# ECONOMIC ANALYSIS OF REPLACEMENT OF CONVENTIONAL WELDING TECHNOLOGY WITH UNCONVENTIONAL

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***Apstract***: *The technological and social environment in which we live changes very quickly. Competition grows from time to time, so it is a constant tendency towards product and service providers to achieve a competitive advantage, and thus satisfy the needs of consumers. In order to achieve the above, the organization is often at a crossroads where important decisions are needed, which are most often related to the investment in new equipment or technology. Also, in parallel with the decision to invest in new equipment or technology, a decision is made to retain or upgrade the existing one. In order to make the right decision, often well-known postulates of engineering economies are often used, which include systematic assessment of the economic values of the proposed solutions. In order for economies to be acceptable, solutions must show the existence of a positive relationship between long-term benefits and long-term costs, as well as ensuring the success and survival of companies in the market. In this paper, the economic cost-effectiveness of replacing the existing electrolytic welding technology with insoluble electrode in inert gas (TIG), the new FSW welding technology is considered.*
*KEY WORDS: TIG, FSW, ECONOMIC ANALYSIS, REPLACEMENT, BENEFITS, COSTS.*

## *1. Introduction*

An important decision facing a large number of organizations, both productive and service providers, is whether existing assets or technologies need to be withdrawn from use, replaced by new ones, or simply retained. Living in a time of strong market competition, which grows at an enormous speed from time to time, high productivity criteria are set before product manufacturers and service providers, which primarily relate to the higher quality of goods and services, and shorter delivery times. In this regard, in order to satisfy the above criteria, the most common is the implementation of the decision, which refers to the replacement of existing assets or technologies, new ones.

The replacement problem, in order to improve operational efficiency and strengthen the competitive position in the global market, requires a thorough analysis and consideration of all the accompanying problems.

The engineering economy provides assistance in deciding on the replacement of assets or technologies, based on an analysis of several proposed solutions. Often, for the use of resources, during the substitution analysis, the term "defender" is used, while the proposed alternatives, which refer to new ones, are called "challengers".

However, the adoption of a specific substitution decision can be influenced in many ways. Thus, for sometime, it may be acceptable for the existing product or technology to be completely withdrawn from use, without replacement, while for some time a decision is made to retain it, but only for spare use. Also, the decision to substitute is influenced by the fact that the increase in market demands can be met by expanding existing capacities or by increasing the capacity of available funds.

This paper analyzes the replacement of conventional welding technology with an unconventional one. Of the conventional technologies, one of the methods of arc welding (TIG) was taken into account, while the friction stir welding procedure - FSW was taken as an unconventional process. When considering, attention is focused on several important factors, which have the greatest impact. Also, consideration was given to the economic parameters of the analyzed technologies.

## *2. Replacement analyses*

### *2.1. Reasons for replacement*

There are numerous reasons that make the questionable profitability of using existing assets or technology, and are most often followed by negative financial indicators. All influential factors, leading to the above mentioned adverse effects, can be grouped into three groups [1]:

- **Physical damage to resources**. Changes related to physical characteristics. Continued use of resources ("aging") leads to a reduction in its efficient functioning. All this leads to a number of related problems such as: increasing planned and unplanned overhauls, increasing maintenance costs, increasing energy consumption, increasing the time needed to perform the operation, etc. Also, during the use of funds, an unexpected event can occur (an accident), which affects the physical state of the assets, and thus impair the economy and the possibility of further use;
- **Changed requirements**. Capital assets are used to produce goods in order to meet the needs of consumers, using existing technology. Changes in demand or a change in product design may be reflected in a change in cost-effectiveness;
- **Technology**. The impact of technology change varies depending on the type of asset itself. Changes in technology, in general, positively affect: costs per unit of production, quality of products or services, etc., and therefore often make decisions about replacement of existing funds, new funds.

Factors that relate to physical damage to assets and changed market requirements may refer to different categories of limitation. In the case of a replacement problem, they do not need to be included in only one of the above factors, but can simultaneously be influenced by factors from all three groups. However, notwithstanding everything, replacing old funds with new assets is most often a good economic opportunity for an organization.

