Vol. 36, No. 3 (2014) 287-292

Tribology in Industry

www.tribology.fink.rs

RESEARCH

Techno-Economic Justification of Reparatory Hard Facing of Various Working Parts of Mechanical Systems

V. Lazić[a], R. Čukić[a], S. Aleksandrović[a], D. Milosavljević[a], D. Arsić[a], B. Nedeljković[b], M. Đorđević[a]

[a] *University of Kragujevac, Faculty of Engineering, Sestre Janjić 6, 34000 Kragujevac, Serbia,*
[b] *High technical school in Kragujevac, Kosovska 8, 34000 Kragujevac, Serbia.*

Keywords:

Regeneration
Wear
Hard-facing
Costs
Techno-economic analysis
Tribology tests

Corresponding author:

Vukić Lazić
University of Kragujevac,
Faculty of Engineering,
Sestre Janjić 6,
34000 Kragujevac, Serbia
E-mail: vlazic@kg.ac.rs

A B S T R A C T

Research in the field of hard-facing of various parts mechanical systems' are being done for technical and techno-economic reasons. The reasons for introducing the new reparation technologies by hard-facing are numerous: three quarters of all the mechanical parts of engineering could be regenerated or manufactured by hard facing; the working life of the repaired part reaches or even exceeds the working life of a new part, while the working life of the hard faced manufactured part surpasses several times the working life of the new part manufactured by some other technology. Large number of damaged and, frequently even broken parts, cause terminations of the working process. Thus, due to difficulties in procurement of new, mainly imported parts, the alternative solution must be applied.
It is sown that the a proper choice of the hard-facing technology is related to the complex procedure of checking the quality of the hard faced layer, what indicates that the reparatory operations could be performed only in specialized regeneration workshops, which are furnished with adequate equipment and corresponding expert and skilled staff. The estimated net benefit for the analyzed parts is exceptionally high, regardless of the fact that the additional external and internal effects have not been quantified.

1. INTRODUCTION

The reasons for the introduction of technology production and repair hard facing are numerous: research indicates that three-quarters of all mechanical parts can be regenerated and production hard faced, service life of repaired part reaches or exceeds the service life of the new part, service life of new in production hard faced part exceeds several times the new part which was not hard faced, low cost repairs, reduced period of termination due to purchasing a new part, which increase productivity, low financing costs and cost of storage [1-4]. A large number of damaged, and often broken, parts cause termination of the process, and the difficulties in the procurement of new, mostly imported parts, must use an alternative such as hard facing-regeneration. In addition, the maintenance of the technical system should take in consideration manufacture of new parts by hard facing, which are expected to extend their service life in relation to the new working parts.

To perform the modeling of hard facing of working parts, which is to prescribe regeneration procedures, it is necessary to perform previous studies in a number of models and real working parts of various types of steel and cast iron. While the surfacing almost every time unique job, because requires the technology customized to each working part, it is possible to establish general procedure for groups of similar parts and then to apply it [2,5-6].

Our previous studies have shown that working life of properly hard faced parts far exceeds working life of new parts [1-3]. In addition, in this way are achieved large savings, increased productivity, reduced downtime of machines and assortment and quantity of necessary spare parts.

2. SELECTION OF THE MOST SUITABLE HARD FACING TECHNOLOGY

In examining the state of the damaged parts should first determine: whether the wear occurred during normal exploitation or because of mechanical damage, which degree of wear is crucial for the decision whether it is cost-effective and safe to use for future exploitation to apply regeneration or part sould be rejected, as well as the size of expected deformation and residual stress [7-8]. After determination of the chemical composition of the base material and working conditions it is possible to create the basic conditions for the design of technological processes. Based on these facts and previously conducted detailed techno-economic analysis, the method of regeneration should be chosen, taking into account the local possibilities of the company. The basic requirement is to obtain the required properties of the regenerated part of the course and the reliability of the estimated work time.

To achieve the above requirements it is necessary to make the proper selection of filler material for hard facing. In some cases of repairation of working parts it is necessary to apply two or more kinds of additional material to inflict an intermediate layer, so called buffer layer, between the layer and the substrate. This reduces the large differences in the chemical composition, structure and, consequently, the thermo-physical properties of the substrate and the deposit. Next follows the selection of process parameters of regeneration, resulting from the properties of the base and filler metal, and demands the size and shape of regenerated parts. The final stage of planning, before the experimental surfacing, is the assessment of the necessity of implementation of special measures and the former, current and subsequent heat treatment.

