UNIVERSITA' DEGLI STUDI
DI TRENTO

DIPARTIMENTO DI INGEGNERIA DEI MATERIALI E TECNOLOGIE INDUSTRIALI

FINAL REPORT

On the consultation contract between

TU.RO.CO. Srl in Padova
and
The Department of Materials Engineering
in the University of Trento

Analysis of the metal surface cleaning process using bicarbonate of soda saturated solution, containing dispersions of solid bicarbonate of soda.

September 2000

1) Choice of the materials:

In co-operation with the Technical experts of TU.RO.CO srl, the materials were identified which were interesting to use for the analysis and the methods were agreed for supplying the samples to be studied.

N° 8 samples of steel of varying hardness
N° 2 samples of aluminium of varying hardness and surface finish

STEEL	**Vickers HARDNESS**
C45	196 HV
C45 milled	196 HV
2312	287 HV
2312 milled	287 HV
HARDENED AND TEMPERED	296 HV
IMPAX	311 HV
ORVAR	489 HV
STAVAX	556 HV

ALUMINIUM	**Vickers HARDNESS**
Die AL (supplied by TUROCO)	130 HV
AL ERGAL55 polished (supplied by TRENTO)	185 HV

2) Treatments

As shown in detail in the table below, the samples underwent surface cleaning treatment using the SOBIJET® method, with one of the machines manufactured by TU.RO.CO. S.r.l.
The jet pressure varied during treatment between 0.5 and 5 bar.
The treatment times varied between 15 and 60 seconds (just one test was performed at 240 seconds on die AL).
A constant distance was maintained for all treatments of 7cm.
The treatments were all performed with the jet perpendicular to the sample. Tests were performed at 45° on the AL ERGAL polished sample.
The bicarbonate granulometry was kept constant at 400 micron (just one test was performed with bicarbonate at app. 300 micron on the AL ERGAL polished sample).

Treatment table (pressures and times)

SAMPLES	PRESSURE (bar)	TIME (seconds)
C45	1 3 5	15 15 15
C45 milled	1 3 5	15 15 15
2312	1 3 5	15 15 15
2312 milled	1 3 5	15 15 15
HARDENED & TEMPERED	1 2 3	15, 30 15, 30 15, 30
IMPAX	1 2 3	15, 30 15, 30 15, 30
ORVAR	1 2 3	15, 30 15, 30 15, 30
STAVAX	1 2 3	15, 30 15, 30 15, 30
Die AL	1 3 5	15, 60 15, 60, 240 15, 60
AL ERGAL55 polished (1° test)	1 3	15, 60 15
AL ERGAL55 polished (2° test)	0,5 1 1,5 3	15 15 15 60
AL ERGAL55 polished (3° test) Inclination 45°	1 3 3 (bicarbonate F)	15 15, 60 15

ANALYSIS OF THE RESULTS

The prepared samples (refer to the previous table) underwent analysis as given in the technical appendix with the contract.
The following values were measured:

- Vickers hardness before and after treatment - Wolfort hardometer
- X-ray diffraction (micro-structural analysis) - Rigaku Geigerflex diffractometer
- Roughness before and after treatment - Hommel Tester T8000-Hommelwerke GMHB and Tecnor mod. Alphastep200 profilometers
- Electronic scanning microscopy (morphological analysis) – Philips microscope XL30
- Atomic force microscopy (morphological analysis) – AFM Burleigh mod. Vista
- Weight drop during treatment - Scales sensitive to 10^{-6} grams

Vickers hardness was measured before treatment and the results are given in the sample presentation table (refer to page 1).
Hardness was also measured after treatment and no significant changes were registered.
This initial result gives a first indication that SOBIJET® treatment affects and changes the analysed metals for thicknesses of just a few micrometers.
The X-ray diffraction levels before and after treatment showed no variations, confirming the superficial change that was after quantified by the morphological measurements.

Three or four roughness measurements were made on each sample and the results are shown in the appendix.
The appendix also gives the average values of the roughness values on the basis of treatment pressure and time.

Comparison of these results allows us to make a synthesis and draw conclusions.

