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ORIGINAL ARTICLE

Wear mechanisms during dry and wet turning of Inconel 718 with ceramic tools

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Abstract The growing demand for products that resist in environments considered severe has stimulated in the last years series of researches. They have the objective to improve the properties of materials and their processing and applications. Among the metals commonly used in extreme temperature and corrosion, there are the nickel superalloys, in particular Inconel 718. However, the same thermal, mechanical, and metallurgical properties, which make it a material of great applicability, also characterized as one of the metals of low machinability. Given that the market trend is increasingly using special materials such as superalloys, a detailed study about the machining of these materials is strategic and it is necessary that companies constantly seek to improve their processes. Besides that, the attention to environmentally safe processes from society and governmental regulation is growing. Therefore, this paper evaluated the performance of different conditions, dry and wet, on external longitudinal turning of Inconel 718 with ceramic tools, identifying the mechanisms and types of predominant wear. For both conditions, notch wear was the main type observed in the experiments and it was more evident during dry machining.

Keywords Turning · Nickel superalloys · Inconel 718 · Tool wear · Ceramic tools

1 Introduction

The growing demand for products for possible application in severe environments has stimulated a lot of research to improve the physical and chemical properties of materials and their machining and applications. During the machining of high-temperature resistant alloys, due to its low thermal conductivity, the heat conduction to the chip occurs in low rate. During the turning process, high pressure and temperature are generated in the contact area between the tool and workpiece. These high temperatures can produce undesirable tenses in the workpiece structure, tool wear, and build-up-edge (BUE) formation. The high material toughness and disorderly chip formation in strip form and spiral also need to be considered [1].

These particularities of the process request the use of a cutting fluid. In contrast, the non-use of cutting fluid can bring environmental improvements and, besides that, it can protect the worker against lots of diseases. When it comes to environmentally friendly process, studies indicate the necessity to understand and develop expertise in machining under dry conditions, because it can bring significant technical changes.

The machining of superalloys demands particular requirements in relation to the tools, due to their especial properties as the limited metal removal rates by the ability of the materials used in the tools to tolerate the generated tenses and temperatures. Thus, the machining cost of nickel-based alloys is very high [2].

Ceramic cutting tools are mostly applied for machining hard materials in industry because of their unique mechanical properties. The high-temperature resistance in ceramic tools makes them able to be used at high cutting speeds, abrasion

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and corrosion resistance, hot hardness, and low chemical affinity. When compared to carbide tools, they present longer tool life [3]. The market shows a tendency in increasing the use of materials based on ceramics, on the precision requirements, and the high quality of the machined surfaces together with the high performance of the tool life [4].

The paper focuses on the analysis of mechanisms and evolution of tool wear when turning Inconel 718, one of the most significant Ni alloys, with ceramic tools, both in wet and dry cutting. The use of modern ceramic inserts in these conditions is the novelty of the study. Their applicability in hard machining was tested in order to enlarge the options considering tool variation.

In addition, the present studies also indicate that the evaluation of Inconel 718 in dry turning with ceramic tools was not strongly covered in literature. This has encouraged this work with an aim on developing knowledge with this issue. Moreover, it is known that companies want to reduce time consumption and costs with a coolant. In this way, a study about the machining of Inconel 718 is necessary for companies due to their strategic decisions in relation to economy and quality.

2 Literature review

Dry cutting can be the best option under the point of view of non-generation of residual cutting fluid, based on environmental and economic reasons. Once that the amount spent in coolant acquisition, use, disposal, and the cleaning is meaningful, up to four times one of cutting tools is used in cutting operations. Coolants are generally used for chip disposal, improvement of machining accuracy, surface finish, and extension of tool life, especially in aggressive cutting conditions in the tool and in the workpiece [5].

In most cases, the dry machining causes high wear rate and results in relatively short tool life, especially when cutting some difficult-to-cut materials [6]. Due to this, the main studies regarding the turning of Inconel 718 were performed using a cutting fluid; therefore, the effect under dry conditions has been slightly investigated [7].

Tool wear can lead to machine down time, product rejection, and can cause other problems such as poor surface quality. The tool life can end in two main ways. The first one is the progressive tool wear because of the wearing away of certain regions of the face and flank of the cutting tool. This gradual tool wear makes the cutting tool replacement necessary. The second mode is the catastrophic tool failure, which ends the tool [8].

