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The reliability of polished porcelain stoneware tiles

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Abstract

The flexural strength and the Young's modulus of as fired and polished porcelain stoneware tiles were investigated. Bending tests were carried out on suitable specimens, cut from five commercial products before and after polishing. The differences found in the flexural strength data were evaluated by the analysis of variance and the determination of the Weibull parameters. The results showed that: (i) the as fired tiles and the corresponding polished tiles cannot be always considered the same material and (ii) the data scattering is usually greater for the polished products, i.e., the reliability of the polished products, in terms of the Weibull modulus *m*, decreases. The results, supported by microstructural observations, surface roughness and Vickers hardness measurements, were directly attributed to the severe damage induced by the first step of machining, i.e., calibrating or grinding. Young's modulus data showed a clear dependence on the pre-existing porosity, i.e., the production process, rather than on the machining induced damage. It was also shown that the conditions and the characteristics of the polished working surfaces strongly depend on the microstructure of the as fired material.

Keywords: Porcelain stoneware; Tiles; Polishing; Mechanical properties; Weibull modulus

1. Introduction

Porcelain stoneware tile represents the best product that has been developed in the sector of ceramic tiles. This product is the results of an industrial process that through a preliminary works sequence, such as grinding of a mix of raw materials (a typical current composition contains 25–30% of kaolin and ball clays, 50–60% of feldspars and 5–10% of quartz sand), slip preparation and spray drying of the slip, attains the production of a powder having a ≈5% of humidity. It is formed by uniaxial pressing, usually at high pressures, 40–55 MPa, and the firing of the shaped tiles adopting thermal cycles of 45–50 min with a maximum temperature ranging between 1210 and 1215 °C, allow to obtain a dense material containing a high amount of glassy phase embedding residual quartz and mullite crystallised during sintering.[1] So, the final product is characterised by very high physical–mechanical characteristics. This makes it possible to subject the working surface of these unglazed tiles to mechanical machining (calibrating or grinding and polishing) in order to improve their aesthetic aspect and increase the competitiveness with the natural stones.

The machining for ceramics is a critical and very expensive process, which depends considerably on both the microstructure of the material and on the working parameters selected.[2,3] If the procedure is not strictly controlled, the resulting polished working surfaces present a technological memory in the form of scratches, grooves, cuts, extensive subsurface cracking and detachment of material.[4] The industrial process to obtain polished porcelain stoneware tiles is very widespread. Even if it improves the aesthetics of the products and thus their competitiveness with natural stone, it causes rather serious deterioration of the working surface.

For ceramics, the removal of material by abrasives involves different fracture mechanisms.[5] In the present case, these mechanisms result primarily in (i) compaction of the material and (ii) damage, such as the formation of grooves, scratches, cuts and widespread subsurface cracking.[6] The actual machining process for porcelain stoneware tiles consists

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of two successive phases. The first phase, a grinding or calibrating step with the use of diamond-based coarse abrasives, removes substantial volumes of material, also inducing localised residual stress[7] and damage of different morphology.[8] These defects, when perturbed, can give rise to further removal of material and, sometimes, to the fracture of the products.[9] After this first phase, the ground surface shows severe deterioration, sufficient to cause a consistent decrease in the mechanical characteristics and service performance.[10] The second phase, the polishing step, carried out using a very long treatment with abrasive tooling, usually containing SiC with decreasing grain size, partially reduces the severity of the damage and improves the appearance of the working surface, conferring the required degree of gloss.[11] To ensure a high surface quality, the damage generated by the calibrating step should be removed. As regards a correct polishing procedure with optimised machining parameters, should be able to completely eliminate the damage induced by calibrating, recovering the best characteristics of the material.[12] Since the actual machining processes are not established on the basis of an exact analytical knowledge of the influence of the machining parameters and the microstructural characteristics of materials,[13] but rather depend on the expertise of the operators, the polished working surfaces generally maintain a technological memory. Polished working surfaces usually present a deterioration of the mechanical characteristics due to a complex system of surface and subsurface cracks induced both directly and indirectly by machining.[14–17] For this class of tiles, a particular role is played by a more dense surface layer, the removal of which uncovers the closed porosity present in the bulk material.[18] It should be taken into account that for these products, in the as fired condition, surface porosity is almost completely absent: the water absorption is almost zero. After polishing, therefore, the working surface presents a decrease in hardness and wear resistance and a higher sensitivity to staining agents.[19–21] Furthermore, the microstructure of the working surface influences the mechanical behaviour of the material. The differences can be remarkable and involve also the reliability, a very important aspect for this class of ceramic tiles, particularly recommended in those applications where high service performances are required. It is therefore particularly important to assess if the machining process causes an unacceptable deterioration of the product, verifying meanwhile that no sound differences exist among the as fired tiles and the corresponding polished pieces.

The aim of the present work was to study the deterioration of the working surface, induced by machining. The method used was the analysis of the scattering of the experimental data, obtained by flexural bending tests, carried out on suitable specimens cut from five different commercial porcelain stoneware tiles, in the as fired and polished conditions. The same machining procedure and working parameters were adopted for all the products. This experimental procedure made it possible to eliminate the effects due to variations among different production lots and to emphasise the role and the influence of the microstructure of the material on the behaviour of the polished working surface of the products.

2. Materials and experimental

Five commercial porcelain stoneware tiles, 30 cm × 30 cm in nominal size, were chosen, denoted in the following as A, B, C, D and E, and their water absorption was determined, following the method recommended in the standard ISO 10545-3. On the basis of the results reported in Table 1 and of the method of manufacture (dry pressing), the selected products are classified as belonging to the group BI_a, according to the standard EN 14411.[22] Furthermore, the mineralogical compositions, determined by X-ray diffraction analysis (Philips, PW 1820/00, The Netherlands) showed, in all the products, the presence of quartz, mullite and glassy phase, only in A and D products also zircon is present. Zircon, in form of micrometrical particles, is generally added in this class of tiles to increase the degree of whiteness.

