PRODUCT LIFETIME

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ABSTRACT

The paper deals with product lifetime, the manner of its definition and methods of its calculation. Today, in an era of intensive development, technicians and machine designers are often in a dilemma about which values to enter into the calculation. Therefore, the authors wanted to indicate the basic principles of defining product lifetime. The paper analyses the technical lifetime, and also the economical, ecological and, even, fashion lifetime, because they are also important, and in certain cases even crucial, for arriving at a final decision about managing the product.
*Keywords***:** *product lifetime, operating life, durability*

INTRODUCTION

Accessing different literature [1, 4, 7, 8], it can be concluded that authors have different interpretations of the concept of "product life". Hence it is necessary to explain, in one place, the basic terms associated with the product lifetime. When the "life" of a product (i.e. machine, in this case), is discussed, at least six types of life should be distinguished: (1) "life at manufacturer's", (2) "life on the market", (3) "life in storage", (4) "life at user's (customer's)", (5) "life after utilization" [8] and, finally, (6) "personal life" of every product (Fig.1).

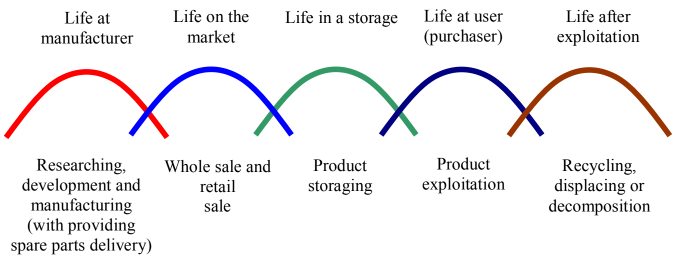

Fig.1 Schematic review of product lifetime phases.

LIFE AT MANUFACTURER

When referring to "product life at manufacturer's" (Fig. 2), it should be noted that "life" signifies the period of time during which the product is "active" at the manufacturer's. It consists of the so called "preparation period" (period of research and development), "manufacturing period" and "final period", when the product is no longer produced, but only its spare parts continue to be produced (if it is foreseen that the product has spare parts).

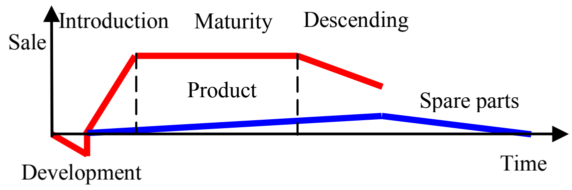

Fig.2 Product life at manufacturer.

The development period comprises the period of time when the product is set up as an idea before it appears on the market. The production period comprises the period when the product comes onto the market encompassing all the time it is manufactured, under economic conditions that provide profitable business. The final period can be very short, when all the necessary spare parts are produced at once and are later successively sold, or it can be longer, when spare parts are successively produced, depending on the demand of orders.

LIFE ON THE MARKET

Life on the market, i.e. "the product life cycle", usually signifies only that period of time when it is present on the market (Fig. 3), from the beginning when it first appears on the market, until it is on sale, with economic conditions that provide profitable business [1]. This period is a long time scale, coinciding with the product's life at the manufacturer, since it directly influences the life at manufacturer, and vice versa. It should be noticed that the product life cycle is not a cause, but is a result of marketing efforts to keep the product on the market as long as possible. In order to avoid an "early death of the product" or "poor life of the product", it is necessary to plan the product's life cycle. The primary objective of all producers is to have a long product life cycle, so that they can recoup all investments in product development and obtain +some profit. However, over time every product technically gets old, i.e. sooner or later it will forced out of the market by a newer product, or its manufacturing is stopped because the product does not produce profit any more. The product survives in the market as long as it is capable of reaching defined objectives and fulfilling the requirements of purchasers and sellers. The product "dies" when it cannot completely fulfill these objectives. The "Entropy law" is especially significant here; it says that everything that exists has a natural predisposition to perish. This means that over time every product necessarily becomes outdated and displaced. All products do not have the same curve of life cycle. It depends on many factors, so that the curve can be "cyclical - recyclical", as a result of stimulating promotion in the phase of declining sales; or it can be "wavy", as a result of discovering new characteristics for its application, or new users, or new markets.

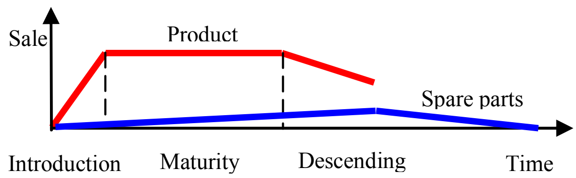

Fig.3 Product lifetime on the market.