Zhuang et al. work investigated the wear mechanism of alumina-based ceramic cutting tools during dry turning of Inconel 718. The author proposed a predictive model, which can guide the effective control of tool wear by reducing the work-hardened layer through the optimization of processing parameters [9]. In another study, experiments in turning nickel-based alloy under dry conditions with ceramic cutting inserts were realized. The uncoated and TiCN-coated Sialon ceramic cutting inserts showed abrasive and adhesive wear. When it comes to tool life, TiCN-coated inserts presented much better results than the uncoated inserts, implying that the coating helps to save the tool from frictional wear [10]. In the Dudzinski et al. research, the author suggests ceramic tool for dry machining of Inconel 718 because they are poor conductors and vulnerable to thermal cracks. Besides that, some ways to move towards dry machining are explored, as different coating techniques [3].

The investigation of surface damage, during turning Inconel 718 with whisker-reinforced ceramic cutting tools, showed different types of surface damage, probably because of the geometric profile, the degree of subsurface deformation, and the residual stress. Besides that, they affirm that ceramics are able to work in much higher cutting speed and it provides an increase of productivity. Besides that, the use of fluid can result in lesser surface damage [11].

Tebaldo et al. turned Inconel 718 in dry condition aiming at the environmental needs. They studied two different lubrication methods and made economic analyses. They could reach similar results as wet machining, but the lowest cost was obtained by the use of a cutting fluid [12]. Li et al. carried out series of tool life experiments using several coated carbides and ceramics by means of rapid face-turning without a coolant. His recommendation for tool inserts for high-speed cutting of Inconel 718 was ceramic inserts of KY2000 with negative rake angle. He also affirms that the major wear mechanisms of nickel-based alloys are interactions of abrasive wear, adhesion wear, micro-breakout, and chipping [13].

Diamond coating was deposited on ceramic silicon nitride inserts, and they realized that the coated inserts showed good behavior in hard metal turning [14]. The life of silicon nitride cutting tools was upgraded from two to four times in turning of hardened steel by applying hard TiN coating on the surface of the tools [15].

3 Experimental work

The experiments were realized in the industry. In this way, some working conditions were employed based on the conditions and experience of the company.

During the machining experiments, the inserts were analyzed by optical microscopy to realize the qualitative and quantitative evaluation of the presented wear. The wear behavior was monitored every 50 mm machined. Table 1 shows the details of the experiment.

Three main ways of tool life criteria were adopted. The first was maximum flank wear (VB_{max}) of 0.6 mm, the second was

Table 1 Experiment planning

Fluid application	MQL	Dry
Ceramic tool	SiAlON	Al_2O_3 + $SiC_{whisker}$
Analysis	Tool wear VB − VB_{max}	Wear mechanisms
Evaluation system	Optical microscopy quantitative	Optical microscopy quantitative
Cutting parameters	Cutting speed = 250 m/min, feed = 0.2 mm/rot, cutting depth = 1.5 mm	

catastrophic failure, and the last one was 600 mm machined length.

3.1 Workpiece

The turning strategy was longitudinal external, because it allows a better control of the parameters and reduces the influence of the vibrations generated by the machine tool and fixing of the tooling. Figure 1 shows the machined workpiece schema.

In order to reduce the influence of cutting interruptions for wear analyses, channels were machined each 50-mm cutting length. Those channels were machined with a depth of 2 mm and 45° chamfer to smooth the entry and exit of the tools.

The workpiece for the experimental tests was manufactured in a cylindrical forged bar of Inconel 718 hardened by precipitation. The physical and mechanical properties are shown in Table 2, where the main characteristics are presented in the material report provided by Weatherford Ind. e Com. Ltda.

The workpiece was also drilled and rough machined in order to eliminate the scale and oxides from the previous processes and facilitate their fixation in the machine.

3.2 Equipment and tools

Machining experiments were realized in a CNC PUMA 350L from Daewoo, with 22 kW of power and 2000 rpm maximum speed. This machine is used in the regular production where this research was realized.

Two different ceramic inserts were tested. Table 3 shows the geometrical characteristics and the substrate material of the insert and the tool holder. The materials selected were SiAlON and Al_2O_3 + $SiC_{whisker}$. They seem to be the most promising by the theoretical framework, and they were indicated by the supplier for nickel superalloy machining. Both tools were with the macro geometry SNGN.