Using a polishing line for porcelain ceramic tiles (Cemar International s.r.l., Italy), 20 tiles for each product were subjected in sequence to machining. The polishing line used consists in three successive working stations: (i) the calibrating station, composed of 14 steps tooling with different abrasive grit in the range 40–180, i.e., diamond and silicon carbide, this last one magnesite-bonded, (ii) the polishing station, composed of 22 steps tooling with SiC magnesite and/or organic resin-bonded, grit in the range 180–8001, and (iii) the squaring chamfering station, featured by a reduced length, composed of a combination of frontal and tangential diamond tools. Neglecting this last station, because not directly involved in the machining of the working surface, in Table 2 are reported the technical details of the first and second working station: type of tools, type of abrasive and the corresponding grit. The speed of the rubber conveyer belt was fixed in 5.5 min^{-1}, whereas the average contact pressure among the tools and the work pieces was 203 kPa. To distin-

Table 1
Water absorption, roughness parameters and Vickers hardness of the tested products

Sample	Working surface condition	WA (wt.%)	R_a (μm)	R_M (μm)	HV (GPa)
A	FA	0.08	2.40	28.30	7.5
	PA	0.08	0.16	5.96	6.0
B	FB	0.07	2.90	25.60	7.1
	PB	0.07	0.19	7.03	6.2
C	FC	0.06	1.80	22.20	6.8
	PC	0.06	0.23	8.20	5.9
D	FD	0.04	2.40	17.20	6.3
	PD	0.04	0.26	7.05	5.8
E	FE	0.06	2.40	22.40	7.5
	PE	0.06	0.18	5.94	5.8

FA, FB, FC, FD and FE refer to the as fired samples. PA, PB, PC, PD and PE refer to the polished samples.

Table 2
Sequence of the steps in the first and second station of the polishing line

Station	Step	Tools	Abrasive[a]	Grit
Calibrating	1	Roller	D	40–50
	2	Roller	D	40–50
	3	Roller	D	60–70
	4	Roller	D	60–70
	5	Planetary head	D	60
	6	Planetary head	D	80
	7	Rollers	D	150
	8	Rollers	D	220
	9	Planetary head	D	120
	10	Planetary head	D	120
	11	Cylindrical head	D	150
	12	Tangential head	SiC (Mb)	120
	13	Tangential head	SiC (Mb)	120
	14	Tangential head	SiC (Mb)	180
Polishing	1–2–3	Tangential head	SiC (Mb)	180
	4–5–6	Tangential head	SiC (Mb)	280
	7–8–9	Tangential head	SiC (Mb)	320
	10–11	Tangential head	SiC (Mb)	400
	12–13	Tangential head	SiC (Mb)	600
	14	Tangential head	SiC (Mb)	800
	15	Cylindrical head	SiC (Rb)	800
	16	Tangential head	SiC (Mb)	800
	17–18	Tangential head	SiC (Mb)	1000
	19–20	Tangential head	SiC (Mb)	1200
	21	Tangential head	SiC (Rb)	8001
	22	Cylindrical head	SiC (Rb)	8001

[a] D: diamond, (Mb): magnesite-bond, (Rb): resin-bond.

guish the tiles on the basis of the working surface condition, in the following the as fired samples are denoted as FA, FB, FC, FD and FE, and the corresponding polished samples PA, PB, PC, PD and PE, respectively. For all the polished samples, the water absorption was determined, following the method recommended in the above specified standard (Table 1).

The surface roughness parameters, average roughness R_a and maximum roughness R_M, of all the products before and after machining, were measured using a roughnessmeter (Hommel Tester, T2000, Germany), according to the test method recommended in the European Prestandard ENV 623-4.[23]

Vickers surface hardness was also determined using a hardness tester (Zwick, 3212, Germany), with an indentation load of 9.81 N. The results here reported are the average of at least 10 valid impressions.

Bending strength tests were carried out on suitable specimens, randomly extracted by cutting the tiles, in the form of specimens 70.0 mm in length and 22.4 mm in width. The thickness of the specimens was the nominal thickness of the as fired product, 7.8 mm (FA), 7.7 mm (FB), 8.2 mm (FC), 7.1 mm (FD) and 8.7 mm (FE). After machining, the thickness of the specimens was reduced to 7.2 mm (PA and PB), 7.1 mm (PC), 6.1 mm (PD) and 7.5 mm (PE). To eliminate the influence of edge cracks, induced by cutting, the long edges of the face of the specimens to be subjected to tensile stress in the flexural strength test, were chamfered at approximately 45°.[24] This procedure made it also possible to take into account both the probable variations among the tiles belonging to the same production lot and, the possible differences of homogeneity existing among the specimens extracted from the same tile. So, there was indirect evaluation also of the efficiency of the different industrial processes, the parameters of which such as powder characteristics (humidity, particle size distribution, etc.), die charging, pressing pressure and firing cycle, are particularly important to define the quality of the fired products. The tests were carried out using an universal testing machine (MTS, 10/M, USA) equipped with a three-point bending device with a 60 mm roller span, and adopting a crosshead speed of 5 mm/min. Contrary to the recommendations reported in the standard EN ISO 10545-4,[25] the tests were carried out, by subjecting the working surface to tensile rather than compressive stress. The method made it possible in the polished specimens, to subject to tensile stress the cracks directly induced by machining and the open porosity revealed by the removal of the surface layer. The results, obtained on both the as fired and polished specimens, were compared to evaluate the effects induced by machining. Young's modulus was also measured, using an extensometer attached to the bending test fixture.

The values of the flexural strength and Young's modulus reported, represent the average of at least 20 valid results, obtained by testing no less than 20 specimens for each product, in both as fired and polished conditions. The consistency of the data was evaluated considering, specimen by specimen, the fracture patterns and the congruence with the testing conditions.

Weibull statistical analysis was carried out on each set of strength data using the following equation:

$$P_n = 1 - \exp\left[-\left(\frac{\sigma_r - \sigma_u}{\sigma_0}\right)^m\right] \quad (1)$$

where P_n is the probability of failure, σ_r is the fracture stress, σ_u is the threshold stress below which the probability of failure is zero, σ_0 is a normalising parameter, often selected as the characteristic stress at which the probability of failure is 0.632 and, m is the Weibull modulus which describes the narrowness of the distribution. Assuming $\sigma_u = 0$, and adopting as probability estimator of failure $P_n = (i - 0.5)/N$, where N is the number of the measurements and i is the ranking number, with $i = 1$ for the weakest specimen and $i = N$ for the strongest, the Weibull modulus m and the parameter σ_0, were determined rearranging the Eq. (1) as:

$$\ln \ln\left(\frac{1}{1 - P_n}\right) = m \ln(\sigma_r - \sigma_u) - m \ln \sigma_0 \quad (2)$$

The scattering in the flexural data and their meaning were evaluated on the basis of the analysis of variance.[26] Since, there is good ground to believe that machining could have introduced remarkable alterations and may also have changed the mechanical behaviour of the samples, the analysis of the variance made it possible to determine if the two populations of data, obtained testing each product in the as fired and polished conditions, can be considered to belong to the same material.