Beside this, the shape of the life cycle curve depends significantly on: (1) style, i.e. the way the product "expresses", (2) fashion, or the influence of the purchasers' momentary desire, which changes slowly, stays popular for some time, and subsequently slowly loses popularity, and (3) whim i.e. momentary fashion that easily and quickly attracts customers, who are looking for some sensation and want to possess something that others do not have; this disappears very fast.
Bearing in mind anticipated changes of positioning in the market, producers should take care with future plans, updating current products and introducing completely new products. This means that every company has to continually accommodate its production program according to market demands. No matter how much the company develops its product, it should realize that its contemporary competitors are doing the same. Producers should never be satisfied with the results

the have achieved; they always have to insist on doing the job better and faster, especially if they want to stay a leader in the market.

LIFE IN STORAGE

Life in storage is the period that the product spends in storage. Some products do not have this kind of life at all, and yet some products spend a very long time in storage. This period comes after manufacturing, but also in the warehouse of some shop, until somebody buys it, and after that, too. The producer has to define this period of time during which the product must be properly conserved. After storage, the product must be able to function properly throughout its projected life cycle. The storage period is especially long for different spare parts, military equipment, armaments, etc.

LIFE AT USER'S (PURCHASER'S)

Every product "has a life" at the user's, too. It has its period of exploitation - "durability of product", which comprises the period from the moment of purchasing until it is completely used and/or withdrawn from service (Fig. 4). For certain products (usually expensive ones), after the product resource is exploited, their rebuilding is undertaken in order to prolong their durability as much as possible. After this, the product can successfully operate for an extended period of time.

LIFE AFTER UTILIZATION

It should be borne in mind that a product "lives on" after its usage, too. This period comprises the time from the end of the product's use until its recycling, if the product is appropriate for recycling, or until the complete natural disintegration of the worn out product ("life at garbage"), if it's not convenient for recycling, or until the moment of burning it, if the product is to be burnt after exploitation [8]. Of course, some products, or their parts, can be used again after use (for example, some parts of old and/or damaged cars); and thus their life continues after utilization. Recycling of products, or of the materials that they are made of, is very important nowadays because of limited natural resources.

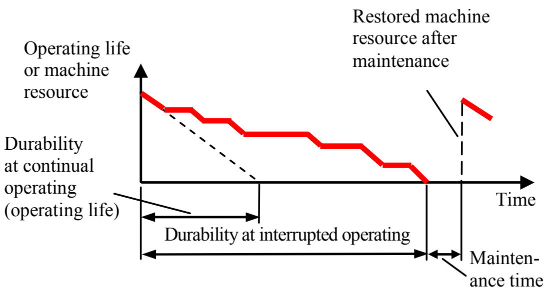

Fig.4 Review of product durability [2].

Life after exploitation obviously depends on many factors such as the type of products, the responsibility of the product user, legal regulations about ecology of the country where the product is used, etc.

Of course, life after product use, in case of products not suitable for second usage, should be avoided, at least, minimized because such products pollute the environment. Today, many positive legal regulations do not allow usage of such rebuilt products. Manufacturers are even obliged to accept back all their used products and to recycle them, if they are convenient for recycling, or to safely dispose of them.

PERSONAL LIFE OF PRODUCT

Certainly, every product has also its personal life, which begins the moment when the material for the product is obtained, continues during its manufacturing, storage, sale and utilization, and finishes with the recycling, or natural disintegration of the product. The lifespan of every product is usually recorded in its service book.

It is preferable that the development period is as short as possible, so that the product can reach the market faster, and its life cycle on the market should be as long as possible, so that all investments in its development can be recouped. Product life at the users should also be long, so that a bigger profit can be made from the same product. Durability has to be long enough to satisfy certain legal regulations, which refer to that product (the durability of products in the machine industry is usually 5 years). Moreover, durability should be adjusted according to the product type and its complexity level, since technically outdated products (for example, products indicated with point 2 on Fig. 5) do not need to have long durability, because very soon they will be replaced with other newer and more modern Product life after exploitation should be minimized, i.e. worn out products should be recycled immediately if they are convenient for recycling, or they should be taken away or burnt, if they cannot be recycled or are dangerous for the environment.