For verification of the proposed technologies, it has been performed comparative tests in laboratory and in working conditions, and, in some cases, comparative test of import parts which are not hard faced and new-hardfaced parts. Laboratory tests are related to the microstructure, hardness distribution and tribological tests and working tests of comparing the working life of new and repaired parts installed in the same machine [2-3,9,12-13].

From the point of view of technical and economic analysis, repair welding technology is a complex set of different types of mandatory procedures, which take into account: the conditions of work, damage identification, estimation of weldability, welding process, filler material, mode of welding and hard facing, applied heat treatment, model and real test. Having in minds the complexity of the process it is necessary to determine the most suitable technical solutions to make the process of repair has led to a degree where it is possible to make a final decision, to buy a new part or to repaire it.

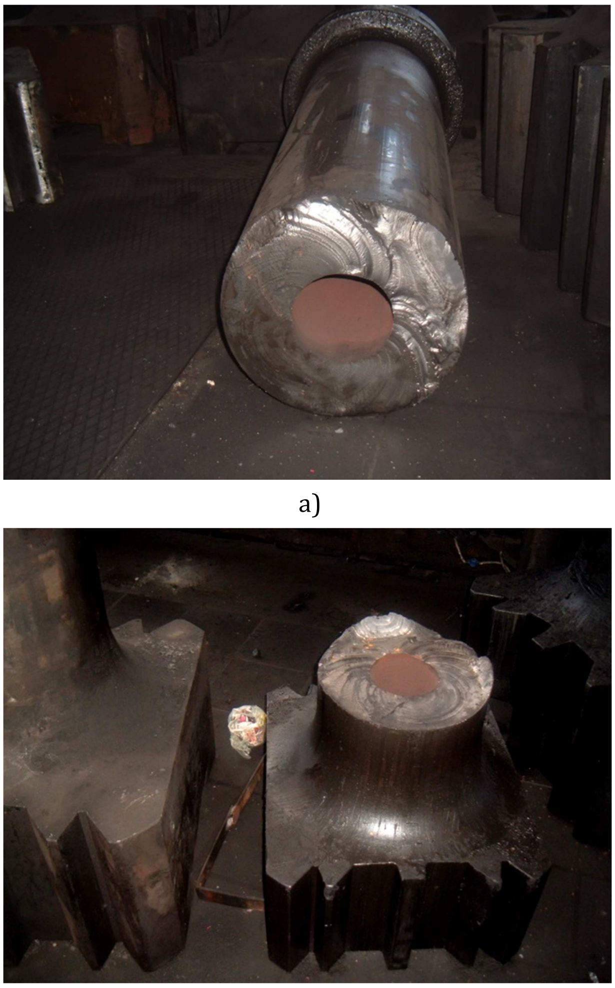
3. EXAMPLES OF IMPLEMENTED REPAIRS

Here was considered the justification of the application of the production and repair hard facing and indicates the cost-effectiveness of repairs to damaged examples of forging hammer, forging press frame and large gear of eccentric presses. It is a repair welding and surfacing damaged or cracked forging hammers, broken and cracked frames, forging presses and large gear eccentric presses [10-11]. To determine the most suitable technology of hard facing, it was necessary to carry out tests on model and working parts. Test hard facing and testing of models have served to establish the initial repair technology, and so approved technologies to "transferr" to the working parts are further checking under actual working conditions.

This paper mainly deals with the technoeconomic advantages of hard facing technology, and complete processes of determining the most suitable technology of each particular section was shown in some of our previously published papers [2-3,5,9-11].

3.1 Regeneration equipments for forging, hammer and press frame

For the regeneration of responsible parts with complex geometries and large masses made of material sutible for tempering require a detailed analysis of the working parts and precisely proposed repair technology. Hammers mallets and presses frames are exposed, during long work, to thermal fatigue due to cyclic temperature changes and impact loads. Due to the high cost and often to impossibility of purchasing new working parts, it is necessary to evaluate the possibility of their repairs. Harsh working conditions sometimes lead to complete fracture and endangering the safety of the workplace. Figure 1 shows crack of one forging mallets originated from fatigue crack propagation. Mallet of forging's hammer, shown in Fig. 2, and frame forging press, shown in Fig. 3, undergo primarily impact compression loads, and, in part, to temperature gradient, that is thermal stresses caused by uneven temperature field [2,7-8]. After a long work of these parts, that is large number of repeated cycles on hammer mallet in frameof presses were observed visible cracks, and on the part of the frame and one mallet it led to complete fracture (Fig. 1 and 3).



a)

b)

Fig. 1. Appearance of cracked mallet of forging hammer.