### *2.2. Factors to be considered in the replacement analysis*

There are several factors that must be considered in the replacement analysis. Once these factors and their dependence are identified, the likelihood of experiencing difficulty in analyzing substitution is low. The most important factors are [1]:

- recognizing and accepting mistakes from the past,
- lost costs,
- existing value and neutral viewpoint,
- economic life of "challangrs",
- the remaining economic life of "defenders" and
- consideration of income tax.

**Recognizing mistakes from the past**. The economic focus of the analysis study is always focused on the future. Any estimation errors made in the previous study, which are associated with existing assets, are not significant. In most resemblances, the inability to predict the future situation is anticipated during the initial assessment period. The organization is often at a crossroads, where it is necessary to decide whether, on the one hand, one should live with all the mistakes and differences from the past, or, on the other hand, to exist in a healthy competitive position in the direction of the future. The most common fears that arise when making this decision is the possibility of losing the value of the existing asset due to the replacement. However, regardless of whether there will be a replacement of the asset or not, the facts show that the loss is inevitable in any case.

**Lost Costs**. It is very important to define a non-returnable loss at a particular point, which is the difference between the carrying amount of the asset and its current market value. Non-refundable costs are not a relevant factor in the analysis of substitution unless they have an impact on income tax, because in this case they must be taken into account in an economic study. It is clear that in practice, when analyzing the replacement, a major error can be made if the non-refundable costs are incorrectly calculated.

**Existing values and neutral viewpoint**. The introduction of a neutral viewpoint aims to bring the concept of value to the existing asset of the "defender" closer. In fact, a neutral viewpoint is an attitude that would occupy a third (impartial, objective) person in determining the current market value of the asset used. This viewpoint forces analysts to focus on current and future cash flows during the exchange analysis, thus avoiding the temptation to retain on past (non-refundable) costs. The current market value of the asset is the exact amount of capital investment that will be allocated to the existing asset in the replacement process. Any new investment cost required to upgrade the existing asset in order to achieve competitiveness with the "challenger" should be added to the current market value of the asset in order to be relevant in the replacement analysis. At a neutral point of view, it takes into account that the assets of the "defender" are equal to the sum of the cost, which is equal to the current market value of the unsold asset and the cost of superstructures, with the aim of achieving co-curricularity with the best available "challenger".

**The economic life of the "challenger".** The economic life of the asset is often shorter than useful or physical life. During the analysis it is necessary to know the economic life of the "challenger" for the reason that a comparative analysis between the existing and the new asset is precisely based on their economic life. Economic data on the "challenger" are periodically updated, and then the replacement analysis is repeated, in order to ensure a continuous assessment of the possibilities for improvement.

**The economic life of the "defender".** It must be taken into account when comparing the current defender with the "challenger", as it is a comparison of different ages. The lifetime of a "defender" should be longer than its economic life, until its marginal cost is less than the minimum equivalent of the "challenger" annual cost in his economic life.

**The importance of the consequences of income tax**. Substituting an asset often results in a gain or loss on the sale of depreciable assets. Consequently, in order to carry out a precise economic analysis in such cases, studies must be made after the taxation process. It is evident that the occurrence of taxable profit or loss during replacement can have a significant impact on the result of engineering studies.

## *3. Project profitability assessment*

Because patterns of capital investment, revenue (or saving) cash flows, and disbursement cash flows can be quite different in various projects, there is no single method for performing engineering economic analyses that is ideal for all cases. Consequently, three methods are commonly used: Present Worth (*PW*), Annual Worth (*AW*), Future Worth (*FW*). This methods convert cash flows resulting from a proposed solution into their equivalent worth at some point in time by using an interest rate known as the Minimum Attractive Rate of Return (*MARR*) [2].

