and to achieve thermal protection so that the amount of welding developed by the electric arc is used for welding. Table 2 gives values for working parameters. It is recommended that the electrode be placed inclined and eccentric to the axis of the reconditioned part. High values of the width/height ratio of the welding cord are required. The depth of penetration of the oxides is up to 10mm.

The main characteristics obtained are a degree of mixing of 50% between the basic material and the additive material; hardness HB = 3500–5000 N/mm2; the weld layers are bonded to pores and inclusions of oxides.

It is recommended that the high alloy steel parts be preheated before loading and annealed after reconditioning.

For the realization of the bimetals resistant to corrosion and wear, the plating head is used with two band electrodes, which uses, by melting with electric arc under flow, high, medium and weak alloy steels. This device is attached to the welding and charging facilities under a flux electrode with a tape electrode. Productivity (molten metal) of 20–30 kg/h is obtained, with 60x0.5 mm band electrodes.

Table 2. Technological parameters for welding load under flow layer

Parameter name	U.M.	Value	
		Wire electrode	Tape electrode
Thickness of cord	mm	2–4	
The diameter of the wire	mm	2–6	
Tape dimensions	mm	–	0,4– x40–100
Current intensity	A	80–400	500–1200
Welding voltage	V	20–30	23–40
Advance (wire, tape)	m/min	1–7,5	1–2,2
Welding speed	m/min	0,2–5	0,16–0,50
productivity	Kg/h	Up to 40	Up to 60

— **Reconditioning by welding of steel parts**

Used parts that can be reconditioned by welding are shafts, axles, gears, etc. It is especially recommended electric arc welding [3]. For the welding of worn steel parts, the welding of the heat–treated parts must be followed by the restoration of the heat treatment, in order to ensure the initial mechanical properties and welding of the alloyed steels to be done with special electrodes.

During welding coating, hard fusible oxides are formed, which can compromise the quality of the work; as a result of the reduced thermal conductivity and the tendency of self–heating, internal tensions that cause cracks occur in the welding of the alloy steels; the worn parts are peeled before being covered with metal (depth up to 4–5mm), depending on the size of the mark, to eliminate the area with a non–homogeneous structure. The welding cords must cover each other at one–layer loading, and at two–layer loading they overlap. The welding of the axle type parts is done symmetrically and alternatively on the parts covered, in order to ensure a uniform heating, in order to limit the thermal effects in the area subject to reconditioning, the rest of the part is isolated from the used area (by water cooling, protection with asbestos).

For the reconditioning of worn parts statically required, 0.15–0.55 mm electrodes and over 0.6 mm sheath electrodes are used for carbon steel or dynamically requested alloy steel.

— **Reconditioning by welding of cast iron parts**

It is executed by welding with oxyacetylene flame. Cast iron rods type VRS 30 or VRS 36 are used as an additive material. Welding of cast iron rods is done hot with rods having the composition: 3–3.4% C; 4–4.5% Yes; 0.6–0.8% Mn; max. 0.66% S; 0.2–0.6% P; 92.18–90.84% Fe.

When reconditioning the castings of gray cast iron, it is recommended for thicknesses up to 10 mm – ϕ 6 mm, for thicknesses 10–14 mm – ϕ7–10 mm and for thicknesses over 15 mm – ϕ10– 5mm. The welding flow will have borax –50%, sodium bicarbonate –47%, silicon dioxide –3%. Flows with compositions are also used: 80% calcined soda; 18% boric acid and 2% silicon dioxide or 56% borax, 22% sodium carbonate and 22% potassium carbonate.

Worn castings are reconditioned by welding under certain conditions, to limit the danger of cracking. The cracks are caused by the internal stresses that occur in the area covered by the weld. Therefore, it is necessary that the cast iron parts be preheated for coating and cooled slowly by coating with charcoal or controlled cooling in the oven. The metal coating is made with interrupted portions to allow the landmark to cool. After welding the piece is cooled slowly by 40°C/h, to avoid cracking in the welding cord. When the duration of the welding operation exceeds 1.5–2 hours it is necessary for the part to be reheated.