The results of the analysis of variance made it also possible to assess the role of the microstructure in determining the behaviour of the materials. To clarify this dependence, extensive observations of the microstructure both of the working surfaces in the as fired and polished conditions and of the bulk material, by the preparation of suitable specimens, were performed using optical (Leica, DML, Germany) and scanning electron microscopy (Jeol, T330, Japan). Furthermore, when possible, considering the low microstructural homogeneity of these materials, fractographic analysis of the fracture surfaces was also carried out to recognise the origin of fracture.

3. Results and discussion

3.1. Water absorption data

Porcelain stoneware tile presents a ceramic body in which, starting from the surface, practically impervious for the high level of sintering of the surface layer due to fast firing cycle used, the porosity gradually increases via a microstructural gradient.[18] Since the polishing operation, removing this compact layer, induces on the surfaces two concurrent populations of defects,[20] it is reasonable to believe that the water absorption may change. These well known morphological differences existing on the surface of the as fired and polished products justify the determination of the water absorption both on the products, the results of which are reported in Table 1. In spite of the previous consideration, the data here found for the differently surface treated samples are coincident. These results can be explained, taking into account that the revealed pores are small and not connected, in this way they do not favour their filling and the consequent retention of the water.

3.2. Roughness parameters and Vickers hardness

The roughness parameters, R_a and R_M, referring to the working surfaces of both the as fired and polished products are reported in Table 1. The machining process generally causes a significant decrease in roughness. For the as fired working surfaces, R_M reaches rather high values, due to the geometrical unevenness rather than to the open porosity, practically non-existent for this class of tiles (Fig. 1). It can also be noted that the machining process, although able to considerably reduce the average roughness, R_a, does not give rise to the same result for R_M, which remains quite high. This trend can be attributed to the open porosity, as result of the removal of the surface layer (Fig. 2).

The Vickers hardness of the polished surfaces generally is lower than that of the corresponding as fired (Table 1). This decrease is the result of two important factors: (i) the widespread damage induced by machining (Fig. 3), and (ii) the open porosity due to the removal of the original more dense surface layer (Fig. 2).[27]

3.3. Analysis of the flexural strength data

The average flexural strength values σ_m and the Weibull parameters, m and σ_0, obtained testing the specimens in

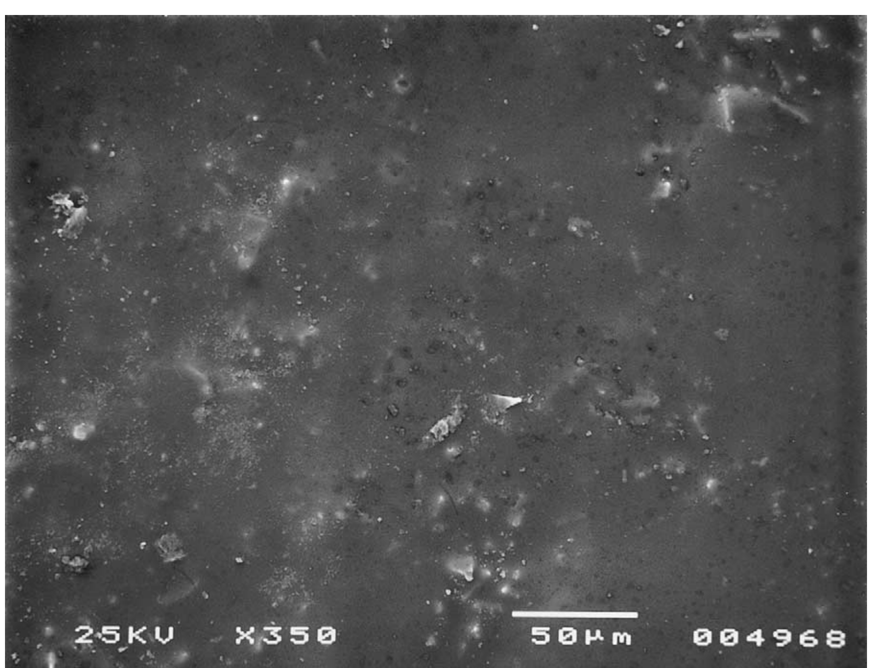


Fig. 1. SEM micrograph of the surface of sample FC, no open porosity is visible.

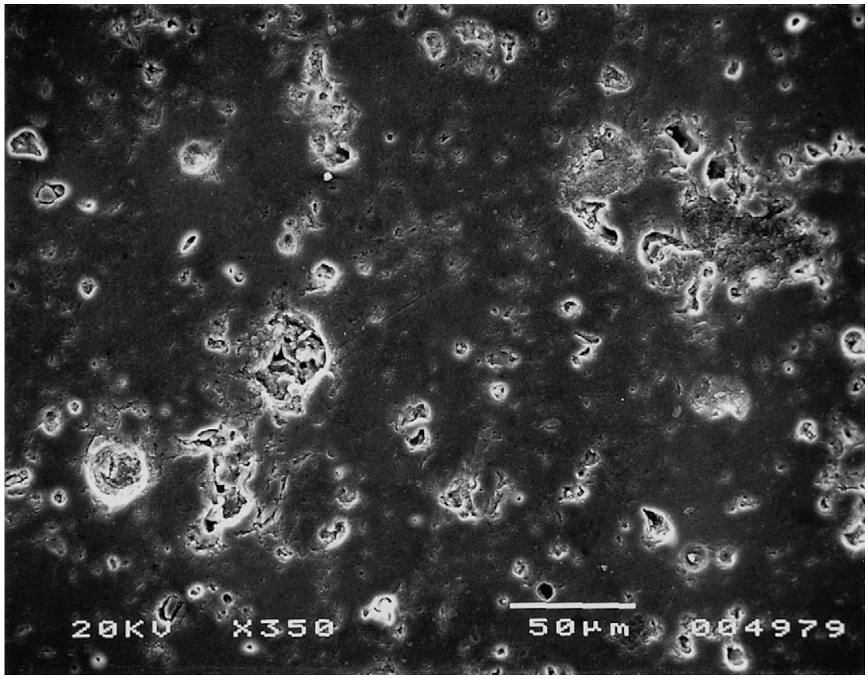


Fig. 2. SEM micrograph of the surface of sample PC, many round pores are present.