***The Present Worth Method.*** To find the *PW* as a function of *i%* (per interest period) of a series of cash inflows and outflows, it ic necessary to discount future amounts to the present by using the interest rate over the appropriate study period (years, for example) in the following manner:

(3.1) $$PW\ (i\%) = \sum_{k=0}^{N} F_k (1+i)^{-k}$$

where are: $i$ - effective interest rate or MARR, per compounding period, $k$ - index for each compounding period ($0 \le k \le N$), $Fk$ - future cash flow at the end of period $k$ and

$N$ - number of compounding periods in the planning horizon (i.e., study period).

The relationship given in Equation 3.1 is based on the assumption of a constant interest rate throughout the life of a particular project. If the interest rate is assumed to change, the PW must be computed in two or more steps.

***The Future Worth Method.*** The future worth metod is based on the equivalent worth of all cash inflows and outflows at the end of the planning horizon (study period) at an interest rate that is generally the *MARR.*

Also, the *FW* of a project is equivalent to its *PW*; that is, $FW = PW(F/P,\ i\%,\ N)$, If $FW \ge 0$ for project, it would be economically justified. Equation 3.2 summarizes the general calculations necessary to determine a project's future worth [2]:

(3.2) $$FW\ (i\%) = \sum_{k=0}^{N} F_k (1+i)^{N-k}.$$

***The Annual Worth Method.*** The Annual Worth (*AW*) of a project is an equal annual series of money amounts, for a stated study period, that is equivalent to the cash inflows and outflows at an interest rate that is generaly the *MARR*. Hence, the *AW* of a project is annual eqivalent revenues or savings (*R*) minus annual equivalent expenses (*E*), less its annual equivalent Capital Recovery (*CR*) amount. An annual equivalent value of *R, E*, and *CR* is computed for the study period, *N*, which is usually in years. In equation form the *AW*, which is a function of *i%*, is [2]**:**

(3.3) $$AW\ (i\%) = R - E - CR(i\%).$$

Also, we need to notice that the *AW* of a project is equivalent to its *PW* and *FW*. That is, *AW = PW(A/P, i%, N)*, and *AW = FW(A/F, i%, N)*. Hence, it can be easily computed for a project from these equivalent values. As long as the *AW* is greater than or equal to zero, the project is economically attractive. An *AW* of zero means that an annual return exactly equal to the *MARR* [2].

## 4. Economic aspects of TIG and FSW methods of welding

In modern industrial production, every production process should be tested in terms of economy. For every company that invests in a new process or technology, it is important to carefully consider all the economic aspects that accompany this process, or technology.

In this paper, the emphasis is placed on welding 6 mm thick sheets, made of Al alloys in the 6000 series (AA 6082-T6). A comparison in terms of cost-effectiveness has been made with regard to welding by electrolytic method of insoluble electrode in protection of inert gas (TIG), on the one hand, and on the other hand, friction stir welding (FSW).

Friction stir welding (FSW) was developed and patented by TWI, Cambridge, UK, in 1991, whose main goal was to overcome the problems that occurred during welding (primarily aluminum alloys) by the process melting. Since its introduction, this process has been constantly improved and the scope of its application has been expanded. FSW is a solid state coupling process using a combination of heat and mechanical work to produce high-quality compounds, without the usual defects characteristic of the melting process [3].

The process itself has found industrial applications in shipbuilding, the aviation industry, auto-moto industry, etc. Additional material or protective gas is not used. The process can be easily automated, so there is no need for highly qualified workforce. The working environment in the case of FSW is cleaner than in arc welding, and there are also no harmful gases, smoke, UV and other harmful radiation. No special preparation of surfaces or edges of slabs prior to welding is required, which greatly reduces costs [4].

What makes the FSW process more economical compared to TIG welding are primarily the costs that are included in the TIG procedure, while in FSW welding they are not present. The estimation of cost-effectiveness is carried out on an annual basis, with the assumption that the welding is performed in one shift, during the working week (ie, it is assumed that the effective working time is about 6 hours during one shift).