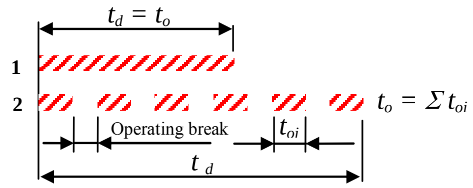

Fig.6 Graphic review of operating life (t_o) influence on durability (t_d) of machine at continual exploitation (1) and for intermittent operating (2) [2].

The basic reasons that cause the replacement of one product type with other are, certainly, technological development and fashion, i.e., the aging of the product and market saturation.

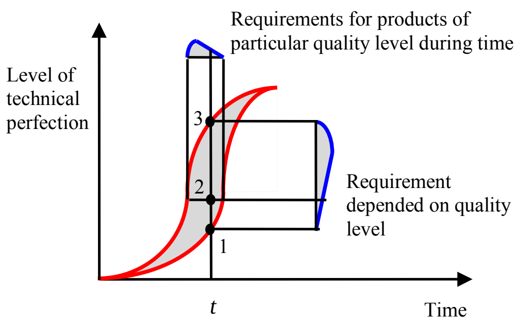

Fig.5 Curve of development and product perfection, 1 - technically outdated product, 2 - technically relatively outdated product 3 - technically the most perfect product.

Modern technologies enable better quality and cheaper manufacturing, less environmental pollution etc., so that new products, by their quality and price, displace products made in a classic way from the market.

Fashion in technique also has a great influence on product placement. Thus, no matter what quality and technical characteristics products may have, if these products are not fashionable, i.e. produced according to an up to date style, purchasers will not be interested in them and they will be replaced by newer (modern) products.

Product aging is a phenomenon in technique generated by establishing new knowledge and developing new technologies that enable some functions to be performed more easily, with better more quality, more economically, faster and with less environmental pollution, so that the older products do not compete any more and are not sought after like before.

Market saturation is a specific phenomenon for most products in the machine industry, because the number of purchasers is limited. After a number of products are sold, further buying can not be expected until some of these products become worn out, or until some new knowledge and technological innovations emerge, that will enable the production of better quality products, and more economically. Only then will purchasers buy new products in order to replace their present devices, but only if they find some interest in them. In the case of widely used products, this problem is overcome by changing models continually, i.e. by purposely building in obsolescence in the design in order to obtain new purchasers with new (better) designs and some small technical improvements. In the car industry, for example, it can be achieved by continual modification to meet environmental regulations, passenger safety regulations, etc.

OPERATIONAL LIFE AND PRODUCT DURABILITY

Operational life of product (t_o), usually a machine, defines the overall time during which the machine can continually operate, under normal conditions and given exploitation regime, without significant decreasing of its basic operating characteristics and with economically reasonable maintenance costs (Fig. 6). This period of time is usually called the **machine resource**.

In many cases machine operating life is represented indirectly, usually by overall performance of the machine throughout its operational life. The operational life, represented this way, shows the number of operations that the machine can perform before it becomes worn out, i.e. before repair. For example, the operational life of agricultural machines is usually expressed by the overall number of hectares of treated area, and the operational life of transport vehicles is expressed by the overall number of kilometers covered, etc.

The duration of a machine's operational life is determined during its construction process and depends on the type of machine and its purpose. Certainly, the duration of its operational life also depends on the manufacturing method, storage, present working conditions, machine maintenance conditions, and on the global technical level of exploitation, so that the operational life of machines in the same production series can be quite different. Correct and careful use of the machine, its quality maintenance by qualified personnel, proper and regular prevention and avoidance of overloading it can significantly increase the operating life of every machine, and vice versa. However, a product's operational life depends on the operational life of its components, which are hard to harmonize, and also on their reliability, so that an average operational life can be defined for complex products.

However, the **actual operational life of a machine** (t_{ao}) can significantly deviate from the **projected operational life** (t_{po}) depending on the operating conditions and the method of use [3]. Systematic overloading of the machine, i.e. its operating with higher revolutions or bigger loads, significantly reduces machine operating life, which can be presented by the **coefficient of the operating regime** (k_o) that directly influences actual operational life

$$t_{ao} = \frac{t_{po}}{k_o} \tag{1}$$

The values of the operating regime coefficient depend on the working conditions and can be adopted as follows: for hard conditions of use k_o = 1.2 to 1.5; for average conditions of use k_o = 1; and for light conditions of use k_o = 0.7 to 0.8 [3]. Of course, these are just approximate values that can be used for rough calculations, and exact values can be obtained only by individual researching of the conditions and use regimes influences on the operational life of specific machines.