both the as fired and polished conditions, are summarised in Table 3. The scattering found for the flexural strength data in the as fired specimens, takes into account only the different variables of the industrial processing cycle: (i) possible variations among the tiles belonging to the same production lot and (ii) possible differences of homogeneity, existing among the specimens extracted from the same tile.[28] The machining process caused a general decrease in the average flexural strength, albeit of different amounts, even if this trend does not necessarily imply an increase in the scattering. Indeed, the scattering for products D and E remains almost constant, for both the as fired and polished specimens. This is also the case for product B, where the difference between the two average flexural strengths reaches the maximum value. On the

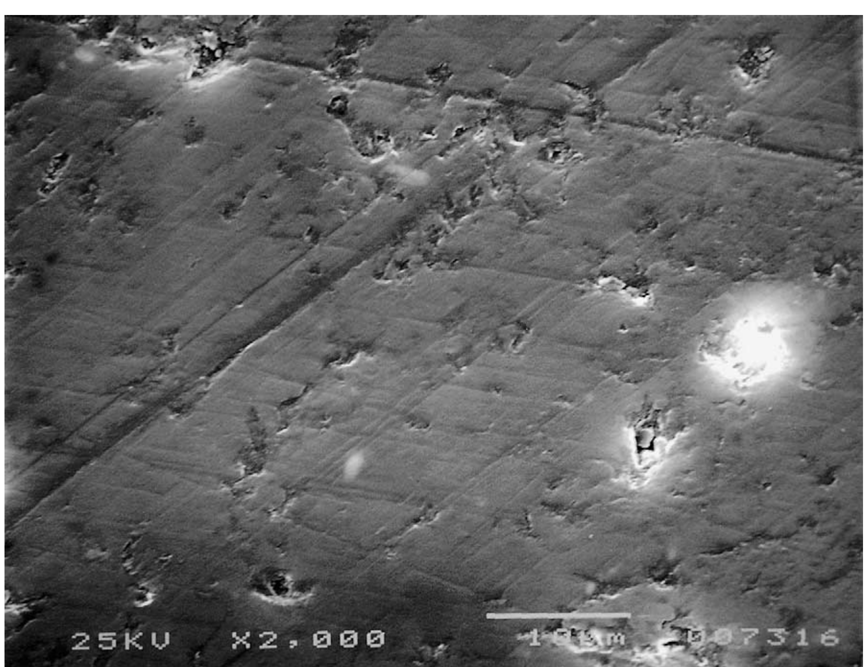


Fig. 3. SEM micrograph of the surface of sample PE, several scratches are still visible.

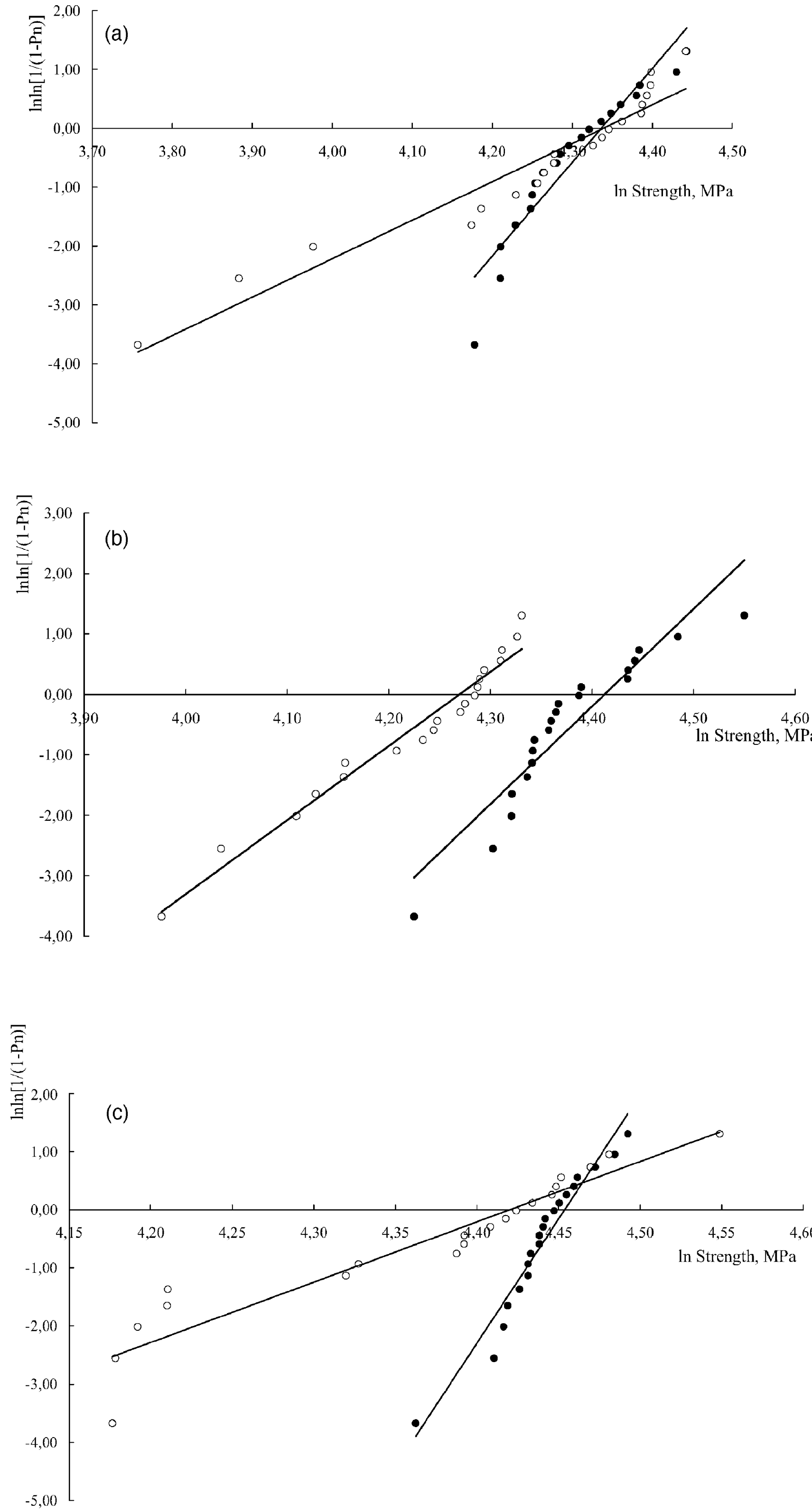


Fig. 4. Weibull plots of samples (a) A, (b) B, (c) C, (d) D and (e) E. Open symbols are referred to the polished specimens, filled symbols are referred to the as fired specimens.