For cold welding (preheating at 100–200°C) electrodes with 63% Ni and 37% Cu are recommended, or bimetallic electrodes with copper core protected with blackboard and with a flux layer composed of 25–30% soluble glass and 75 – 70% chalk.

— **Electrochemical coatings**

The technology consists in electrochemically depositing a metal layer on the surfaces of worn parts. It is applied to small parts, not being justified in terms of energy consumption and the complexity of the installations in large parts. The main advantages of electrochemical coatings, compared to the welding load are the addition of processing is about 30–40% lower, the danger of cracking is eliminated, the structure of the worn part material is not changed, the coated surfaces have high hardness and the deposited layer is uniform and it can be controlled precisely.

The parameters of the electrochemical coating technologies are the coating duration, current density and temperature at which the process takes place.

— **Copper plating**

It consists of electrochemical deposition of copper in the used areas. It is used for the reconditioning of bronze parts or for making a protective layer for steel parts that are chromed, nickel or carbide.

The coating bath contains copper sulphate electrolytes (200 g/l water and sulphuric acid 50 g/l water). The anode is an electrolytic copper plate with thicknesses of 5–10 mm. The cathode is the worn part. The thickness of the deposited electrolytic copper layer is 0.01–0.015 mm/h.
The coating technology is characterized by the following average values: current density 1–5 A/dm2 (without shaking) and 5–25 A/dm2 (with shaking); voltage 1.5–2 V. Sulphate and alkaline electrolytes are used.

— Zinc

It has the role of protecting the parts against corrosion. Acid and alkaline electrolytes are used. Sulphuric acid electrolytes have stability, good current yields and are non–toxic. Increased corrosion resistance of zinc plated parts is achieved by passivating metal deposits with chromic acid solutions.

— Nickel

It consists in electrochemically covering the worn surfaces of the parts, with nickel. It has limited use due to the high costs. It gives the piece resistance to wear and corrosion. Electrolytes based on sulphate, flu borate, sulphamate etc. are used. It is recommended that depending on the position of the electrolyte and the working regime the pH should be from 2–6 with a maximum variation of ± 0.2. Boric acid is used for this. The technology comprises three stages. In the first step, 0.02 A/dm2 is used, in the second step 0.2 A/dm2, in the third step 1 A/dm2. Chemical nickel consists of depositing nickel on parts with complex and degreased surfaces without the use of electric current.

— Chrome plating

It consists in depositing at low temperatures, on the cathode, at the passage of electric current, the metallic chromium, which adheres to the surface of the piece, forming a film. Chroming gives the parts great resistance to mechanical wear. The thickness of the layer is 0.005–0.8 mm. The casting speed is 0.015–0.030 mm/h.

Table 3. Chroming procedures

Technological parameters	Normal hard chrome plating	Cold hard chrome plating	Hard chromium plating with self–regulating electrolyte	Porous chrome plating	Reversible chrome plating	Spray chrome plating
Particularities			Composition of constant electrolyte, homogeneous deposition at variations + 5°C	After hard chrome plating the polarity is reversed (anodic pickling)	The bath connects 10 min cathode and 10–15 min anode	Electrolyte charged with pump and sprayed on the part
Electrolyte	CrO_3 H_2SO_4 100: 1	CrO_3 H_2SO_4 In high concentration	CrO_3 H_2SO_4 $SrSO_4$ K_2FsiO_8	CrO_3 H_2SO_4 120: 1	CrO_3 H_2SO_4 100: 1	CrO_3 H_2SO_4 100: 1
Current density in A/dm²	35–45	30–100	40–100	50–60	60–150	35–45
The voltage in V	30	30	30	30	30	30
The temperature of the bath in °C	56–58	18–22	45–55	50–60	56–58	56–58
Layer thickness in mm	1	1	1	1	1	1
Current efficiency in %	13–15	30–33	17–18	14–16	14–16	13–15
Filing speed in µm/h	30–42	80–100	45–50	45–50	60–80	30–42
Hardness in N/mm²	12000	7000–8000	12000	12000	12000	12000

Chrome plating is applied to steel, cast iron and non–ferrous metals. When done in thick layers it is called hard chrome plating. Hard chromium plating has a wide scope determined by the properties of the layers deposited. Hard chrome technology is used for refurbishing large series parts. The main features of the chromium technology are the electrolyte is based on chromic acid, the current efficiency decreases with the increase of the chromic acid concentration and with the temperature and it increases with the current density.

