

Considerations Regarding the Extension of the Service Life of Metal Wear Components from Urban Means of Rail Transport

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Abstract. The paper presents proposals for technical solutions based on the interest shown by transport companies in the country to reduce the cost of maintenance of means of transport by increasing the service life of metal components that, in traffic, are subject to a severe process of wear degradation. Specifically, the paper proposes solutions to solve these problems in the case of urban public transport by rail (tram).

The results obtained by ISIM Timisoara (implemented at public transport companies in the country) in the field of reintroduction into operation of used metal components from trams are presented.

It also presents new, innovative and efficient technical ideas and solutions, from the point of view of the cost / performance ratio and in compliance with the conditions for guaranteeing traffic safety.

It is proposed to design and implement a flexible, complex and high-performance automated system for the reconditioning of tram wear components.

The implementation of the proposed automated solutions will ensure: significantly increasing the service life of parts subject to wear, reducing the costs of loading with functional layers by increasing productivity, improving part quality due to automation of the loading process, use of constant process parameters, established, controllable during process.

Innovative solutions are also proposed for: mobile automated inspection system for determining the degree of wear of tram wheel bandages; method of real-time monitoring of the welding loading process; technical solution to protect the rubber damping elements against overheating and degradation (the solution allows the tires to be reconditioned without removing them from the wheels).

Accurate and efficient uses of automated systems, process programming units are specific approaches to the development and modernization of welding and reconditioning technologies by welding.

Introduction

The current requirements at international level, to increase the efficiency in the field of material production have imposed the implementation in industrial practice of new concepts of design and economic manufacture of parts. Loading by electric welding is one of the most frequently used processes in this direction, due to the multiple advantages it confers. It extends to the production of new, standard or unique parts, but also to the activities of repairing manufacturing defects or those that have appeared in operation.

The definite and unanimously appreciated advantages of this process are well known as they generate important benefits [1-4]:

- increasing the operational durability of loaded parts, by up to max. 300%, by protecting the wear surfaces with adequate materials in correlating the characteristics of the operating stresses;
- reduction of the consumption of special steels by up to 90% by replacing them differentially in the composition of weight bearing structures with carbon steels or low-alloy steels, over which, in the area subjected to wear, welding-compatible materials are deposited meeting the base level of specific strength requirements;
- reduction of energy consumption by up to 65% by eliminating operations specific to the classical processing process;

- increasing operational safety and reducing the risk of damage to loaded parts, as a result of improving the quality level;
- reduction of operating costs.

The outstanding performances achieved in welding loading technologies are due to the harmonization of knowledge of metallurgy, physics, tribology, terotechnics, strength of materials, electrical engineering, chemistry, in the production of new filler materials, new manual and mechanized equipment, and currently due to mechanization and process automation.

Reconditioning and restoring the profile of worn parts, performed carefully and correctly, can lead to a significant extension of service life. Reconditioning must therefore be used after a correct understanding of its benefits and limitations. If applied effectively, it is an important tool in controlling degradation as well as reducing the total maintenance costs of public transport.

ISIM Timisoara has developed research programs [5, 6] in order to find solutions for:

- the reintroduction in the exploitation process of the used metallic elements, with reduced material and financial efforts and at the superior qualitative parameters;
- increasing the life / operation of some metal components subject to wear, by covering the active surfaces with layers with superior characteristics to the basic material (hard, anticorrosive layers).

The research was based on the interest shown in recent years by transport companies in the country (RAT Timisoara, RAT Iasi, CTP Arad, RAT Oradea, RAT Bucharest) to reduce maintenance costs of transport by increasing the service life of metal components that, in traffic, are subjected to an accentuated process of degradation by wear.

Modernization and efficiency of welding / welding loading processes requires the application of a package of technological and organizational measures in order to increase productivity by automating technological processes, increasing the deposition rate, welding loading speed and reducing the volume of material imperfections in during the process.

Companies with a tradition in the field worldwide are preoccupied and have achievements in the field of reconditioning by mechanized welding (LINCOLN ELECTRIC – USA, CLOOS – Germany, BUG-O - USA, ESAB - Sweden, etc.).

In the country, most welding work is generally carried out by the manual welding process with coated electrodes and by the manual MIG / MAG process. Some companies with activities in the field of welding have introduced a certain level of mechanization, as a result of internal and external collaborations, respectively through their own tooling activities. Automated welding does not have a very wide application area.