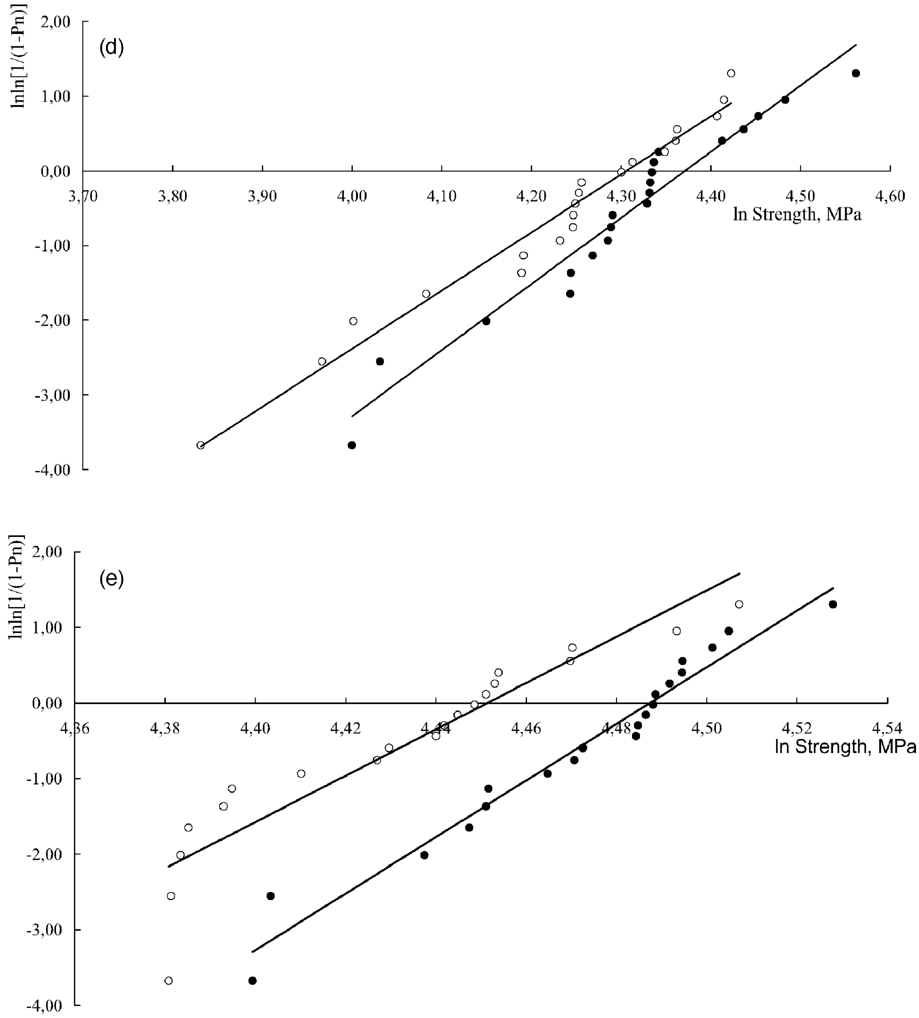


Fig. 4. (*Continued*).

contrary, product A, characterised by the lowest difference in σ_m between FA and PA, presents a very high scattering for PA. Product C is also characterised by rather higher scattering after machining.

Table 3
Average flexural strength, average Young's modulus and Weibull parameters of the tested products

Sample	Working surface condition	σ_m (MPa)	*m*	σ_0 (MPa)	*E* (GPa)
A	FA	73.9 ± 5.4	15.9	82.2	63.0 ± 1.1
	PA	71.3 ± 11.2	6.5	75.2	63.3 ± 1.4
B	FB	79.9 ± 5.7	16.1	85.8	64.4 ± 1.8
	PB	68.6 ± 6.3	12.3	72.0	64.2 ± 1.4
C	FC	84.9 ± 2.3	42.7	85.5	63.2 ± 3.0
	PC	79.2 ± 8.5	10.4	79.1	62.5 ± 3.4
D	FD	74.9 ± 9.7	8.9	82.7	61.9 ± 3.0
	PD	69.7 ± 9.9	7.8	74.0	64.6 ± 3.0
E	FE	87.6 ± 2.8	37.4	89.8	62.3 ± 2.5
	PE	84.2 ± 3.1	30.6	90.1	65.1 ± 3.7

FA, FB, FC, FD and FE refer to the as fired samples. PA, PB, PC, PD and PE refer to the polished samples.

To thoroughly examine the variations in the flexural strength data, the analysis of the variance was carried out. Based on the data of the statistical analysis, the results can be divided into two groups. The first group regards the case in which the calculated ratio $F_{0.95}$ is lower than the critical value, reported in the tables of the percentiles of the *F*-distribution, while the second one is the case in which $F_{0.95}$ is higher than the critical value.[25] According to the analysis results, the flexural strength data, for products A and D, both in the as fired and polished conditions, belong to the first group. After machining, these materials can be considered to be the same statistical population as the as fired samples. The calculated ratio $F_{0.95}$ for FB, FC and FE and PB, PC and PE, however, is higher than the respective critical value. This means that products B, C and E, before and after machining, cannot be considered to belong to the same statistical population.

