INNOVATION AND RECYCLING OF ALUMINIUM CASTINGS IN THE FORM OF PLASTIC REPAIR METAL ADDITION FOLLOWED BY MACHINING

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Nowadays, recycling is very often discussed topic though its realization varies. One way the recycled material has to be collected, subsequently sorted, melted, cast repeatedly and the casting has to be respectively machined. Otherwise given casting can be recycled by repair in a form of material adding. This way of repair is suitable especially where the product of the casting is degraded due to material missing for example as a result of cavitation. This method not only saves the environment and lowers the cost of recycling, but is also very time and cost effective.

KEYWORDS

Aluminium, recycling, process, material, waste, procedure, material loss, damage

1 INTRODUCTION

Recycling is one of the most discussed concepts in today's modern world. It has demonstrated positive impact on our environment. The right example is aluminum. It is used perhaps in all industrial sectors from automotive to food industry [Michna 2005].

Aluminum recycling process is most likely well-known to many and will be briefly discussed in the next article. Aluminum recycling process in comparison to its production represents considerable savings in time and energy [Michna 2005].

Is it even faster and more convenient to recycle or refit certain components types and parts? It all depends on a type of damage or degree of wear of given component or part. However if the component needs to be recycled because of its broken off part or because of loss of the material some other way such as rubbing off of material or loss of material due to aluminum oxygenation due to chemical or weather conditions, then it is proper to consider the use of more feasible and faster way such as fill in of the missing material especially if the component is of high shape complexity. Component is usually alright except for the defect such as broken off small piece or wear due to operation activity. Good example could be shape complicated shaft that after some time of use misses some of the material due to wear. In this case it is appropriate to fill in the chafed material and the added spot machine to original parameters in order to save time and money [Michna 2005].

2 CONVENTIONAL METHOD OF ALUMINUM RECYCLING

Aluminum is the most valuable material in separated waste and can be recycled "indefinitely" [Michna 2005].

As regards recycling aluminum is really a grateful raw material. It does not loose any of its original properties after repeated processing and at the end of the recycling process has exactly the same quality like at its beginning. The most recyclable aluminum products are without the doubt tin cans. There are other recycling programs that process sizable aluminum pieces such as building parts and automotive parts. Those are later made into window frames, wires, hosepipes and electronic components [Michna 2005, Dyadyura 2016, Panda 2011, 2012, 2017, Duplakova 2018, Jurko 2012, 2016, Monkova 2013, Gombar 2013, Mrkvica 2012, Leššo 2010, 2014, Balara 2018, Krehel 2013, Krenicky 2012, Olejárová 2016, 2016, 2018, Prislupcak 2014, Pandová 2012, Mačala 2012, Ragan 2012, Valíček 2016,].

Collection and sorting:

Aluminum recycling starts as any other recycling process with collection of separated waste. Aluminum is not separated from other metal materials until it is in separation center. And the like with other recycled materials separation process is the key from the aspect of further processing since many cans are made also from other materials, for example a steel [Michna 2005].

Figure 1. Aluminum recycling uses 95% less energy than its production from raw materials

Crushing:

Sorted aluminum is compressed into cube packs that proceed to the crusher. Being crushed into small pieces makes aluminum easier to melt and dispose of impurities. For example the surface paints on cans [Michna 2005].

Purifying:

Next the small pieces of aluminum undergo control under the strong magnet that will pull out all the remaining steel pieces. Magnetically cleaned aluminum needs to be disposed of all the remaining coats of paint. Besides chemical cleaning the material will undergo cleaning by a hot air that will get rid of all the paint and ink remains [Michna 2005].

Ingots and Presses:

Thus cleaned product is subsequently melted in the oven and cast into molds, most often into so called ingots. Ingots present the first intermediate product that leaves recycling centers and is subsequently pressed. Aluminum sheets are more durable and flexible and are used to make specific products such as cans, foils and various spare parts. When they go out of service the whole process can start again [Michna 2005].