Chromic acid with a concentration of 250 g/l CrO_3 is used to prepare the electrolyte. Above these limits the efficiency of the current and the power of penetration decrease, and the losses of electrolyte caused by the hydrogen and the oxygen that are released, become great.
Chromium deposits are optimal for the CrO_3/SO_4 2– ratio of 100 and 200. Table 3 presents the main chroming technologies.
The hard chrome plating layer has high thermal conductivity and low thermal expansion coefficient. The hard chromium gives the deposited layers sensitivity to strokes, determined by the presence of hydrogen. The main chromium electrolytes are presented in Table 4.

Table 4. Composition and working regime of the main chromium electrolytes

Electrolyte composition working regime	Electrolyte concentration g/l			
	A	B	C	D
Chromic anhydride	150	250	350	200–300
Sulfuric acid	1,5	2,5	3,5	–
Strontium sulphate	–	–	–	5,5–6,5
Potassium fluosilicate	–	–	–	18–20
Temperature, in °C	55–65	45–55	35–45	50–70
Current density in A/dm²	45–100	15–60	10–30	40–80
Current efficiency in %	14	12	11–12	17–19

The use of chroming is limited by high energy consumption, neutralization of used solutions in complex installations and forced ventilation installations of the chromium baths and of the general chromium workshop (requires additional spaces).

— Metallization

Metallization is a modern technology for reconditioning used parts, which consists in coating by casting molten metal micro pulverized on the worn surface, giving the piece wear and corrosion resistance. Metallization can be done cold or hot.

— Cold metallization process

The principle of use of metallization is based on an exothermic reaction of physic–chemical origin. At the time of projection on a specially prepared surface, the particles of micro pulverized alloys (with diameters of 10–150 microns) are at a temperature close to that of melting.
Due to the temperature of the particles, when they reach the surface of the piece, exothermic reactions occur, producing an enough high heat to cause the metal granules to melt from the surface layer of the piece and to produce a micro–weld. The diffusion of the pulverized particles in the cold metallization processes cannot be achieved, because the particles cool at high speeds and therefore no structural bonds can be obtained. Upon reaching the part, the particles deform and cool rapidly. The blades that adhere to the surface roughnesses are formed, accumulating by successive deposits in layers with thicknesses of 0.03 – 5 mm.
The molten particles have a reduced thermal inertia. For this reason, they suddenly cool down and transfer a small amount of heat to the part they are depositing. In the deposition area, the surface of the metallic part does not exceed 90°C. As a result, there are no structural changes, geometric deformations and the heat treatment of the part is not affected.
The rapid cooling of the molten particles causes additional stresses in the deposited layer. The size of the stresses and the thickness of the layer depend on the size, the composition, the temperature of the particles, the speed of deposition, the spraying distance, the metallization process used.

— The hot metallization processes

In this situation the piece to be reconditioned, has the worn surface prepared in the same way as for the "cold" process, but it is preheated.
The micro pulverized additive alloy is designed with a metallic installation. There is a mechanical clamping between the base metal and the additive alloy. The latter is then melted. The deposition obtained is homogeneous, free of pores and oxides. In figures 1, 2 and 3 are presented two metal parts that are reconditioned by metallization.

3. RESULTS AND DISCUSSION

— Proposals for improving the functional characteristics of the pumping units

In most cases where an attempt was made to improve the metallic characteristics of the components of the pumping units, it was taken into account, in addition to the cost of the proposed variant, the duration of the repair, which has the largest share in the life of the pumping unit.
The duration of the repair, in the case of the pumping units that equip the pumping stations of irrigation or of the desiccation is as important as in the case of the stationing of the agricultural

machines and the combines due to the malfunctions. In both situations, their exploitation must be carried out strictly within a certain period of the year, and for a certain period.