Durability (or exploitation life) **of a machine** (t_d) defines the overall time of machine operation with breaks, usually expressed by years, until all its resources are exhausted (Fig. 4 and 6). Durability depends on the projected operational life of the machine (available machine resource) and on the intensity of its usage. Certainly, more intensive usage and shorter operating life result in a reduction of the machine's durability, and vice versa. When all its resources are exhausted, the machine is removed or, if possible, it is repaired. Thus, machine resources are restored (partly or even completely) and it can be used again. Of course, repairs can be done only a certain number of times, after that a new machine should be provided, not only because of its efficiency, but also because it is technically outdated.

Dealing with the exact definition of product durability, it should distinguish functional, technical, economical, ecological and fashion durability.

Also, there is projected durability and actual durability of a machine.

Projected machine durability (t_{pd}), called machine durability, is calculated using the formula

$$t_{pd} = \frac{t_{po}}{365 \cdot 24 \cdot k_e} = \frac{t_{po}}{8760 \cdot k_e} \qquad (2)$$

where:

k_e - coefficient of machine engagement, calculated according to the expression:

$$k_e = k_1\, k_2\, k_3\, k_4\, k_5\, k_6\, k_7 \qquad (3)$$

where:

k_1 - the coefficient of machine usage represents the ratio of the number of days in a year when a machine can be used, and the overall number of days in a year. For machines used every day during a year, the value of this coefficient is 1, and for other machines, it is smaller and depends on the machine's purpose.

k_2 - the coefficient of working days represents the ratio of the number of working days and the overall number of days in a year. For a week of five working days, the value of this coefficient is 0.69.

k_3 - the coefficient of shifts (duty periods) represents the ratio of the duration of a shift in hours and the overall number of hours in a day. For an eight hour working shift k_3 = 0.33, for two working shifts k_3 = 0.66 and for three working shifts k_3 = 1.

k_4 - the coefficient of repairing down time represents the ratio of machine operating time and the total time of operating and the down time for repairing. Thus, this coefficient depends on machine reliability and the organization level of the repairing operations. This coefficient is 1 for machines which operate in a particular season, and for other machines which operate according to a calendar regime, the coefficient k_4 is smaller than 1, usually 0.85 to 0.95, or smaller.

k_5 - the coefficient of machining time represents the ratio of machining time and the total machining and service time (time for regulation, serving and maintenance of the machine). This coefficient varies from 0.85 to 0.95 for manually regulated machines.

k_6 - the coefficient of loadings represents the ratio of effective operating time and total effective operating time and backlash time (if it exists). This coefficient can vary, especially if proper technological planning is not performed. Its value is usually in between 0.7 to 0.95.

k_7 - the coefficient of unexpected breaks represents the ratio of actual effective operating time and total actual effective operating time and machine break time caused by malfunctions that can be repaired immediately. The value of this coefficient is about 1 for properly designed and used machines, and it is much lower for the machines used by unskilled and unqualified personnel.

The values of these coefficients should be carefully considered, because they have a great influence on the accuracy of the final results.

Actual machine durability (t_{ad}) is calculated using the formula

$$t_{ad} = \frac{t_{pd}}{k_r} \qquad (4)$$

When defining the operating life and durability of a machine, attention should be paid to the equal durability of particular components, i.e. the machine should be designed so that its components fail at the approximately same moment. Thus, all maintenance procedures are reduced to the smallest amount, and the machine is fully used. Of course, this is very hard to achieve.

For example, if the machine is designed to last five years, it could last up to 7.14 years by more careful handling (eq. 4), or its durability could be reduced to 3.33 years by negligent use. Since, in certain cases, manufacturers have to provide for a machine duration of 5 years, under rough conditions and negligent handling, it follows that a machine could operate for 7.5 years under normal operating conditions, and such a carefully handled and serviced machine could achieved up to 10.71 years. In order to achieve such a long duration, it should make it an expensive machine, and because of that, it is possible that the machine would become technically outdated during this period. Thus, the producers usually try to avoid manufacturing machines with such a long duration by giving precise directions on how to choose the appropriate machine. For example, producers of universal gear reducers use a service factor (f_B) in their catalogues which influences the choice of the appropriate gear reducer. So, if a purchaser wants to buy a reducer for a heavy drive, according to the appropriate service factor, he will choose a bigger reducer (reducer with bigger load capacity). For other products, this problem is solved by giving precise maintenance instructions and by designing machines that are easy to service, so that the machine can achieve the actual duration of 5 years, even for heavier regimes of use.

