Recycling of Titanium and Titanium Alloys turnings

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Recycling of Titanium and Titanium Alloy turnings to be remelted for aeronautical applications, decontamination from Aluminum metallic and other metals.
Some information regarding Titanium turnings - 1

Metal turnings are generated by mechanical process of removing material from raw metal pieces to obtain finished pieces of any metal or alloy. The machines used for these operations are lathes, cutters and other machines. In the case of titanium and titanium alloys, turnings are generated by a machining process to obtain mainly aeronautical and biomedical products and minimally for the automotive sector.

The machining process for the production of aeronautical and biomedical pieces generates a remarkable amount of waste, such as turnings. Due to the fact that, at least in aeronautical applications, titanium alloys and aluminium alloys are structural alloys although for different applications and antagonistic between them and with different mechanical characteristics. In some Italian factory, titanium products are usually processed, on the lathes or cutters, after aluminium products or/and vice-versa. As a result, the production waste, and chips in particular, are mixed during the process, among great difficulties and often through complex operations of separation of metals or alloys. As for the solid waste, the separation is much easier with the use of appropriate analytical instruments and also thanks to the different specific weights of the materials. Therefore, on the domestic market of titanium waste we can find a great amount of turnings, but they are often severely contaminated by other metals or alloys. This is due to the lack of knowledge or interest by operators that fail to appropriately clean the machines after each operation in order to remove any traces of a specific metal or alloy.
Some information regarding Titanium turnings - 2

This happens in workshops where the waste material is considered poor and has a low value or the production must be stressed. As a result, a quantity of that material is redirected to the production of Ferro-Titanium (a ferroalloy used in steelmaking and added to the steel to improve its quality), while other quantity is mixed with stainless steel turnings.

While in case of Nickel-base alloy turnings (Inco 625, 718, Hastelloy C-276, ect.) producers are more interested in the quality of the waste material, as its market value is much higher than Titanium.
Some information regarding Titanium turnings - 3

This scenario of the Italian market of Titanium turnings led CO.FER.M to focus on an innovative recovery facility. It consists of a set of specific machines that at the end of the process will obtain Titanium turnings decontaminated, provided that the base of the entire process is the same type of Titanium alloy, for example only Ti 6Al 4V, and not one Titanium alloys with different Ti alloys mixed together for example: Ti 6Al 4V plus Ti 6Al 2Sn 4Zr 2Mo or more alloys, in that case, it would be impossible to separate them but only Aluminum or other metal alloys, if present in the turnings, in this case the turnings is diverted on the fabrication of Fe-Ti if value of Ti is more or equal to 88%.

In the CO.FER.M. facility we mainly treat the Ti 6Al 4V Titanium alloy, commonly known as Grade 5, which is specifically used for aeronautical applications (in this moment in Italian plant there is F-35 project) or for biomedical applications as: Ti 6Al 4V ELI, in the same plant could be processed singular type of turnings such as these:

- Ti 6Al 2Sn 4Zr 2Mo
- Ti 6Al 2Sn 4Zr 6Mo
- Ti 6Al 7Nb
- Ti CP (Commerci ally Pure)
- Other Ti alloys
- Zirconium
Planning of Titanium turnings treatment - 1

CO.FER.M.’s facility for the treatment of turnings follows a specific process based mechanical drying by centrifugation (turnings are usually wet, as they are produced by machines where a great quantity of cooling lubricant is used to refrigerate the piece and the tool) and on the passage through an “Eddy Current” machine for Aluminum decontamination, while magnetic iron alloys are removed through demagnetization belts positioned before the centrifuge (spin-dryer) and eventually after the centrifuge and after the eddy current machine.

In the processing of turnings, when these come from ingots or slabs they are particularly long, therefore they are put into a “crusher” named Arboga, to reduce their length, so that they will be processed more easily and directly in the decontamination machine (Eddy current), after passage on a demagnetization belt positioned at the end of the crusher. In this case they are not centrifuged, as their humidity levels are acceptable (less than 3% of water).