Just as a crop cannot wait for weeks or months, repairing an agricultural machine or combining defects, waiting for a landmark on the other side of the globe, so the plant needs urgent water but not over a very long period which would require repair of an irrigation pumping unit; also, the high level of water from a drainage channel, which threatens the flooding of some agricultural crops or even human settlements, must be resolved as a matter of urgency.

From the point of view of the methods of reconditioning of the parts of the pumping units, two technologies were used, the technology of reconditioning by complementary addition and the technology of reconditioning by metallization.

Figure 1. Ax pump DV 2–87

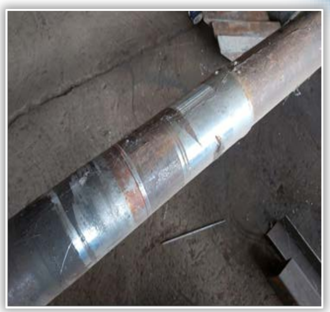

Figure 2. Used pump shaft

Figure 3. Damaged thread

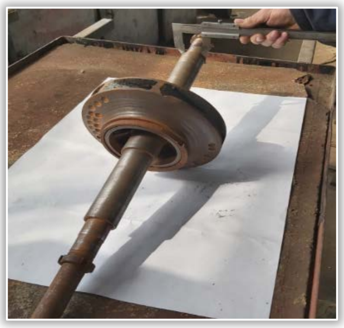

Figure 4. Decalibration of fuse channel shaft

— **Reconditioning technology through complementary addition.**

Because the size of the pumping units studied is large and very large: a pump shaft DV 2–87 has a length of 5 m, and a diameter of 150 mm (figure 1) does not justify the repair by replacing it with a new part, for a shaft wear of 0,5–2 mm, (figure 2); either for thread wear (thread deleted figure 3) or for a shaft decalibration containing the breakdown channel (figure 4).

For a Danube pump rotor –750, open type rotor, the repair that would usually consist of replacing a blade (figure 5), can be reconditioned by applying a steel compensating bar.

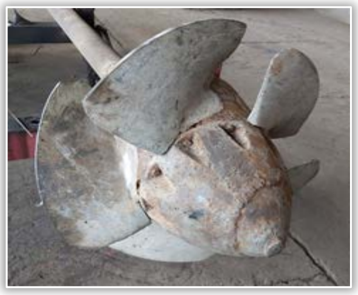

Figure 5. Pump rotor requiring blade replacement

Figure 6. Rotor machined by cutting on the lathe

For this procedure, after the rotor has been caught and balanced in a SN 600 x 5000 lathe, (figure 6) a piece of material from a higher quality steel is cut than the one from which the blade is manufactured (figure 7).

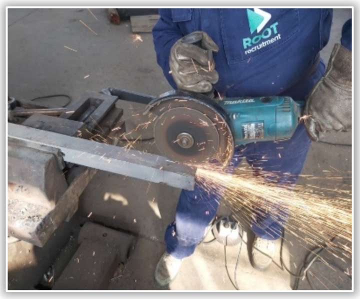

Figure 7. Cut piece material added

Figure 8. Welded piece added

After the addition of the material has been welded on the blades of the rotor (figure 8) it follows a machining by cutting in order to obtain the technological diameter necessary for the operation of the pump in parameters.

At the end of the reconditioning process, a dynamic balancing is performed based on addition or lack of material, applied to the rotor hub or as close to its axis of rotation.

The reconditioning with compensating part is realized by mounting a bush of a steel superior to the one from which the shaft is reinforced by welding, after which by a machining by cutting the initial diameter of the spindle, the thread corresponding to the new one or the groove channel is obtained preferably at a position 180° from the original.

— The technology of reconditioning by metallization

Metallization as a reconditioning process whereby I aim to recover the axis of a shaft working in a rubber bearing, I believe that it can be realized in two variants, namely metallization with flame, metallization with electric arc and metallization with high frequency currents [4, 7].