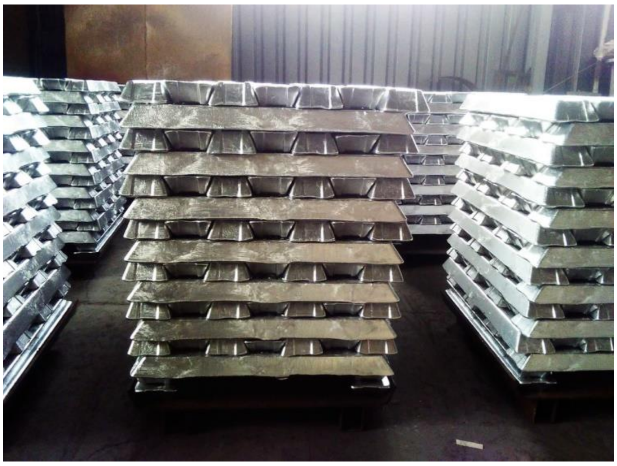


Figure 2. Previous tin cans

Why to recycle ?

As we said before aluminum can be recycled basically indefinitely. And that's one of the reasons why 75% of aluminum produced in last 100 years is still in circulation. One ton of recycled aluminum saves more than 6000 liters of oil and 95% energy and emissions that would be created by its production. One recycled tin can saves enough energy to play one music album on iPod [Michna 2005].

3 RECYCLING / REPAIRS OF ALUMINUM PARTS BY ADDING THE MISSING MATERIAL

In last section we described the standard process of aluminum recycling that has without the doubt many advantages in comparison to aluminum production. Now let's find out if we are able to recycle the parts and components in more effective way-by their repair. We will focus on the components that lost their function because of the break off of some of their parts such as eye with an internal thread or eyes the cables go through. Another process that retires aluminum component from service is wear of the functioning spot by abrasion. Most of the time this includes shafts and cylinders. Basically this kind of damage can be found everywhere where there is a mutual friction of the components. The last and the most infrequent form of aluminum components material loss is through the oxidation. It is caused by effect of oxygen and enhanced by temperature alternation and adding some aggressive materials such as salt. For example this kind of damage is most often seen on aluminum break clippers. Often we run across the material loss damage due to cavitation, mainly on ship screw propellers [Michna 2005].

Each of the damages mentioned above can be repaired appropriately by adding the missing material and subsequently machining it to component's original geometric shape [Michna 2005].

This process pays off mainly with the components of shape complexity since their production is financially and time consuming [Michna 2005].

We encounter this kind of repair mainly in area of maintenance. But can this process be used anywhere else? For example as a method of refurbishing of the components instead of processing them in conventional manner by recycling them and repeatedly casting and machining them? We can expect considerable savings in time and money using this process [Michna 2005].

Material:

As a key component will be material. It is logical that we will use aluminum for the repair of the aluminum part. Currently in the market there is a growing portfolio of the products and the producers that are interested in the development of such materials. These repair products are two component products. The first component in our case is fine aluminum powder. The second component is the binder. The binder is chosen based on our repair needs without affecting component's functionality. Thus if the component is exposed to higher temperatures we would not use the epoxy based binder. More expensive and rather more often used are the binders that function on the principle of chemical reaction. Their main advantage is that they are nonflammable and can be used under water while they still keep most of the properties of the original material including its machinability [Michna 2005, Rimar 2016, Vojtko 2014, Zaborowski 2007, Straka 2013, 2014, Panda 2013, 2018, Markulik 2016, Michalik 2014, Janekova 2014, Sebo 2012, Bielousová 2017, Dobránsky 2019, Pollák 2018, Mitaľ 2019].

Work procedure:

Work procedure is simple. At first we prepare the repair area. It is important to clean and degrease the area. Next we mix aluminum powder and the binder. We apply the mixture on the surface being repaired in a way that thickness of the mixture applied would surpass the surface level of the original material. Such a mixture dries generally from 3 to 15 minutes depending on the surrounding temperature as well as the surface temperature of the repaired component and finally on the properties of the repairing material. After the curing is completed the repairing material is machined as needed. It can be lathed, milled or we can choose other treatment suitable for our application [Michna 2005].

Figure 3. Sample of repairing liquid aluminum

4 PARTICULAR APPLICATION WITH MACHINING

There are many possibilities for utilizing of this recycling system. In general, the more difficult the component repair is and the more expensive the purchase of the replacement component, the higher the effect of utilizing of this form of repair. As an example we can mention repair of screw-propeller damaged by cavitation [Michna 2005, Martinec 1997].