In order to increase the deposition productivity and the capacity of the reconditioning workshops of the worn components, the problem is to implement modern and high-performance welding loading systems, which also ensure a high level of deposition quality. In this way, the volume of work for the final mechanical processing of the loaded surfaces is reduced and thus the reconditioning activity becomes even more efficient.

In this context, ISIM Timisoara proposes the design and implementation of flexible, high-performance automated systems for the reconditioning of tram wear components.

Specifically, based on an active partnership between ISIM Timisoara and the partner applying the results, important problems can be solved from a technical and economic point of view:

- reducing the costs of maintaining the means of urban public transport by rail (tram), by increasing the lifespan / operation of metal parts subjected to an accentuated process of wear during operation;
- increasing traffic safety by using modern, automated execution, reconditioning and control techniques for metal parts subject to wear during operation.

The solutions approached for increasing the life of the parts subject to wear and reintroduction in the process of operation of worn metal assemblies, will comply with the conditions to guarantee traffic safety.

Necessity / Justification

The service life of some 'active' tram components is limited, in some cases due to wear caused by metal-to-metal friction (e.g. between rails and wheels). In the case of a journey of about 200 kilometers per day (approximately 60,000 km per year) for a tram car, the average service life of a wheel, for example, or a pair of wheels (monobloc axle) is 12 months. As a result, some autonomous utilities and urban transport companies have adopted the solution of reconditioning used parts from the tram.

For example, in Table 1 are presented the parts that were reconditioned a few years ago at a large urban public transport company in the country and the number (approximately) / month:

Table 1 Parts of the tram that were being reconditioned

Part name	Material	Pieces/month	Welding process
Grease box	230-450W	32	111 / 135
Wheel hub	R52 4b	92	111 / 135
Axle half-coupling	S355	30	111
Axle half-coupling	S355	20	111
Circular coupling	S355	20	111
Wheel bandages	B4 UIC810	60	121

The transport company owned 420 trams, of which about 320 ran daily.

Mostly used parts have been / are reconditioned by manual electric welding, except for the tram wheel rims where the process is performed with semi-mechanized machines made by ISIM Timisoara between 1993 and 1994.

Even if the technical level is no longer current, this generation of cars are still used today, the reconditioning of used elements being economically advantageous. For example, the costs of reconditioning the bandages from a bogie (4 pcs.) at that time was 5,500 lei, while the replacement with new bandages cost 8,000 lei. The prices are the ones from the moment of the analysis, the costs with the reconditioning being on average with min. 30% smaller.

In addition to technical and comfort issues related to public transport, an important issue is noise and vibration pollution, which is one of the factors particularly harmful to human life and activity. It is also caused by the movement of road transport in general and trams in particular, being mainly due to wear and tear beyond the permissible limit of metal components in contact / movement.

A study on the noise level produced locally by trams (conducted at the Polytechnic University of Timisoara) revealed that trams generate the total levels of sound pressure shown in Table 2, (at a distance of 7-10 m from the measurement microphone with a speed of 30 - 50 km / h) [7].

Table 2 Sound pressure level - generated by trams

Transport means TRAMS	Total sound pressure level (dB)		
	Minimum - 79	Average - 88	Maximum - 93

It was found that the measured values are exceeded by 20 ÷ 30 dB for all categories of protected areas. The high values of the noise level are largely due to the following factors: wear and tear and unevenness of the rail, pronounced wear of metal parts in dynamic contact, change of direction of travel at line intersections, change of travel speed.

The vibrations and noise produced by trams are of interest in two respects: their influence on the driver of the means of transport and passengers, as well as on the environment (residential areas, schools, hospitals, etc.).

The conclusions of this study demonstrate the need for regular maintenance of public transport, one of the important ways being the reconditioning by timely welding of metal parts with a degree of wear beyond the permitted limits.

Replacement of used components involves high material and financial costs, so it is preferable to recondition them in order to ensure operational safety.

ISIM achievements in the field

ISIM Timisoara has had close collaboration relations with urban public transport companies in the country for over 30 years. In this context, collaborations have been developed in the field of repair by welding of used metal components from trams, including the design and manufacture of specialized welding machines:

- **Two equipment for mechanized repair of used areas for tram bandages by flow welding process (SAF)** – Fig. 1a, b.