The square geometry, in the ceramic inserts used, was chosen because it is a robust geometry that enables a 45° cut side angle, which according to various references ensures a better tool performance when machining nickel alloys. The geometry tested was null and there was a null clearance angle. However, the tools were fixed on supports that gives a −8° inclination angle.

3.3 Fluid application condition

The tests were realized with cutting fluid application and dry condition. The cutting fluid used was an emulsion of vegetable-based water miscible oil, Vasco 1000, with 10% concentration, supplied by *Blaser* Swisslube. It was applied externally on the tool with a flow rate of approximately 30 l/min and 1.45 MPa pressure.

The SiAlON ceramic insert provider suggests the use of fluid, considering its good toughness and high resistance to thermal shock; on the other hand, the fluid application was not recommended by the supplier with the ceramic insert Al_2O_3 + $SiC_{whisker}$.

3.4 Cutting parameters

The cutting parameters were defined based on the industry expertise, also considering the tools manufacturer's recommendations and based on pretests performed by the company. Table 1 shows the final cutting parameters, which were used in the analyzed tests.

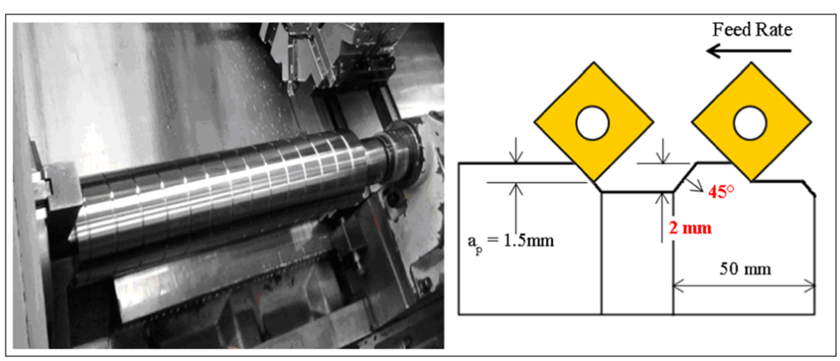

Fig. 1 Schematic drawing of channels machined and details of the workpiece

Table 2 Physical and mechanical properties of Inconel 718

Density [g/cm^2]	Tensile strength [Mpa]	Yield strength [Mpa]	Hardness [HRc]	Elongation at failure [%]	Thermal conductivity [W/m K]
8.19	1264	959	37	35	11.4
Yield strength (YS0.2) [KSI]	Ultimate tensile strength (UTS) [KSI]	Elongation (A4) [%]	Reduction of area (RoA) [%]	Impact energy (Charpy-V) [ft-lbf]	HRC
138.18	182.75	37	47	49–53	

4 Results and discussion

The results from the experiments are presented in the form of tool wear behavior graphs and mechanisms and types of wear images, as well as the statistical treatment data.

4.1 Ceramic tool with cutting fluid application

The graphs in Fig. 2 present the tool wear behavior for the two different ceramic tools, during wet machining. In a global analysis, it is possible to conclude that the best condition for wet turning was reached by SiAlON insert. Its life lasted 2.06 min. For Al_2O_3 + $SiC_{whisker}$ tool, the wear was higher. For this reason, it was not possible to do the minimum number of measured points in the wear behavior curve, according to ISO3685 standard.

The graphics show the wear analysis sequence. The first one exhibits four different points of analyses and explains that the tool wear was raising according to the cutting time and reached 0.6 mm, the lifetime point, after 2.06 min. The second one shows a worse behavior; in the first analysis, it presented higher wear then it was expected by the lifetime. However, it did not increase considerably in the second examination. The second situation goes against the wear behavior expected by Klocke [16]. The author explains that it may increase in the beginning and, as the time goes by, it stabilizes and then the wear rises again. On the other hand, the first graphic shows a wear behavior according to the one described by the author.

SiAlON experiment conforms to several results obtained by other researchers in turning of nickel-based superalloys with high cutting parameters, and there is a connection to its excellent toughness and abrasion resistance and exhibits good chemical stability [17, 18]. Because of these qualities, the machining was performed with SiAlON insert and cutting fluid presented resistance to notch wear.

The use of cutting fluid can cause an increase of tool life because of lubrication and cooling effects. It reduces the cutting forces and the temperature in the tool. However, these effects are not clear in high-speed machining, mainly, when ceramic inserts are used [3].