Figure 4. Repair of screw- propeller

Particular application and study of machining possibilities:

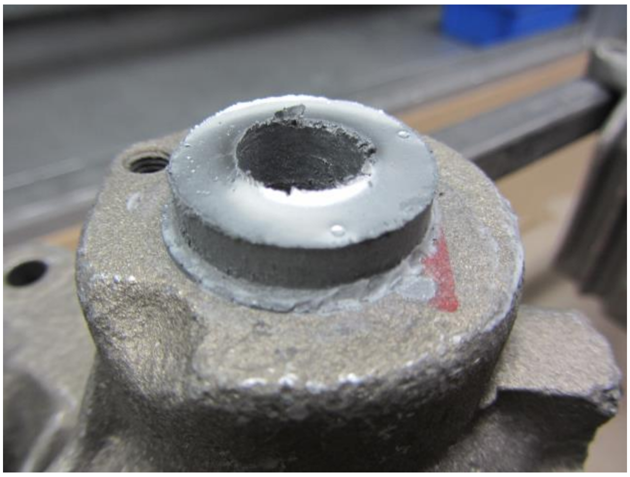
For particular application we will use aluminum - plastic metal from DIAMOND. This is a two faze product. Its hardening is accomplished through chemical reaction duration of witch is influenced by ambient temperature. The higher the temperature the shorter the material hardening time. Repaired damage involves broken part of an aluminum component. The repair starts by material application on the area of a missing part, followed by its milling to the original part's shape before the damage happened [Michna 2005, Martinec 1997].
The first and most important step is the surface preparation. Generally it is appropriate to apply the material on clean and degreased surface. In our case it is ensured by washing. The second step involves work place preparation. It is useful to have everything ready since the material hardens within 5 minutes. Component needs to be well clamped and all the containers and tools need to be ready. By doing so we can prevent unnecessary delays that could easily result in production of scrap. In case we tried to pour semi harden material on the repaired spot, it would lead to inadequate filling of the pores of the repaired component resulting in possible fracturing off of the applied layer during its milling or eventually during the use of the component. In such case, mostly due to failure to comply with manufacturing procedure, the good news is that in 99% the component can be placed back again into the repairing process where the repair is done correctly [Michna 2005, Martinec 1997].

Figure 5. Material ready for application

In some cases, like in ours it is necessary to create some mold, preferably from non stick and non porous alkaline polyamide material such as industrial silicon. Such mold is easily assembled, does not impair harden material by sticking to it and is appropriate for a single repair as well as for the mass production. Its main advantage in mass production is that it does not need to be cleaned between the repeated uses because it does not contain any residues from its previous use [Michna 2005, Martinec 1997].

(a)

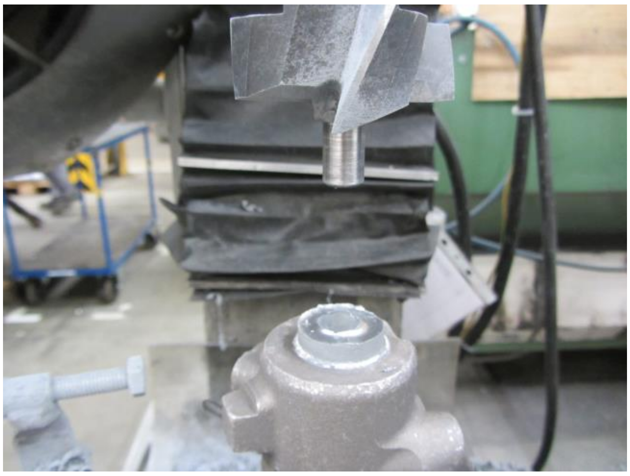
(b)



(c)

Figure 6. (a) Damaged component because of the broken ring ; (b) Mold with repairing material already applied ; (c) Mold removed, component ready for milling

As it is obvious from the pictures, we replenished lost material. Now the question is how to machine existing material to achieve the original geometry of the aluminum component. According to given geometry the most suitable way of milling is milling with classic milling machine that was slightly modified in accordance with requirements for achieving the original ring geometry of the aluminum component. It is important to realize one fact. Even though we used powdered aluminum on aluminum component, there is no aluminum component that is made out of pure aluminum, but its alloy. Dural - 6061 is the most industrially used aluminum alloy with copper and magnesium additives. Mechanical machining of the repaired part will differ from the original alloy material in adjusted cutting speed, quality, swarf shape and possible use of the cooling emulsion. We will be using cutting speed of 150 rpm in this particular application. This speed may seem too slow, but we need to remember that we are only machining the added material and ideally we should avoid touching the original one. Use of different cutting speeds and the coolants depends on given application. Trial is the best way these parameter settings are achieved [Michna 2005, Martinec 1997].