The values of Weibull modulus, *m*, are in agreement with the scattering found for the flexural strength data. The Weibull plots for all the products analysed A, B, C, D, and E are reported in Fig. 4a–e, respectively. In spite of the decrease of the volume[29,30] of the polished specimens due to the removal of the surface layer, *m* shows a general decrease, particularly consistent for product C. This trend can be attributed to the microstructure of the material, the pores revealed by the removal of the surface layer, and to damages directly induced by the machining process. These concurrent flaw populations, only present in the polished products, play different roles in the mechanical behaviour of the materials. Although these flaw populations do not always cause a significant change in the average value of the flexural strength, nevertheless they can contribute to increase the data scattering and thus to decrease the reliability of the material. Since, in the present work, the machining process was kept constant, the results concerning the polished specimens can be attributed to the microstructural texture of the materials.

Products A and C show a consistent decrease in reliability after machining, 59 and 77%, respectively. The machining process, for these materials, introduced new flaw populations, not homogeneously distributed on the working surface. The SEM observations of the polished working surfaces showed the presence of a large amount of porosity (Figs. 2 and 5). In particular, the presence of many agglomerates of pores, not homogeneously distributed on the working surface can be considered responsible for the consistent decrease in Weibull modulus. The fact that FA and PA belong to the same population, differently from FC and PC, means that for product A, although the machining process caused a scattering of the results, lower *m*, it has only a slight effect on the value of the average flexural strength.

For product C, the surface machining introduces defects, the size and morphology of which not only lead to an increase in the scattering of the results, but also to a considerable decrease in the average flexural strength σ_m, so much so that the two tested populations are different. As regards, rather deep scratches (Fig. 6a), and larger areas where material has been detached (Fig. 6b), are visible.

The decrease of the Weibull modulus for PB, PD and PE is less evident 23, 11 and 18%, respectively. Among all the tested materials, FD shows the lowest reliability. For PD, *m* decreases, but remains rather close to that of the as fired material. This low value is essentially due to its rather considerable low microstructural homogeneity. The damages induced by the machining process, slightly influence the mechanical behaviour of the material. The two sets of flexural strength data for FD and PD belong to the same population. For this material, the influence of microstructure is prevalent (Fig. 7).

Product E is characterised by very low data scattering, for both the as fired and polished conditions. Although the value of *m* is less for PE than for FE, confirming the general trend found in all the products, its value is however the highest. This result can be attributed to: (i) a high homogeneity of the material and (ii) an efficient second step of machining, able to remove the calibrating induced damage. The working surface of PE contains only few and rather narrow pores, in the range of 2–10 μm in diameter, essentially due to its processing, (Fig. 8). From this point of view, the product E can be considered a very good material. The particularly low standard deviations, characterising both FE and PE, are able to explain the results of flexural strength.

For product B, machining is detrimental, causing both a decrease in σ_m and a larger scattering of the results. Machining not only removed material uncovering the closed porosity, but also induced several scratches and large areas of cracked

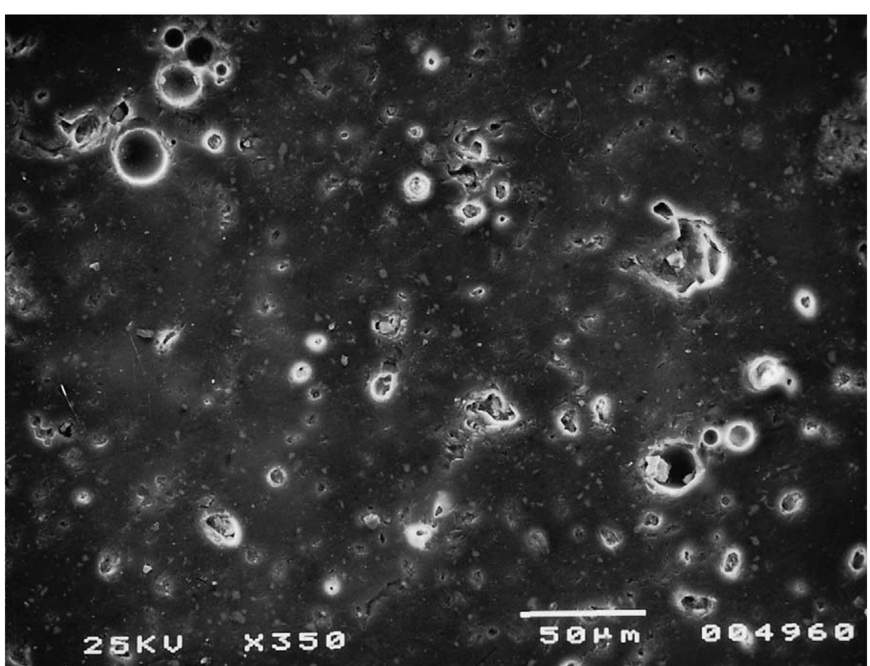
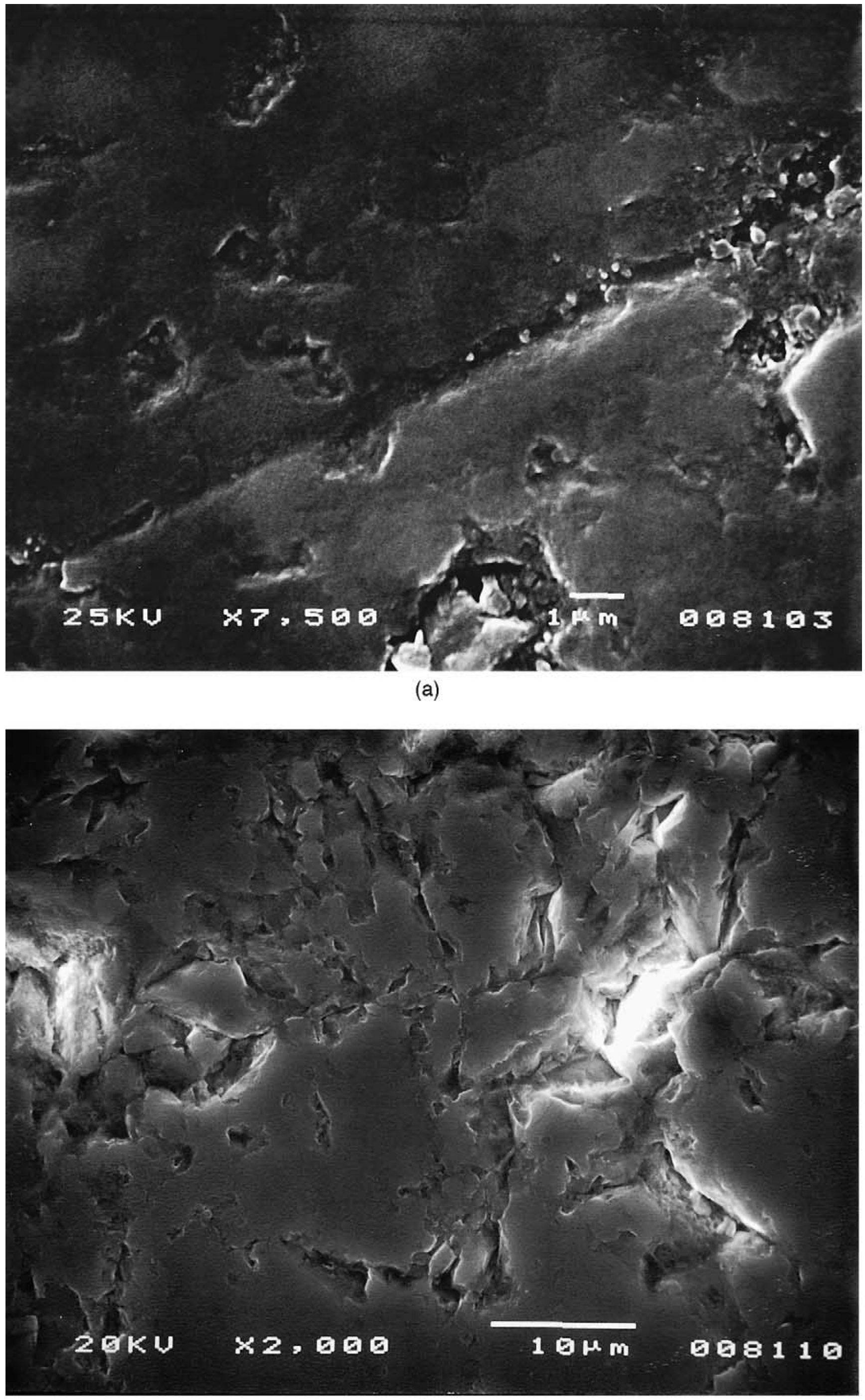