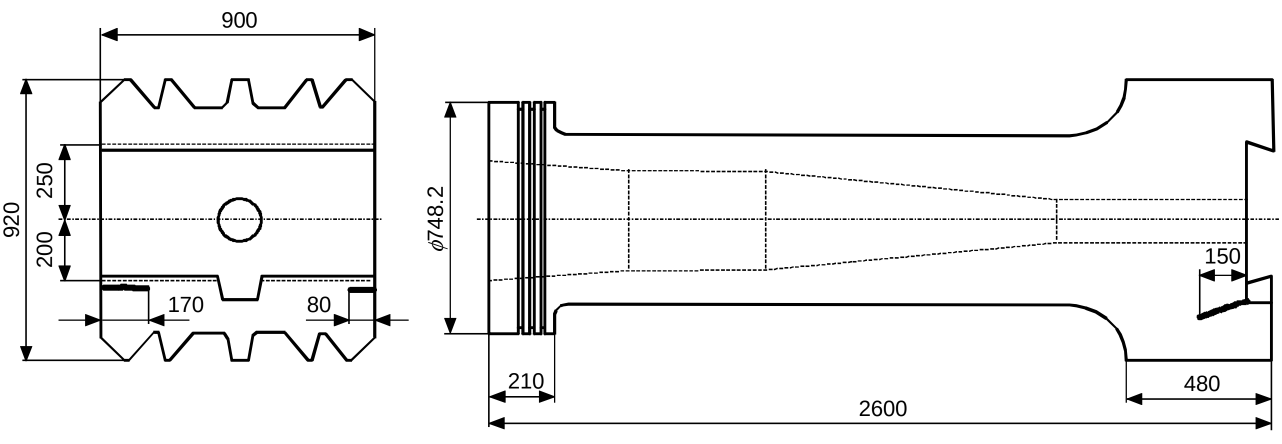
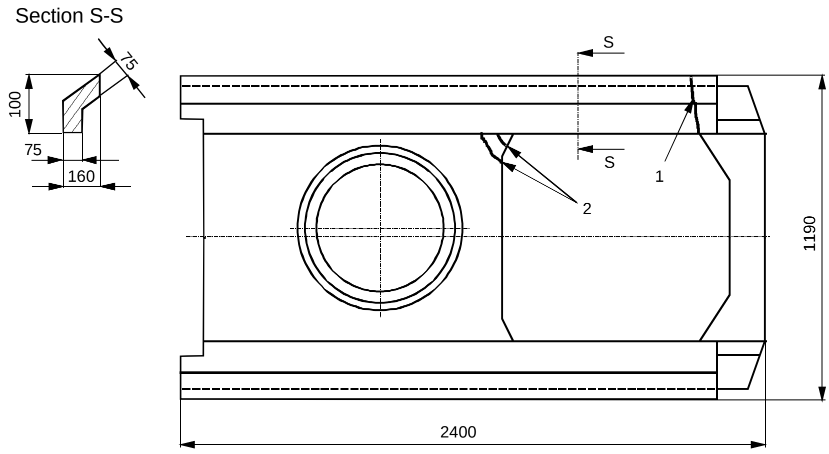
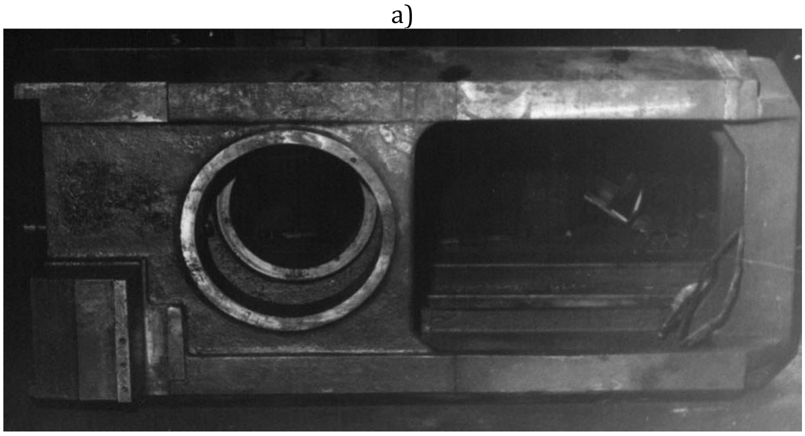


Fig. 2. Appearance of the ram and places of the noticed cracks.



a)



b)

Fig. 3. Frame of vertical forging press: a) sketch of frame (1 - place the fracture and 2 - observed cracks) and b- regenerated, machined and heat treated part.