The production line consists of:

**Crusher machine (Arboga)**

- Crushing for long turnings
- Conveyor belt
- Magnetic decontamination belt
- Recovery box for processed turnings
Planning of Titanium turnings treatment - 2

**Centrifugation (Spin-drin) plant (see the photo at the end):**

- Feed hopper for turnings
- Conveyor belt
- First demagnetization belt
- Sieve for fines separation
- Storage tank before centrifugation
- Conveyor belt feeding the centrifuge
- Centrifuge
- Conveyor belt expelling dried turnings from the centrifuge
- Possible demagnetization belt
- Recovery box for dried turnings

**Eddy current machine (see the photo at the end):**

- Feed hopper
- Conveyor belt leading to vibrating feeder
- Vibrating feeder of “Eddy-Current” machine
- Eddy current machine for Aluminum, Bronze, Brass, Copper decontamination.
- Storage box for Aluminum.
- Conveyor belt expelling processed Titanium turnings
- Additional demagnetization belt
- Recovery box for processed turnings
The decontamination treatment of Titanium turnings consists in feeding the material in the two machines described above: *centrifuge/spin-dry (crusher if necessary) and Eddy-current machine*.

After drying the material by centrifugation, could be arrive until to 2-3% of water. A single passage through the machine is sufficient, and sometimes, when the turnings have a particularly low or absent content of contaminants, the passage through the spin-dry and the previous passage through the demagnetization belt may be sufficient to obtain a suitable material, however according to our experience and internal practices, at least one passage through the eddy current machine is always advisable.

Wet turnings (arrive up to 30% of H₂O) are brought slowly but steadily to the centrifuge and inside a chamber with a conical disc spinning very fast (about 1500 RPM). Due to the centrifugal force, the turnings are soaked with an emulsion of oil and lose water.

The water mixed with oil is collected in a tank outside the machine and will be disposed of within the law, while the turnings come out of an exhaust opening positioned on the conveyor belt which feeds the recovery tank.

After the drying process by centrifugation, the previously weighed turnings are moved to the hopper in the decontamination machine.
Description of the process: «Eddy Current» - 2

The process of decontamination may require up to 3 passages through the eddy current machine in order to remove completely the metal contaminants, mainly Aluminum and Copper, if present, and in some cases small pieces of bronze and brass.

*The eddy current or Foucault currents, are currents induced in conductive metal masses that are immersed in a variable magnetic field or that, moving through a constant or variable magnetic field, is this variation of the magnetic field that generates these currents.*

Normally the Titanium turnings requires a maximum of two passages through the “eddy-current” machine and in some times a single passage may be sufficient to guarantee the specifications requested by the clients.

The number of passages through the “eddy-current” machine is based on the chemical analysis of turning samples, 1st origin of material and during the process are taken regularly and tested after melting them inside an arc furnace with a non-consumable graphite electrode in an argon atmosphere. The sample, called “button”, is obtained by melting of the turnings is then examined with a quantometer, a traditional instrument for analysing of metals, if the levels are within the parameters requested by the custom specifications, the material is released to be packaged and sent to the client.

If test results are not good, an additional passage through the eddy current machine will be necessary.
Scheme of turnings preparation

1. Material acquisition, humidity and check analysis
2. Magnetic separation and centrifugation or crushing and magnetic separation
3. Removal of Aluminum and other Met. or Alloys by "Eddy current" machine
4. Final magnetic separation
5. Chemical analysis of the turnings
6. Packaging storage identification and certification and shipping to the clients
Graphics of analysis of turnings

Initial analysis

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<td>Mo</td>
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<tr>
<td>Sn</td>
<td>0.044</td>
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<tr>
<td>Cr</td>
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Analysis after first passage through EC machine

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Analysis after second passage

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<td>Cr</td>
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Photos of the Process:

Photo 1: Line of centrifugation (spin-dry)

Photo 2: Line of decontamination: Al and others

Photo 3: Turnings processing
Conclusions

It is obvious that the eddy current machine can separate only single metals, such as aluminium, copper or pieces of brass and bronze, but not metals which are part of the processed Titanium alloy, a for example:

*if we process some Titanium 6Al 4V turnings which appear to be contaminated by a different Titanium alloy, for example: Ti 6Al 2Mo 4Zr 2Sn, in that case, as titanium is the matrix and the other elements are part of the alloy, those turnings cannot be decontaminated, and will be redirected to the production of Fe-Ti.*

*The same type of decontamination process to remove Aluminium, Brass, Bronze, Copper and magnetic materials from Titanium turnings can also be used for turnings of Zirconium 700 and its alloys : 701-702.*

*The process described in this presentation is covered by “Patent N° 102018000011004” issued by Italian Ministry of Economic Development (Ministero dello Sviluppo Economico).*
Thanks for your attention