Fig. 1 shows the average values of roughness variation after the various treatments on all the samples, on the basis of hardness.
It can be noted that ***on samples with hardness above 250 HV with pressures up to 5 bar, no appreciable variations were found in roughness.***
For hardness values below 250 HV, there is no general rule and the type of material, pressure and treatment time must all be taken into account.
We can also note that C45 steel with hardness below 200 HV, not showing any difference between the treatments at various pressures, behaves like steel with greater hardness.
The aluminium samples behave completely differently.
Both the ***samples of aluminium, showed the same behaviour:***
for pressure above 1 bar, the roughness variations increased drastically (refer also to Fig. 2) while for pressures of 1 bar or below, the behaviour was the same as for steel.

The fact that materials with the same hardness (C45 steel and Ergal55 Aluminium) behave differently, shows that ***the material hardness parameter is not the only one to be taken into consideration, but also ductility***.
Ductility of the various types of aluminium is notably higher than that of steel.

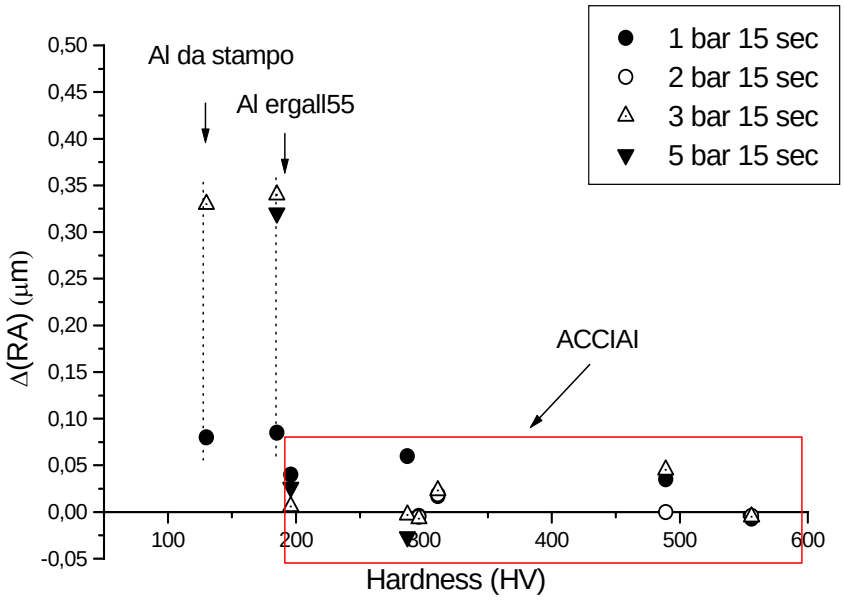

FIG. 1 - Variation in surface roughness of all the samples on the basis of their hardness

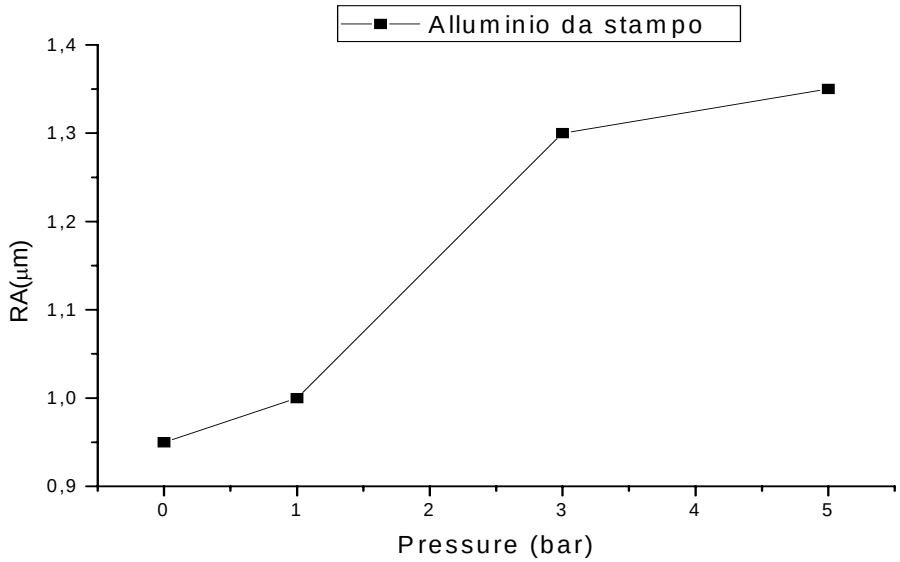

FIG. 2 - Variation of the surface roughness of AL die samples on the basis of the jet pressure