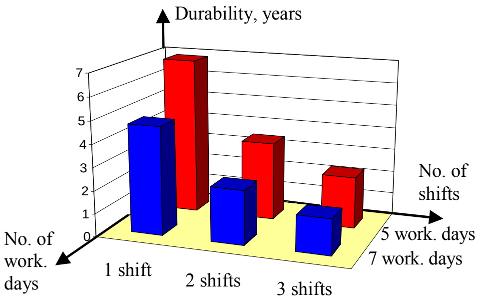

Fig.7 Machine durability depending on number of shifts and working days, for operating life of 10000 hours and normal exploitation conditions.

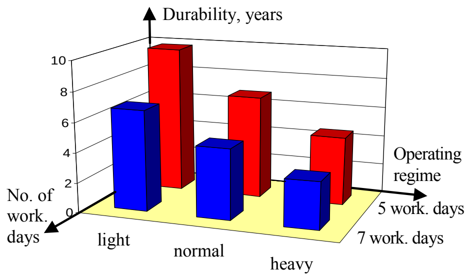

Fig.8 Machine actual durability depending on operating regime and number of working days, for operating life of 10000 hours and one shift per day.

Calculation of necessary operating life also depends on many other factors. For example, for machines with the same projected operational life, different values of projected durability can be obtained (eq. 2 and eq. 3). This depends on the coefficient of machine engagement k_e, i.e. on its application, operating conditions and working organization. The influence of the number of shifts (k_3) on projected machine durability will be analyzed according to the following assumptions: that the machine is used during the whole year ($k_1 = 1$), that the machine is installed in a factory with a five day working week ($k_2 = 0.69$), that the machine operates according to a standard calendar regime ($k_4 = 0.9$), that some manual regulation of the machine needs to be done ($k_5 = 0.9$), that there are some machine backlashes during its operation ($k_6 = 0.9$) and that the machine is properly designed and handled by qualified personnel, so that there will be no breaks ($k_7 = 1$). For a machine operating life of 10000 hours, for normal working conditions and assumed operating characteristics, it follows that its projected durability is 2.27 years if it is operated during three shifts; or 3.44 years if it is operated during two shifts; and 6.88 years, if the machine is operated during one shift only. However, if the machine is operated all seven days in a week, the projected durability would be 1.57 years for use over three shifts, 2.37 for use over two shifts, or 4.74 years for use over one shift (Fig. 7). The actual durability could even be 9.83 years for light, or 4.59 years for heavy usage conditions, assuming working characteristics for working over one shift and five days in a week, or it could be only 3.16 years for heavy, up to 6.77 years in light use conditions, for working in one shift but all seven days in a week (Fig. 8). If it is necessary to provide a projected machine durability of 5 years, for the previous assumed operating conditions, and for working over three shifts seven days a week, its projected operating life should amount to 31930 hours. Such machine design which provides 5 years durability, even for the heaviest working regime, is certainly not good. Such machines would be robust and very expensive, which is not convenient for purchasers, and would also have a long life, which is not convenient for the producers. In the meantime, those long life machines would become technically outdated, and after a certain time, some of them should be replaced, even if they are still capable of being used. This certainly represents global waste and should be avoided.

TECHNICAL AND OBSOLETENESS PRODUCT AGING

Technical aging of a product represents a condition of the product when a new and modern product appears on the market. There is technical product aging of the first type, which occurs at the moment when it is possible to produce a modern product due to technical and technological progress. Technical product aging of the second type occurs at the moment when such a new product comes onto the market. Fast technical development, that will cause rapid technical product aging, should be considered when defining the technical aging of products.

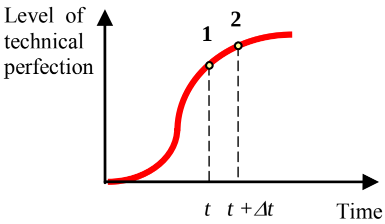

Fig.9 Schematic review of technical development curve.

The technical development curve gives the best review of this process. For example, at the point $t + \Delta t$ (Fig. 9) a more economical and rational product can be manufactured than the product which was produced earlier, at point *t*, if all technical and technological possibilities available at that moment are utilized.