Fig. 5. SEM micrograph of the surface of sample PA.



(a)

(b)

Fig. 6. SEM micrograph of the surface of sample PC: (a) scratch and chipping and (b) cracked area.

material that contribute to an increase in the size of the flaws. Fig. 9 shows the working surface of PB, where a long cracked area, of about 100 μm, is visible.

3.4. Analysis of the Young's modulus data

The values of the Young's modulus of the materials both before and after machining are reported in Table 3. The elastic modulus of a material depends on the microstructure, in particular on the phases present and on the shape and distribution of the porosity, which is considered as a second phase with $E = 0$. The mechanical properties, such as elastic modulus, decrease with increasing porosity.[31,32] Taking into account their particular microstructure, it seemed interesting to verify if the increase of porosity present on the polished working surface due to the damages induced by machining, can affect

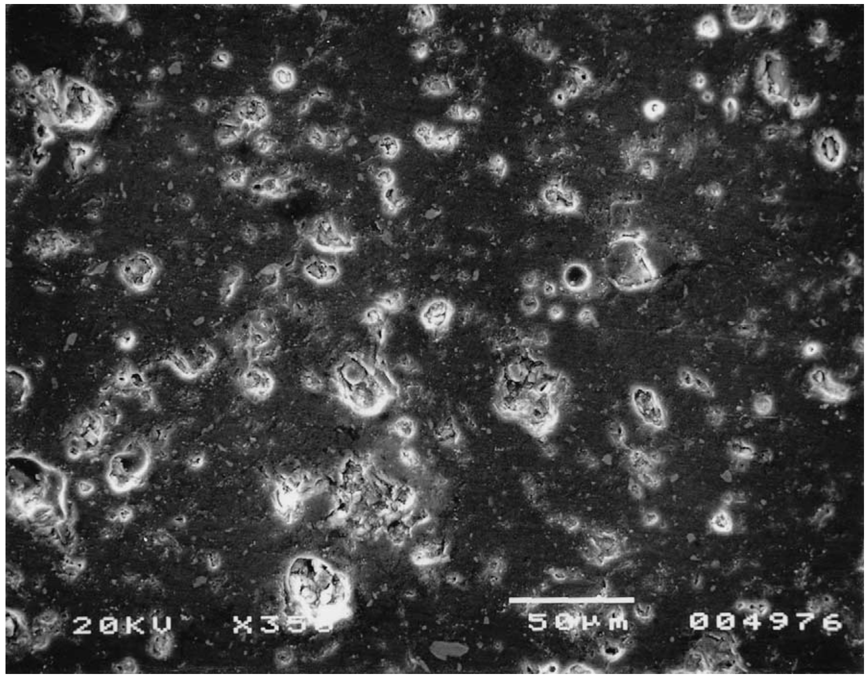


Fig. 7. SEM micrograph of the surface of sample PD, many pores and processing defects are visible.

the elastic modulus. In this regard, the following assumptions were formulated: (i) the machining of the working surface by the removal of a layer more dense in respect to the bulk material[15,18] cannot, according to its small thickness and low porosity, significantly modify the microstructure in respect to the as fired condition, (ii) since pre-existing, the bulk porosity revealed by machining, does not affect the elastic modulus, and (iii) if the volume fraction of the machining induced damage is lower and/or equal to that present in the removed layer, the elastic modulus does not change. This latest assumption strongly depends on the material microstructure, i.e., the industrial process and machining procedures and parameters. As previously specified, the damage induced by the calibrating step, is still evident after polishing and, in any case, is able to modify the behaviour of the working surface and decrease also the flexural strength of