Taking into account that these are parts of large dimensions and complex shapes, and that components are subject to dynamic and thermal loads, they are dimensioned on the basis of the increased level of security, taking in account that the technology of repair requires special measures. Frame of forging press is made by casting in sand midium carbonized cast steel. In contrast, mallet of pneumatic forging hammer as one of the most loaded mechanical parts is made of low alloyed steel for improvement.

Complete technology for regeneration of damaged mallets of forging hammers and frames of presses is shown in [6,10-11], and here we will look at the technical and economic indicators of regeneration of mallets of forging hammers.

Following data are relevant for comparison:

<u>A. Price of the new part is: 83987 €</u>

(This price includes price of a new part-67470 €, tax -12144 €, the Customs 3373 € and the cost of shipping and transportation services- 1000 €);

<u>B. The total real costs of repair: 4912 €</u>

- Identification and damage detection:3 days × 8 (nh/day) × 10 (€/nh) = 240 €;
- Machining of damaged area: 10 days × 8 (nh/day) × 12 (€/nh) = 960 €;
- Selection of the most suitable hard facing technology: 8 days × 8 (nh/day) × 15 (€/nh) = 768 €;
- Model testing: 4 days × 8 (nh/day) × 12 (€/nh) = 384 €;
- Surfacing of real working parts:20 days × 8 (nh/day) × 10 (€/nh) = 1600 €;
- The costs of machining operations of surfaced areas: 10 days × 8 (nh/day) × 12 (€/nh) = 960 €.

Based on these data one can conclude that the total cost of repair far lower than the cost of a new part (less than 6 %). Therefore, the analysis of "buy" or "repaire" is apparently resolved without more detailed analysis of the positive effects that mallet regeneration allows.

3.2 Repair of large gears - toothed hub of eccentric presses

Techno-economic analysis of reparature welding and hard facing of damaged teeth serrated coupling hub with mass of 500 *kg*, shown in Fig. 4, is performed after the repair has already been performed, because it is a unique part that could not be easily obtained. The coupling is exposed to harsh environmental conditions and is made of alloy steel for improvment. Since it is a conditional weldable steel, it is necessary to prescribe a particular technology for repairs. It is achieved through previous model tests [5, 10]. The analysis of obtained results leads to the most suitable hard facing technology which is "transferred" to the real part.

Fig. 4. Appearance serrated coupling hub.

In economic analysis "buy" or "repaire" it is not made estimation of the effects that can be performed with a *benefit-cost* (BC) analysis, or more precisely by using the life-cycle-cost (LCC) that would give a more precise and more clear advantages of application of taht advanced technology [3]. A comparative analysis is performed after two and a half years of work hard facing of rack hub couplings.

As relevant data for comparison are taken:

<u>A. Purchase price of the new parts: 26500 €</u>
(This price includes price of a new part, the cost of taxes, customs duties, freight forwarding services and transport).

<u>B. The total real costs of repair: 3380 €</u>

- Identification and damage detection:1 day × 8 (nh/day) × 10 (€/nh) = 80 €;
- Machining of damaged area: 2 days × 8 (nh/day) × 12 (€/nh) = 192 €;
- Model testing: 3 days × 8 (nh/day) × 12 (€/nh) = 288 €;
- Selection of the most suitable hard facing technology: 1 day × 8 (nh/day) × 15 (€/nh) = 120 €;
- Surfacing of real working parts:10 days × 8 (nh/day) × 10 (€/nh) = 800 €;
- Cost of production services (processing hard faced teeth and transport) 1900 €.

Based on these data one can conclude that the total cost of repairs is significantly lower than the cost of purchasing a new part (less than 13 %).

Also, it should be mentioned that in some papers [14] is indicated on energy analysis and energy saving with hard facing. Based on the energy consumption analysis, the authors in that paper concluded that reparation of a damaged and worn hammer's ram is justified because the electric energy consumption for reparation of the ram is 2.6 times less than for production of a new one.