Welding of Al plate, thickness of 6 mm, in TIG welding, requires the preparation of these plates, which relates to the edging of the edges by the milling process. In addition, the welding of Al alloys is difficult due to the presence of a layer of Al oxide on the surface of the panels, so for the high-quality TIG welding it is necessary to remove the oxides by means of chemical reagents and mechanically. In addition to all of the above, it is recommended that during TIG welding of materials, whose thickness is greater than 3 mm, it is preheated for 30 minutes, which again requires certain costs. As FSW welding is known to be solid, it should be noted in this connection that the costs of preparing the material are minimized, i.e. there are no [5].

In addition to the cost of preparing welding materials, the TIG welding process also shows the cost of additional material, while FSW is a welding process without additional material. When welding the AA6082-T6 alloy with a thickness of 6 mm, an additional material made of an alloy of ER4043 [5] is used.

In addition to the above, large costs are present in the use of a protective atmosphere. In order for the TIG procedure to be performed well, it is necessary to use a protective atmosphere. It is these costs, to a large extent, that contribute to the fact that the TIG procedure falls into high-cost procedures.

According to [5], the total cost of TIG welding for the 1m alloy AA6082-T6 is 80 €, and the total time required for preparing the material and welding 1 m of said alloy is 90 minutes.

According to the literature source [6], the welding power of AA6082-T6 for the TIG process is 3850 W, while for the FSW process it is 3382 W. Therefore, the difference in the cost of electricity consumption is negligible, so when considering the economy, it will not be taken consider.

However, for the execution of FSW welding, a special tool designed for this type of welding is required. Tool construction is a crucial parameter that influences the quality of the welded joint. On the tool itself, welding forces act, which lead to negative effects, such as tool wear. In addition to the active forces, in the process of welding, the tool generates heat through the tool, which implies that the tool must be made of adequate material, which is adapted to the base material. According to the recommendation of the literature source [7], for the FSW welding of the AA6082-T6 alloy, a tool made of steel for working in hot state JUS C.4751 is used [8]. In addition, the tool has to be thermally processed so that its hardness meets certain requirements, and thus processed smoothly executes the welding process. The tool is made by cutting, and therefore the estimated costs of material and tool making, and its thermal processing are 100 €/piece. As stated above, during the welding process itself, due to the high resistance of the welding material and the forces that act during the process, the tool suffers from some damage, thus losing its high-quality functionality, so it is necessary to replace it with new ones.

## 5. Example of analysis of technology replacement

The company that deals with welding aluminum panels is considering investing in new welding technology (FSW), which would replace the existing electrolytic welding technology with insoluble electrode in inert gas (TIG).

If an effective working time of 6h is assumed during one shift (five working days a week and 52 weeks during the year), the use of TIG technology leads to costs (preparation of materials, additional material and protective gas) in the amount of 20000 € / year [5, 6]. TIG welding equipment could be sold on the free market for 1300 € and written off after five years of exploitation.

The investment in a new, modern equipment costs 70000 € [9]. The market value after 5 years of use is 50000 € [2], with the annual spending on the special tools necessary for the implementation of welding to be 2400 €. If the minimum acceptable wage rate (*MARR)* for the company is 20% per year, it should be opted for economically more cost-effective technology.

Solution: The first step in solving this problem is the determination of the investment value of the "defender" (equipment for TIG welding). From a neutral point of view, the investment value of a "defender" represents its current market value and is 1300 €. It will be approached to calculate the *PW*, and based on this, decide to retain or replace existing technology with a new one:

*Defender*:

$$PW\ (20\%) = -1300\ € - 20000\ €(P/A, 20\%, 5)\ - 61100\ €$$

*Challenger:*

$$PW\ (20\%) = -70000\ € - 2400\ €(P/(A,20\%,5) + 50000\ €(P/F,20\%,5) = -57082{,}12\ €.$$

According to the calculated, the *PW* "challenger" is greater than the PW "defender". In this way, it was pointed out that TIG welding technology was necessary to replace FSW technology. The diagram in Figure 1 shows the difference between the present value of the equipment and the future value of the equipment. It is evident that during the five-year period under review, the economic advantage of FSW technology is significant in relation to TIG welding technology.