Fig. 3 shows the roughness variation of all the treated samples at 1 bar pressure for 15 seconds, on the basis of their hardness.
It was noted that for less hard materials (different aluminium samples) the roughness variation was very small, and therefore we can claim that:
for treatments with pressure at around 1 bar on low hardness materials with elevated ductility, the initial roughness is not notably changed.
The general effect why SOBIJET process, involving just the surface part of the samples, does not change initial surface roughness, is confirmed by the electronic scanning microscopic analysis (SEM) and atomic force microscope (AFM) (refer to the appendix).

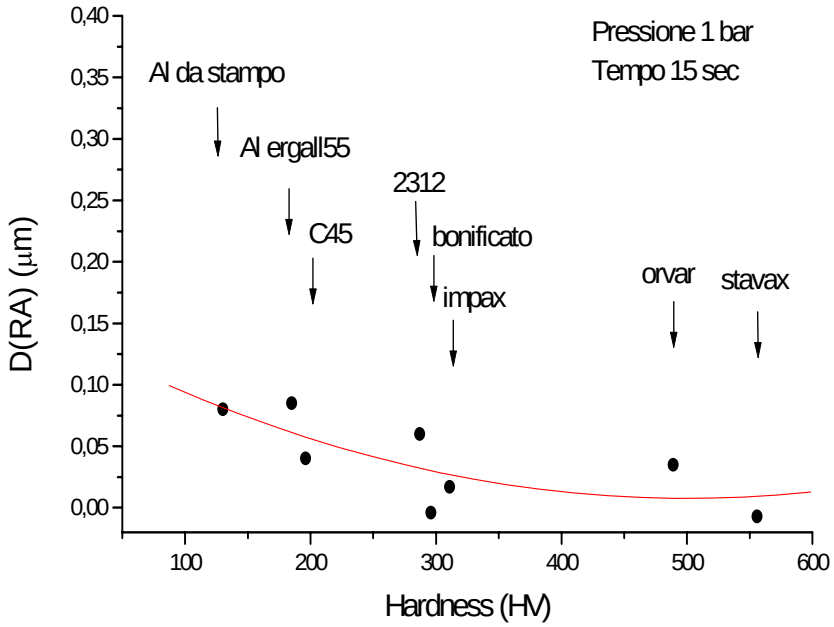

FIG. 3 - Variations of surface roughness of all the samples, on the basis of their hardness for jet pressure treatment at 1 bar for 15 seconds.

On the basis of these results, the different behaviour is evident between the samples of steel and aluminium in the sense that aluminium is easier to damage at pressures between 1 and 3 bar. We must clarify if the greater damage is accompanied by a weight loss caused by removal of surface material.
Two tests were performed, the details are listed in the appendix, with final polishing to less than a micrometer for each test, 4 samples of AL ERGAL55 and then treatment with pressures between 1 and 3 bar for different lengths of time. Special care was paid to washing and drying the samples to ensure no deposit or impurities were left.
The results have shown how the variations in weight (where they exist) are to the millionth of a gram.

Therefore we can claim that the cleaning process does not remove material from the surface, and any unevenness (in the order of micrometers) that can be found in less hard and ductile materials, is caused by the first layers of the sample compacting.

The same results were obtained treating a series of 4 polished samples of AL ERGAL55 at pressures between 0.5 and 3 bar, for different lengths of time and a 45° jet.

The results (given in the appendix) show that, using sensitive scales to the millionth of a gram, there was no significant removal of material even if roughness gradually increased for treatments at increasing pressure between 1 and 3 bar, thus confirming the data obtained previously (refer to table B) with the values remaining considerably lower than a micrometer.