4. CONCLUSION

Proper selection and application of technology of repair and manufacturing hard facing it is possible to achieve a number of advantages compared to the installation of new parts. This is primarily refered to the extension of the servica life of the analyzed parts, increase of productivity, reduction of delay time, reduction of inventory costs and other benefits derived by applying welding technology. It is shown that a proper choice of hard facing technologies associated with complex procedure of checking quality of the deposit, indicates that the repair work can be performed only in specialized workshops for regeneration, which have adequate equipments and appropriate skilled staff. The expected net benefit for the analyzed parts is very high, irrespective of the fact that have not been quantified additional external and internal effects. After the successful implementation of these new production technologies of surfacing in these areas, it is possible by appliing of a similar procedure to form a knowledge base and to use it for maintenance of equipment for forging, and other similar mechanical parts.

Acknowledgement

This research was partially supported by the Ministry of Education and Science of Republic of Serbia through Grants TR 34002, TR 35021 and TR 35024.

REFERENCES

[1] R. Wasserman: *How to save millions by reducing inventories of spare parts*, Eutectic-Castolin Institute for the Advancement of Maintenance and Repair Welding Techniques, 1971.

[2] V. Lazić: *Optimization of the hard facing procedures from the aspect of tribological characteristics of the hard faced layers and residual stresses*, PhD thesis, Faculty of Mechanical Engineering, Kragujevac, 2001. (In Serbian).

[3] R. Čukić: *Techno-economic analysis of production and reparatory hard facing of various parts of machine systems*, PhD thesis, University of Belgrade, Serbia, 2010. (In Serbian).

[4] V. Lazić et al.: *Selection of the most appropriate technology of reparatory hard facing of working parts on universal construction machinery*, Tribology in Industry, Vol. 33, No. 1, pp. 18-27, 2011.

[5] M. Mutavdžić et al.: *Model investigations of the filler materials for regeneration of the damaged parts of the construction mechanization*, Tribology in Industry, Vol. 30, No. 3&4, pp. 3-9, 2008.

[6] V. Lazić et al.: *Reparation of damaged mallet for hammer forging by hard facing and weld cladding*, Tehnical Gazete, Vol. 16, No. 4, pp. 107-113, 2009.

[7] A. Wernoski: *Zmeczenie cieplne metali*, Wydawnictwa Naukowo - Techniczne, Warszawa, 1983. (In Polish).

[8] R. Pasierb: *Spawanie žarowytrzymalych stali chromowo-molibdenowo-wanadowych*, WNT, Warszawa, 1982. (In Polish).

[9] V. Lazić et al.: *Selection of the optimum technology of the forging dies reparation from the aspect of tribological characteristics*, Tribologia - Teoria i Praktyka, ROK XXXVI, NR 2/2005, pp. 11-30, 2005.

[10] V. Lazić et al.: *Development and application of welding technologies for regeneration of damaged working parts of forging presses and hammers*, in: *Welding and Joining Technologies for a Sustainable Development and Environment*, 24-26. 05. 2006., Timisoara, Romania, pp. 341-346.

[11] V. Lazić et al.: *Energetic analysis of hard facing and weld cladding of an air powered drop hammer damaged ram*, Thermal science, Vol. 13, No. 2, pp. S269-S284, 2010.

[12] V. Lazić, M. Mutavdžić, D. Milosavljević, S. Aleksandrović, B. Nedeljković, P. Marinković, R. Čukić: *Selection of the most appropriate technology of reparatory hard facing of working parts on universal construction machinery*, Tribology in Industry, Vol. 33, No. 1, pp. 18-27, 2011.

[13] S. Rakić, V. Lazić, S. Aleksandrović, S. Mitrović, R. Nikolić, D. Milosavljević, R. Čukić: *Reparatory and Manufacturing Hard-Facing of Working Parts Made of Stainless Steels in Confectionary Industry,* Tribology in Industry, Vol. 34, No. 3, pp. 138-151, 2012.

[14] V. Lazić, M. Jovanović, A. Sedmak, S. Aleksandrović, D. Milosavljević, B. Krstić, R. Čukić: *Energetic analysis of hard facing and weld cladding of an air powered drop hammer damaged ram*, Thermal science, Vol. 13, No. 2, pp. S269-S284, 2010.