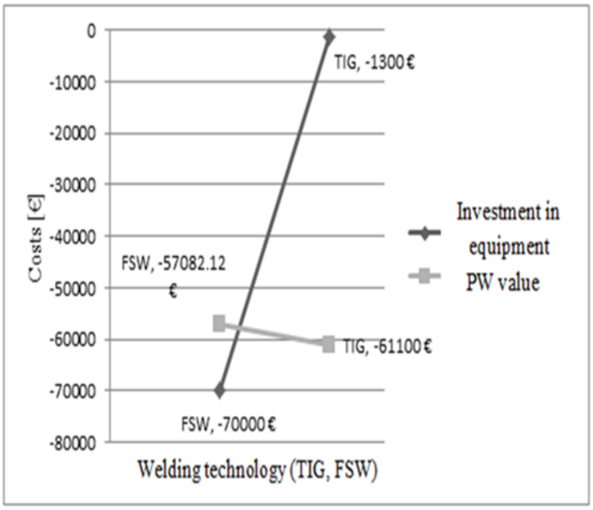


***Fig 1.*** *A graph of present values "defender" (TIG) and "chalanges" (FSW)*

Figure 2 graphically depicts the cash flows of the "defender", which refers to the TIG welding process and the "challenger", which refers to investment in new technology (FSW). In this case, the "challanger" is a better alternative than the "defender" because it has a higher PW value. Therefore, the extra benefits of investing in the new technology of 70000 € ("challanger") have a present value that is: -57082,12 € - (-61100 €) = 4017,88 €, or:

$$PW\ (20\%)_{\text{Difference}} = -68700 + 17600\ (P/A,\ 20\%,\ 5) + 50000\ (P/F,\ 20\%,\ 5) = 4017{,}88\ €.$$

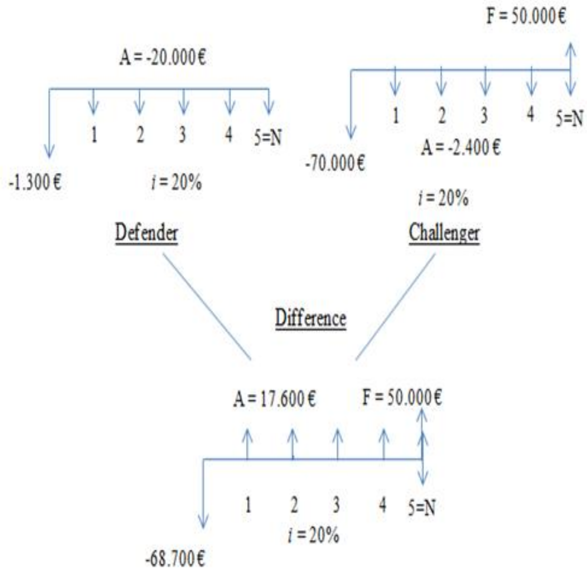


***Fig 2.*** *Cash flow diagram of the defender, challenger and their differences*

## 6. Conclusions

In the pursuit of market survival and the provision of profits, in times of strong market competition and increasingly demanding consumer needs, the organization often makes decisions about replacing existing or new technologies, which will, in a longer period of time, ensure its survival and growth in a competitive market.

Analyzing and comparing the costs of existing and new technology (resources) are basic aspects of engineering practices.

The consideration of the economic cost-effectiveness of replacing the existing arc welding technology with insoluble electrode in inert gas - TIG ("defender"), new welding technology with mixing - FSW ("challanger") was carried out on the basis of the known postulates of the engineering economy, using the current value method (PW). Based on this method, in the considered five-year period, it was concluded that the investment in new technology is much more favorable than the alternative to retain the existing welding technology, which in the considered period leads to a large number of costs, which primarily relate to costs: preparation materials, costs of additional materials and protective gas costs.

All of the above points to the fact that making a decision to invest in new welding technology for the company under consideration is the correct path to maintaining and strengthening market competitiveness and ensuring the profit and survival of the organization on the market.

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