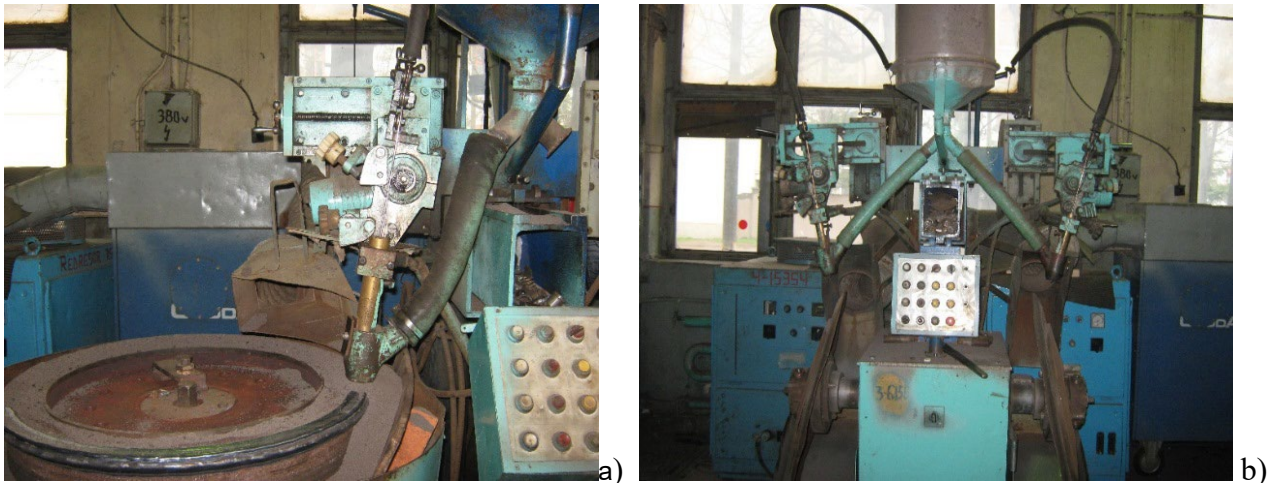


Fig. 1 a) The machine for loading the bandage on the front surfaces; b) The machine for loading the bandage on the rolling surfaces

In order to cover the whole range of areas that could potentially have wear (Fig. 2), two constructive solutions of mechanized SAF welding machines were designed and made:

- The machine for loading the bandage on the front surfaces (Fig. 1a);
- The machine for loading the bandage on the rolling surfaces (Fig. 1b).

Main features:

- Mechanized SAF welding process;
- The tires are reconditioned and removed from the wheel to protect the rubber shock absorbers from the influence of the high process temperature specific to the SAF process;
- The welding speed is continuously adjustable by adjusting the bandage rotational speed.

Important advantage: High deposition rate / high productivity, characteristic of the SAF process

Major disadvantages:

- due to the fact that the temperature at which the reconditioning part heats up is very high (1200-1400°C) it is necessary to remove the tires on the wheels to protect the rubber shock absorbers, which requires additional labor costs;
- SAF is not a “visible” and “clean” process, due to the formation of the slag layer; after making a welding bead, the repositioning of the welding head for the next bead is done manually, previously it is necessary to remove the slag and careful cleaning (of the previous deposit);
- there is no possibility of tracking during the actual loading process, if the technological parameters fall within the prescribed limits;
- the criteria / conditions for ensuring the principle of repeatability are not met.

The machines were made between 1993 and 1994 and are still in operation at RAT Bucharest.

- **Reconditioning installation by MIG / MAG mechanized welding of used components from public transport**

ISIM Timisoara made for three transport companies in the country, installations for reconditioning by mechanized MIG / MAG welding of used metal surfaces (interior and exterior) from rolling stock components: tram wheel tires, tram axles, tram tubular half-couples, coupling engine, universal transmission joint, axle end bearing assembly. In Fig. 2 are presented other

representative parts that are reconditioned by using this type of installation, highlighting the areas prone to heavy wear.