— Flame metallization

The metal material to be added (wire or powder) is melted by means of an oxyacetylene flame. Oxygen (4 bars) and acetylene (0.5 bars) have separate circuits and adjustable flow rates. To increase the speed of movement of the particles in the filler material a compressed air or inert gas jet is used. More compact layers are obtained, with better adhesion to the base metal and superior strength.

— Electric arc metallization

By this process the melting of the metallic material to be added using the thermal effect of the electric arc is obtained, which is obtained by approaching two poles connected to the poles of a current generator [5, 6]. The spraying, acceleration and design of molten metal particles are performed using a compressed air jet.

— High frequency currents metallization

Uses voltages of 8 –9.5 kV for the oscillator tube, corresponding to an anodic current of 2–2,2 A and a grid current of 0.2 –0,25 A. The spraying is done with a compressed air jet or inert gas.

The deposition technology, the deposition regime (temperature, velocity, particle oxidation degree) decisively influence the properties of the deposited layer.

The main factors that influence the properties of the deposited layer are:

≡ temperature of the particles of metal sprayed, which the higher the plastic state of the particles is more accentuated and thus ensures a good adherence to the base piece;
≡ the degree of oxidation of the particles, which the higher their adhesion is weaker (to reduce the degree of oxidation, inert gases are used);
≡ the length of the particle trajectory, the long trajectories allowing the oxidation of the particles lead to weakening of the adhesion. It is recommended that the deposits be made in two stages, in the first stage the length of the trajectory is 80 –90 mm, and in the second at least 120 mm;
≡ temperature of the base part, by heating the base part to a certain temperature increasing the adhesion of the addition metal, the homogeneity and the mechanical properties;
≡ the thickness of the deposited layer, which determines the proportional increase of the adhesion of the deposited layer;
≡ particle velocity (150–250 m / s), which the higher the particle adhesion, the better due to higher energy and shortening of the trajectory travel time.

The main operations of the metallization technological process are the preparation of the metallized surface and the metallization itself. Preparing the surface is done removing the layer of oxides, greases, oils, etc. By blasting, subsequent surface preparation operation, in addition to removing dirt and oxide layer, an increased degree of roughness is achieved which ensures a better adhesion of the microparticles in the addition metal.

The metallization operation is carried out as follows: the piece to be metallized is fixed in the universal of a lathe, and the metalizing device is fixed in place of the knife holder. For the part it is recommended 30–60 rpm for an advance longitudinal of the metalliser of 1.25–2.5 mm/rot [8]. The actual metallization operation must be executed as quickly as possible (maximum three hours), after the preparation of the surfaces.

Metallic powders for metallization may contain Ni, Co, Fe, Cr, Cu, Mo, B, Al, powdered ceramics. The addition wire is made of carbon steel, alloy steel, stainless steel, Cr, Mo, Cu, Ni, etc. There are materials that diffuse, under certain conditions, creating homogeneous layers with improved properties, of which: molybdenum applied with flame of combustion; exothermic compositions based on Ni and Al; other than Ni–Cr; bronze with Al. These materials adhere to most steel and aluminium alloys, but not to copper and its alloys [9,10]. Bringing to the nominal size of the metalized part is done by turning and grinding or only by grinding.

Advantages of metal reconditioning:

≡ allows the coating of any piece, with complex geometry and any material;

- allows the deposit of metal layers of the most diverse;
- the thickness of the layer can vary between 0.03 and 5 mm;
- the deposited layer has worn resistance, lubrication properties, corrosion resistance;
- it does not cause deformation or loss of strength, nor does it change the structure of the base material;
- high productivity;
- realizes low cost prices.

In some situations, through metallization an extension of the life of the parts by 300% is ensured.

4. CONCLUSIONS

Following the analysis of the type of wear that appeared on the metal parts that enter the component of the pumping units during their operation, it is decided which the best reconditioning technology is.

The reconditioning activity comprises a succession of technological operations (mechanical processing, heat treatment, metal coatings, welding, etc.) by which a worn part as a result of its operation or damaged, through damage is restored to the functional parameters of use.

The opportunity to perform the refurbishments is based on technical–economic analyses and the cost of the refurbished part.

For parts where the cost of reconditioning represents over 50–60% of that of the new part, reconditioning is not recommended.

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