If it is not achieved, so if the new product has worse characteristics than the older one, then it has to be redesigned and developed again, until the necessary characteristics are achieved, or until its development is abandoned and another product is considered.

Usually, the actual durability of a product, designed for wide consumption, should be as long as the time necessary for developing a new generation of product, or just longer than this. Nowadays, that period is usually 1 to 5, rarely 10 years, and it is considered as adequate durability for most products. However, products designed for small and specific markets, for example cranes and elevators, should have a durability of at least 40 years. Also, product durability depends a lot on the level of the technical solution (solution quality) achieved. If the quality of the solution is low, there is no need for the product to have long durability, because it will be technically outdated very soon. These products are not required any more on the market, and products of this technical level will be replaced with new ones, (this is shown on the product development curve on Fig. 5). At point *t*, products of quality level (1) are technically outdated and should not be produced anymore, i.e. they have very short operational life. Products of quality level (2) are acceptable, and the products of level (3) are the most required and they can have a long enough operational life. On the same diagram (Fig. 5) there is a curve of the requirement for products of certain quality levels. It is obvious that demand rapidly decreases with reducing levels of technical perfection of the product. However, in order to succeed in selling these products, their much lower price must

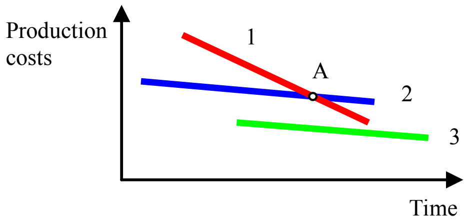

Fig.10 Schematic review of changing of production costs during time: (1) average production costs, (2) production costs using present (old) machine and (3) production costs using new modern machine.

compensate for their technical defects, which certainly affects negatively on successful business of the company that produce them.

The obsoleteness durability of a product represents the time period after which using this product is not economically viable anymore and it depends on technical progress in the field where the product belongs. The moral expiration date occurs at the moment when the production costs (using a particular machine) become equal to the average production costs in the country, or abroad. With further usage of this machine, high production costs occur, not only because of the increasing maintenance costs, but also because of outdated solutions, which affects the production with these machines, which is much more expensive than the average.

The moment of obsoleteness expiration date is defined by the intersection of the average production costs curve (1) and the production costs curve for a machine which moral aging is observed (2), marked by point A in Fig. 10. Assuming that a few years after first using our aforementioned machine, a new, modern machine comes onto the market, providing lower production costs (curve 3 in Fig. 10), it does not mean that our machine will become outdated at that moment. It will operate with reduced efficiency for a certain period of time, and will still be comparable to the new machine because of lower amortization costs, and it can be used until point A in Fig. 10. Machine durability until the moment of its obsoleteness expiration date should be adopted as the optimal durability of machine. However, this parameter is naturally unknown at the time of machine design, so that optimal durability, for every type of machine, is adopted as a period for which it is estimated that the moral expiration date will not occur.

CONCLUSION

Product lifetime is undoubtedly an important feature of every product from which depends not only its structure, but the decision on his purchase, and decisions about treatment with it. This paper reviews the operational life and durability of the product with the intention of highlighting the mutual dependence of all sizes of lifetime and the need for consideration how they affect the final value of operational life and projected durability of products (machines). Particularly is highlighted the impact of the shifts (duty periods) and the type of regime of exploitation on the durability of machine life, as well as the adoption of unjustified operating life, if it is necessary to ensure that projected durability meet the hardest conditions of exploitation. Namely, in these cases is achieved an extremely long life of products under normal conditions of exploitation, which would certainly welcomed by some customers but their usage is ceased due to technical expiry despite they are in very good working condition. This would certainly represent a pure loss for society as a whole. Therefore, it is particularly necessary to access the construction and sale of machines that are designed to work in extremely difficult working conditions, especially those intended for a normal operation. Such an approach to manufacturing can be best seen on the example of the car.

In addition, in this paper, the author points out the need for a detailed definition of economic, ecological and also fashion durability, because they have undoubtedly a significant influence in making final decisions on product treatment.

ACKNOWLEDGEMENT

The article was written within the collaboration on the CEEPUS programme CII-RS-0304-02-0910 - Technical Characteristics Researching of Modern Products in Machine Industry (Machine Design, Fluid Technics and Calculations) with the Purpose of Improvement Their Market Characteristics and Better Placement on the Market realized between Mechanical Engineering Faculty in Bratislava and Faculty of Technical Sciences University of Novi Sad.

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