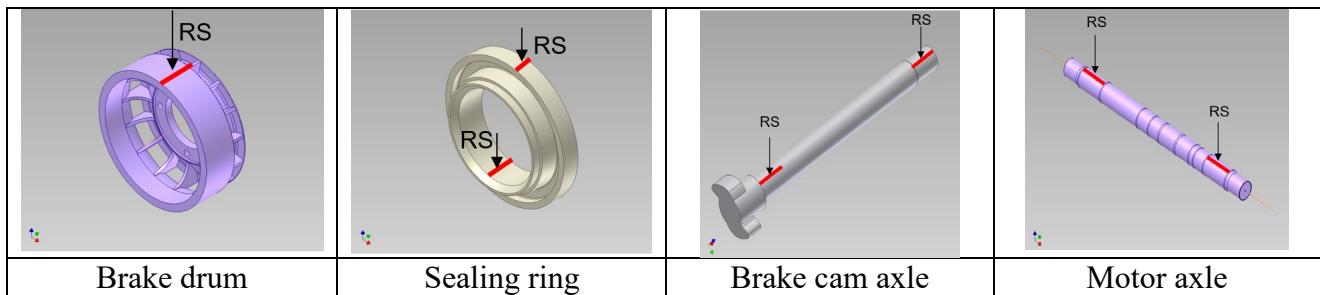


Fig. 2 Rolling stock components that can be reconditioned by MIG / MAG welding

In Fig. 3 the equipment is presented in the following operating / application situations: wheel tire reconditioning (a); axle shaft reconditioning (b) in the bearing mounting area and drum type reconditioning (c).

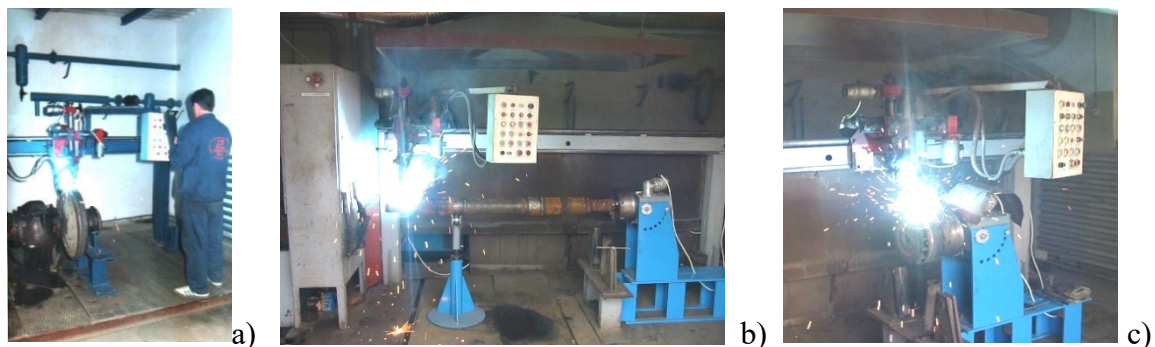


Fig. 3 MIG / MAG mechanized welding reconditioning equipment: a) wheel bandages; b) axle shaft, in the bearing mounting area; c) drum type parts

How the installation works:

Worn parts, ready for welding, are fixed to the clamping / actuating devices in the welding position. After positioning the welding head, the deposit will be made:

- of a welding bead by rotating the bandage (Fig. 3) with 360° plus $2...5^\circ$ (adjustable) and performing the required step manually by manual control;
- of successive cords, the step (horizontal or vertical) being performed automatically.

Fig. 4 shows the areas susceptible to reconditioning and the macroscopic appearance of a specimen taken from a bandage in cross section in the direction of welding / loading.



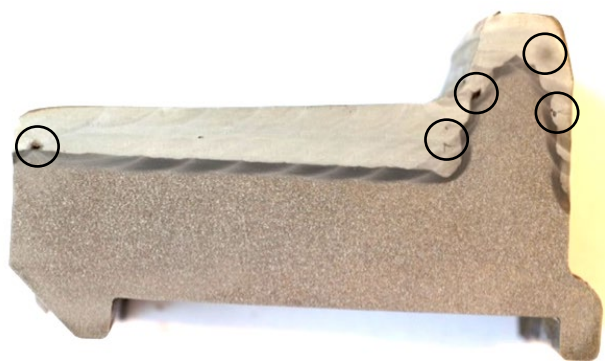
Fig. 4 Tram wheel bandage (I-IV reconditioned areas by mechanized MIG / MAG welding)