Measurements on samples of AL ERGAL55 polished and treated at 3 bar for different lengths of time (15 and 60 seconds) showed that with time roughness did not increase, confirming the result obtained with die aluminium treated at 3 bar for 15, 60 and 240 seconds, according to which roughness remained constant as time increased (refer to FIG. 4 and Table A).

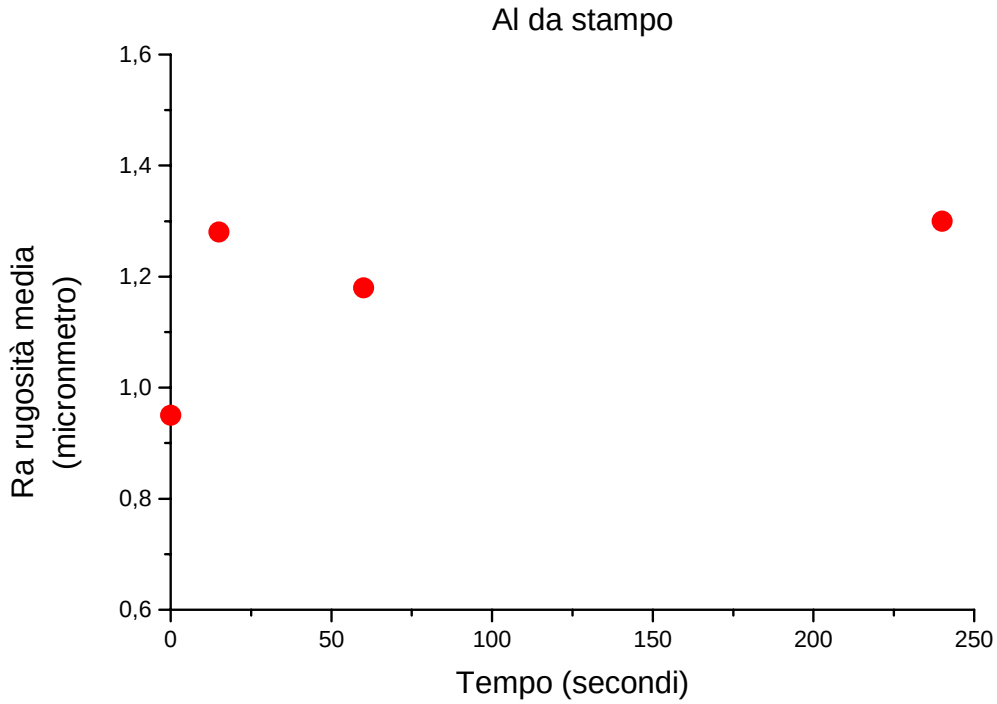

FIG. 4 - Average surface roughness on die aluminium samples, after cleaning with jet pressure at 3 bar on the basis of the time of treatment

Die AL	Average roughness
Initial conditions	0.95 micrometers
P=3 bar, T=15 sec	1.28 micrometers
P=3 bar, T=60 sec	1.18 micrometers
P=3 bar, T=240 sec	1.30 micrometers

Table A

Another consideration should be made about the limited roughness levels that were measured (a few micrometers: refer to the following table) with reference to the size of the bicarbonate particles (400 micrometers). The effect of the SOBIJET process can be compared with processes that tend to make the surface flat, smoothing any bumps that may be caused by unrefined processing.

AL ERGAL55	Roughness - polished area	Roughness - treated area
P=0.5 bar. T=15 sec	0.025 micrometers	0.075 micrometers
P=1 bar. T=15 sec	0.025 micrometers	0.110 micrometers
P=1.5 bar. T=15 sec	0.030 micrometers	0.140 micrometers
P=3 bar. T=60 sec	Insufficient surface available	0.370 micrometers

Table B

The last consideration regards the optic features of the treated surfaces. The measurements taken on AL ERGAL55 mirror polished samples have shown that treatments at 0.5 bar for 15 seconds, already cause a certain opacity and therefore tests must be performed at lower pressure levels to establish the best levels for this treatment.