(a)

(b)

Figure 7. (a) Component before machining ; (b) Component after machining, final component repair

In this application it is appropriate to generate long swarf, since the swarf is relatively soft/limp and moldable. The swarf is not perilous to the operator, it falls close to the place of machining and cleans up quite easily and fast. Advantage of this material is that it does not notably dull the cutting tool and that way the same tool can be used to machine number of pieces without the need for tool care. Use of coolant is undesirable in this application, because considering the shape of the swarfs it would cause sticking of the swarfs to the cutting tool and the workpiece and would result in tearing out of the material from the repair place. Its absence is welcome since there is no need for cleaning and caring for emulsion itself [Michna 2005, Martinec 1997].

Figure 8. Swarfs of the machined material "plastic metal"

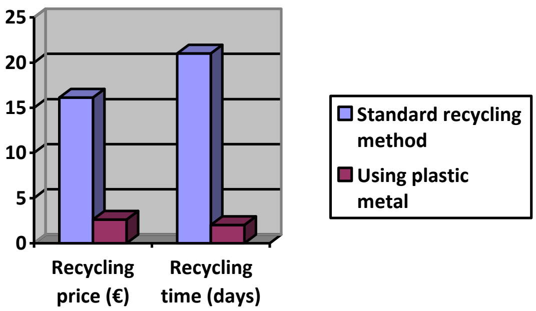
During this process average length of the swarf reaches length of 130 mm +/- 20 mm. As it was mentioned before the shorter swarf would be unsuitable in this case [Michna 2005, Martinec 1997].

4 DISCUSSION

As it was mentioned at the beginning it is not always reasonable to recycle the part by conventional method. In given application the manufacturing cost of a new part after this kind of damage by conventional method is estimated at 16.13 Euros which includes collection of damaged part, its melting, repeated casting and complicated machining. This price does not include the cost of transportation. Also another factor to consider is time savings. The earliest possible delivery date counting transportation to and from the supplier is 3 weeks which sometimes presents difficulties in meeting the production requirements. It is important to mention that this process is worth mainly in remanufacturing and not in production of the new pieces [Michna 2005, Martinec 1997].

Recycling of the piece by the method of adding the missing material to it instead of conventional method is less time and money consuming. The cost of the repaired piece including material and labor cost of applying the material and the milling is 2.62 Euros. The time needed for this process are 2 working days. Applying of the material is done the first day followed by the next day milling to allow enough time for proper material hardening at any temperature in any season. Besides that this kind of recycling is safer for the environment [Michna 2005, Martinec 1997].

Table 1. Price and time comparison of the classic recycling method of the part and its repair by material adding



Benefits:
Time saving due to faster return of the component back into manufacturing process
Financial savings during recycling of the component by the form of repair
Material diversity of repair materials
Safer for environment

Cons:
Impossible to use in every application
During complicated applications making of the mold is necessary
Added material does not have the 100% properties of the original one

6 CONCLUSIONS

Recycling of the components using remanufacturing is mainly focused on the lowest cost of their return to the market since their price must be always below the cost of the new one. Of course the company wants to make a profit. Oftentimes it can not avoid expenses associated with labor cost, storage facilities, technology, energy and often even buy out of used component that would be refurbished. Because of that it is very important to set up manufacturing processes and technologies in a way to minimize the cost [Martinec 1997].

It is necessary to consider if given technology can be used for particular application. It is not recommended to repair extremely strained surfaces since the repairing material has generally lower strength than original one. Also it is appropriate to test the functionality of applied technology, to make sure it would satisfy customer's quality requirements [Martinec 1997].

Secondly, in comparison to conventional form of recycling, successful application of adding of the material technology represents considerable savings in time and money. Suitability of its application is for example everywhere where there is remanufacturing of the parts, in most cases such are the castings [Martinec 1997].

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