At the time of implementation, the specialized MIG / MAG welding reconditioning installations, made and put into operation at the autonomous public transport utilities in Timisoara, Arad and Iasi, ensured the following economic effects:

- the expenses with reconditioning / used part represent max.30% of the purchase price of a new part;
- significant increase in operational safety for mechanized reconditioning compared to manual;

- reduction by approx. 50% of the labor required for reconditioning, by:
 - reduction of auxiliary times affected by machining operations after welding, as a result of uniform deposits;
 - reduction of the auxiliary times necessary to disassemble the bandages on the wheels, respectively axles;
- reduction of consumption of electricity and welding materials by approx. 20%;
- decrease (by approximately 70%) of the import of new components necessary for the means of transport of foreign origin.

In this generation of machines, the positioning of the welding head for each deposit, depending on the lip profile of the bandage is done manually, being dependent on the experience and physical condition of the welder operator. For this reason there have been cases in which the inadequate positioning of the welding head favors the formation of defects according to Fig. 5 (Marked areas have defects such as lack of melting, cracks and voids).



Obs.: The loading of the bandage from which the sample was taken was made at CTP Arad. After loading by welding the bandage was processed by cutting at the prescribed dimensions.

If, with the technique currently used, the costs of reconditioning a bandage are lower by approx. 30% compared to the cost of a new bandage, we estimate that by automating the process and eliminating the disassembly / assembly operations of the wheel tires these costs could reach 50% (from the cost of a new bandage).

Fig. 5 Highlight bandage areas with possible defects

Given the limitations of the techniques presented, we consider it very useful to implement new solutions for automation, control and monitoring of the welding process.

Proposals for High-Performance Automated Welding Loading System

The current requirements that are manifested at international level have as objective the implementation in industrial practice of new concepts of design and economic manufacture of parts. Charging by electric welding is one of the commonly used processes in this direction. The process extends both in the production of new parts, series or unique, and in the activities of remodeling manufacturing defects or in operation.

In order to increase the productivity of deposition and the expressive capacity of the workshops of reconditioning of used components, the problem is to make modern and high-performance welding equipment, automated, to ensure a high level of deposition. In this way, the volume of work for the final mechanical processing of the loaded surfaces is reduced and thus the reconditioning activity becomes even more efficient.

Solutions are proposed for the realization of the following systems / methods / technical solutions:

- automated, flexible and efficient system for reconditioning the wear components of the trams;
- mobile automated inspection system for determining the degree of wear of the tram wheel tires;
- method of real-time monitoring of the welding loading process;
- technical solution to protect the rubber damping elements against overheating and degradation.

Flexible automated system for welding loading, which performs and controls (in automated mode) the welding loading process and automatically generates at the end of the loading sequence a process sheet with details on compliance and consistency of prescribed parameters and its final result. This will include information on the evolution of the technological process (sampled values of the main process parameters): welding current; welding voltage; shielding gas flow; welding speed; the load ratio, to validate the conformity of the configuration and the dimensions obtained in

comparison with those prescribed. Within the flexible automated system, five action drives will be implemented for the actual welding program.

The system must ensure:

- loading by automated welding of a wide range of parts (bandages, axles, wheel hubs, half-couplings, etc.) with different configurations, of different sizes and with different loading surfaces (circular or flat);
- spatial, continuous, programmed deposition of several rows, respectively layers;
- a very high precision in operation, in order to avoid the appearance of shape or structural defects that can be formed due to two causes (related to the automated system):
 - errors of positioning of the welding head in relation to the reconditioning surfaces;
 - deviations from the technological parameters prescribed for loading;

Monitoring and control system of the welding process, which must detect in real time the appearance of defects (pores, cracks) and their positioning in the deposited layer; it is proposed to research and test the possibilities of using infrared thermography in real-time monitoring of the process.

Recent research, conducted by ISIM Timisoara has shown that infrared thermography can be a viable method for monitoring automatic or semi-automatic welding processes [8-10]. The use of the method can provide information on process stability, constancy of welding parameters, induction of imperfections and / or defects, respectively analysis of the quality of welded joints by thermal imaging, as well as adjustment and optimization of welding parameters by feedback connections. The verification of the method in terms of identifying imperfections in welding, revealed that they can be highlighted by the thermographic method as it is a thermal barrier that prevents heat from spreading inside the examined object according to its thermal characteristics, imperfections having different thermal conductivity in relative to the homogeneous material.