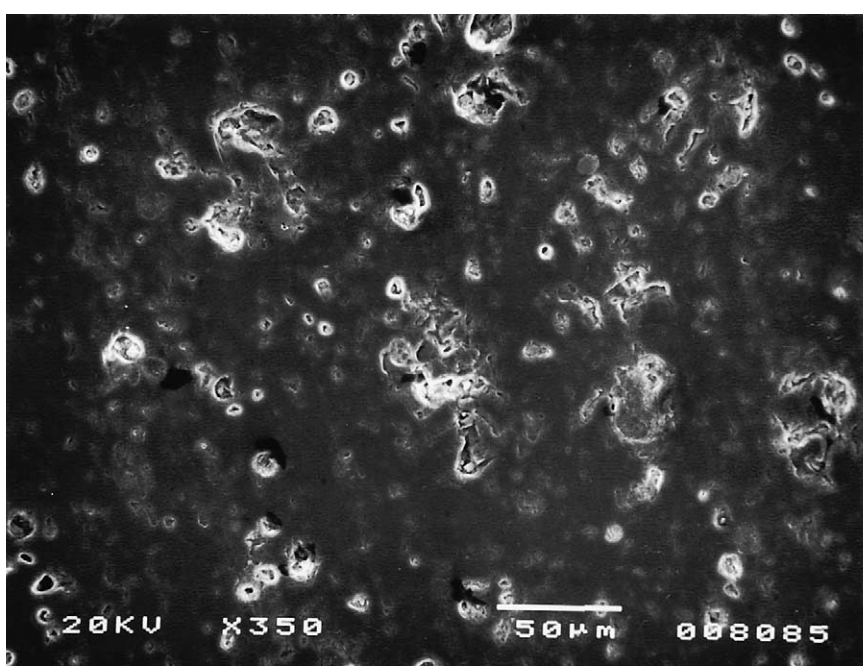


Fig. 8. SEM micrograph of the surface of sample PE.

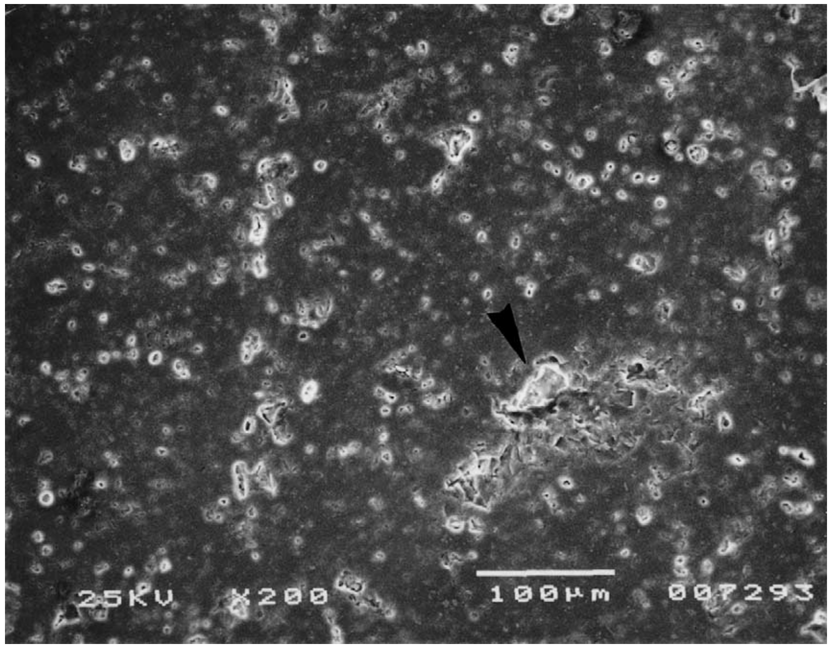


Fig. 9. SEM micrograph of the surface of sample PB, the arrow points out a large flaw.

the material, increasing the scattering of the experimental data.

The analysis of the elastic modulus results brings to light some interesting points: (i) the elastic modulus of all the samples lies in a very small range, (ii) there are some variations among the average values in the as fired and polished conditions, even if not particularly high, and (iii) the scattering is low.

The first point can be explained assuming that the microstructural characteristics of all the samples are almost similar. The second point means that the Young's modulus does not seem to be influenced by the conditions of the working surface. After machining, the working surface shows: (i) a certain amount of pre-existing pores (closed porosity) revealed by the removal of the more dense surface layer and (ii) different typologies of damage, directly induced by the calibration step and no more removed by the following polishing step.

On the basis of the obtained results, it is possible to point out that the machining damage is not able to cause significant variation in the Young's modulus data. Since, an increase of the total porosity should cause a decrease of the Young's modulus, it can be supposed that the damages induced by machining, in terms of volume of voids, may be considered very close to the porosity present in the surface layer removed by machining. In fact, after polishing, the variations of the data scattering are not particularly high. So, the slight increase in the elastic modulus, recorded for the samples D and E, has be attributed to an improvement of the microstructure. Since, the scattering does not significantly change, from as fired to polished conditions, the differences existing among the investigated samples, belonging to the same production lot, can be attributed to a lack of homogeneity of the material, as a results of a not strictly controlled industrial process, rather than to the induced machining damages.

While the effects of the induced machining damage can be observed in the flexural strength data, an increase of the total porosity would have caused a decrease of the elastic modulus and not an increase.

Within the products here investigated, it is possible to assert that the volume fraction of porosity introduced by machining, can be considered less or equal to that present in the surface layer in the as fired condition and then removed.

4. Conclusions

Five commercial porcelain stoneware products were selected and the working surface of each product was subjected to a machining process (calibrating + polishing), adopting the same procedure and parameters.

The working surfaces of the different products were analysed, determining the roughness parameters and Vickers hardness and observing the microstructural texture. Furthermore, to clarify the effects due to the machining, flexural strength and Young's modulus were measured, by testing suitable specimens cut from as fired and the corresponding polished tiles. The results obtained lead to the following conclusions:

- Machining of the working surface causes a decrease in Vickers hardness and in the roughness parameters R_a and R_M.
- Removal of the surface layer, by machining, reveals the closed porosity and induces also a widespread and complex system of surface and subsurface damages.

- Even though the average flexural strength values σ_m of the as fired and polished products can be very close, the reliability of the polished product, in terms of Weibull modulus *m*, can strongly decrease.
- On the basis of the results obtained by the analysis of variance, the flexural strength data for the as fired and corresponding polished products, can be, in some case, considered as belonging to statistically different populations.
- The Young's modulus depends on the microstructural characteristics and is not be considered influenced by machining induced damages.
- The behaviour and the characteristics of a polished product depend on the machining process. In this context, homogeneous microstructures are favoured.
- Suitable machining procedures and working parameters can improve the performances of the polished products.

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