CONCLUSIONS

The studies carried out on the selected samples have shown that SOBIJET® treatment involves and changes metals by just a few micrometers of thickness, even at elevated pressure levels.
On samples with hardness above 200-250 Vickers HV with pressure up to 5 bar, no appreciable variations in roughness were registered.
For samples with hardness below 200 Vickers, the behaviour between steel and aluminium samples was different: steel, not very ductile, continued with no real variations in roughness, while aluminium more ductile, modified at pressure above 1 bar.
For pressures of 1 bar or less, the behaviour of the aluminium samples was the same as that of steel, with limited effects on surface roughness, which, in specific cases, became duller.
During cleaning processes, no material is removed. Any variations in evenness are caused by compacting the first layers of the samples. This effect is more evident in materials with low hardiness and high ductility.
Roughness variations are shown in the first seconds of treatment and remain unchanged for prolonged treatments.
A test was performed using bicarbonate with smaller grains and the results showed no significant change in roughness.

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Appendix

Samples of polished AL ERGAL55 (**first test**)

Four samples were taken of Ergal 55 (aluminium) with 185 Vickers hardness, polished to 1 µm

Sample nr. 1: reference sample

Sample nr. 2: 1 bar for 15 sec. at 5/7 cm

Weight before treatment	6.12025 g
Weight after treatment	6.12021 g
Percentage weight change	6.536E-4 %

Sample nr. 3: 1 bar for 60 sec at 5/7 cm

Weight before treatment	6.07645 g
Weight after treatment	6.07608 g
Percentage weight change	6.09E-3 %

Sample nr. 4: 3 bar 15 sec at 5/7 cm

Weight before treatment	6.04112 g
Weight after treatment	6.04094 g
Percentage weight change	2.98E-3 %

Appendix

Samples of AL ERGAL55 polished (**second test**)

4 samples of Ergal 55 (aluminium) were taken with 185 Vickers hardness, polished to 1 μm.

Sample nr. 1: 0.5 bar for 15 sec at 5/7 cm

weight before treatment	6.07459 g
weight after treatment	6.07459 g
average weight change	0 %

Sample nr. 2: 1 bar for 15 sec. at 5/7 cm

weight before treatment	6.06191 g
weight after treatment	6.06191 g
average weight change	0 %

Sample nr. 3: 1.5 bar for 15 sec at 5/7 cm

weight before treatment	6.11670 g
weight after treatment	6.11670 g
average weight change	0 %

Sample nr. 4: 3 bar for 60 sec at 5/7 cm

weight before treatment	6.03679 g
weight after treatment	6.03593 g
average weight change	14.25E-3 %

The roughness values are given in the REPORT

Appendix

Samples of AL ERGAL55 polished (**third test**)

4 samples of Ergal 55 (aluminium) were taken with 185 Vickers hardness polished to 1 µm.

Sample nr. 1: 1 bar for 15 sec at 5/7 cm inclination 45° bicarbonate "G".

weight before treatment	6.03197 g
weight after treatment	6.03197 g
average weight change	0 %
initial surface roughness	0.025 µm
treated surface roughness	0.140-0.155 µm (measured in various areas)

Sample nr. 2: 3 bar for 60 sec. at 5/7 cm inclination 45° bicarbonate "G".

weight before treatment	6.07234 g
weight after treatment	6.06911 g
average weight change	53.19E-3 %
initial surface roughness	0.025 µm
treated surface roughness	0.400-0.500 µm (measured in various areas)

Sample nr. 3: 3 bar for 15 sec at 5/7 cm inclination 45° bicarbonate "G".

weight before treatment	6.11144 g
weight after treatment	6.11092 g
average weight change	8.5E-3 %
initial surface roughness	0.025 µm
treated surface roughness	0.400-0.450 µm (measured in various areas)

Sample nr. 4: 3 bar for 15 sec at 5/7 cm inclination 45° bicarbonate "F".

weight before treatment	6.05802 g
weight after treatment	6.05728 g
average weight change	12.2-3 %
initial surface roughness	0.025 µm
treated surface roughness	0.450-0.465 µm (measured in various areas)