The method was verified experimentally at ISIM Timisoara, when using the friction stir welding (FSW) process, at which the temperatures developed in the welding materials during the welding process was 350 - 1200°C (depending on the plasticizing temperature of the alloys to be welded) [9-11].

Given the positive results obtained, it is proposed to use the method for electric arc welding, where the process / process conditions are completely different (temperatures of up to 1200-1300°C are reached in the investigated area).

The mobile automated inspection system must determine as accurately as possible the degree of wear of the tram wheel tires; the data obtained from the inspection process are saved and used to program the operating cycle of the automated system for loading by welding; an inspection sheet is generated, based on the data obtained from the inspection process as well as the related recommendation (whether or not it is necessary to recondition the respective part).

The mobile automated inspection system will use laser sensors to measure distances, using a process without direct contact, offering a number of important advantages: This type of sensors offers resolutions of the order of millimeters and allow high measurement rates. The sensors are specially designed for industrial use, suitable for a wide range of applications such as: measuring depths, precision measurements, without direct contact, distances and thicknesses, positioning, etc.

Mobile automated inspection system presents the following innovative solutions:

- Mobility is the main innovative element of the system and its major advantage, allowing easy use directly at the beneficiary's premises and identification of parts that need reconditioning without the need to disassemble them for inspection, thus reducing the time required and eliminating costs related to labor procedures for disassembly / assembly of part as well as replacement of related consumables;
- Wear analysis algorithms are also an innovative element, which is based on the analysis of data obtained from precision measurements of laser sensors used to determine the size of the bandage, its thickness and the characteristics of damaged areas (dimensions, depths etc.) thus allowing much faster and more accurate identification of parts that require reconditioning.

Wheel cooling system - in the case of tram wheel belt, which are reconditioned without being removed from the wheel assembly or the wheel train, respectively. The system will ensure the control and maintenance of the bandage temperature during the loading process at values that do not affect the integrity of the rubber shock absorbers and the prescribed properties of the base material - deposited material assembly.

The cooling method of the bandage will allow to obtain important labor savings (disassembly / assembly of the bandages on the wheels is avoided, an operation that represents $\approx 15\%$ of the total cost of reconditioning).

The main reason why it is important to implement automated solutions is due to the expected results: significantly increase the life of parts subject to wear, reduce loading costs with functional layers by increasing productivity, and improve part quality due to automation of loading process, use of established constant process parameters, controllable during the process.

Also, by using the automated system, the quality of the deposits does not depend on the physical condition of the welder operator, his training and experience (in the field of welding) can be of medium level. In this case the exhaust systems become more efficient from the point of view of the health of the welder operator, the control of the automated system being made from a distance (2-3m from the area where the charging is actually done by electric arc welding).

Manual welding requires good professional training and experience, physical effort and concentration for a long time, inhalation of noxious substances resulting from the process (even if there are exhaust installations).

Conclusions

- The main reasons for the regular maintenance of means of transport are: increased operational safety, safety and comfort of passengers, reduction of noise, increase the life of wear components, reduction of malfunctions;
- Rehabilitation by welding of used components allows to reduce the operating costs of public transport;
- The use of automated welding loading systems ensures a uniform deposition of the layers, which has the effect of reducing by $\approx 10\%$ the labor for post-welding operations (machining to restore the profile of the reconditioned parts to the prescribed dimensions).
- With the technologies and techniques used so far in the reconditioning of used parts, a saving of approximately 30% can be made compared to the purchase of new parts;
- Increasing productivity through automation, compared to manual / mechanized processes, improving the quality of deposits (reducing defects and making uniform layers), eliminating the disassembly / assembly of bandages in the case of tram wheels, will ensure lower prices for reconditioning used parts, in average by about 40-45% compared to new parts;
- Reconditioning and restoring the profile of worn parts, performed carefully and correctly, can lead to a significant extension of service life. Reconditioning should be used after a proper understanding of its benefits and limitations. If applied effectively, it is an important tool in controlling degradation as well as in reducing the total maintenance costs of public transport.

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