It is possible to see the tool wear in Fig. 3. The pictures show notch and abrasion wear on the insert. In the first picture, the occurrence of notch and abrasion wear is clear, and 61.8 s later, there is a significant increase in wear rate. However, the third picture does not show a substantial difference in comparison to the second picture, 30.6 s before.

The predominant wears, as can be identified by analyzing the images, were notch wear and flank wear. Those are the main failure modes, which limit the tool life. Due to the high cutting temperatures, oxidation and diffusion also occur [3]. Several researchers [18–21] who tested ceramic inserts in the machining of nickel superalloys have already reported the same wear situation.

In the same condition, Al_2O_3 + $SiC_{whisker}$ insert was tested. Figure 4 shows that the notch wear was the main limiting factor in the tool life. It is important to observe the specific wear geometry, which is probably associated with extreme friction conditions generated in this region, due to burr formation. The first picture shows notch wear in the work piece and in the insert; 30.6 s later, the second analysis shows an increase in notch wear and besides that the appearance of abrasion wear.

Burr formation occurred during turning Inconel 718. It is irregular and creates great friction conditions between the tool and workpiece at the time of cutting depth. This friction, together with the action of diffusion and oxidation mechanisms, which tend to reduce the abrasion resistance of the insert, generates an extremely favorable condition in relation to the appearance of notch wear in the tool. An evidence of burr formation in experimental works is observed in Fig. 5. It shows the chip removal from two ceramic tools tested during

Table 3 Characteristics of the ceramic tools and the tool holder

	Rake angle (γ) [°]	Clearance angle (α) [°]	Radius (r) [mm]	Substrate material
Insert geometry	0	0	1.2	SiAlON
	0	0	1.2	Al2O3 + SiCW
Toolholder angles	−8	−8		

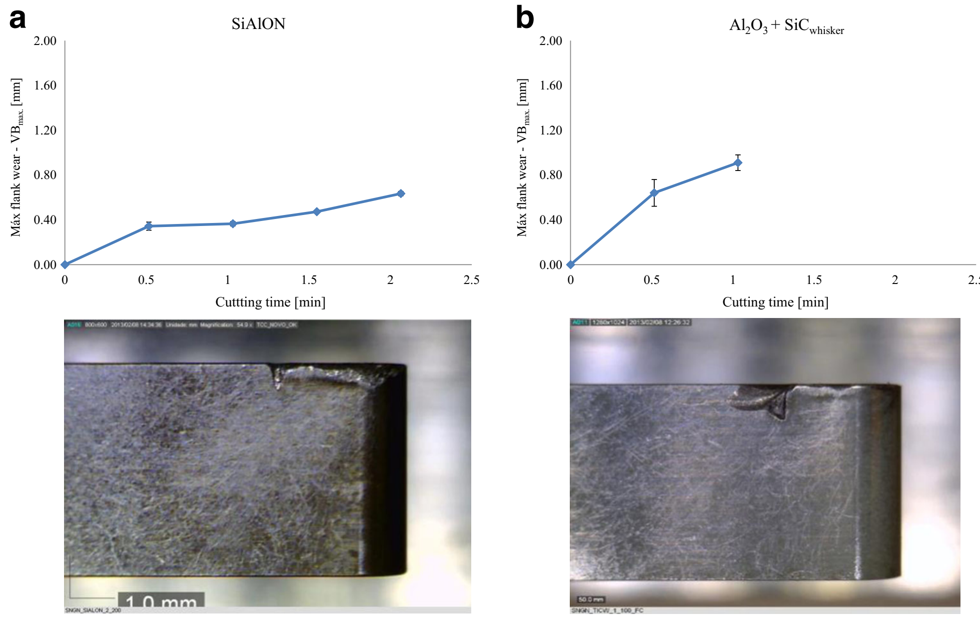

Fig. 2 **a**, **b** Wear behavior graphic VB × cutting time

wet turning. The burr presence on the chip is visible in Fig. 5, mainly, on the chip generated by Al_2O_3 + $SiC_{whisker}$ insert, which had a higher notch wear rate. This fact, added to the high work hardening of the material, increases the tendency to notch wear, as a layer of high hardness is formed in the cutting depth position in the cutting edge of the insert.

The burr formation can be related to several factors, mainly the tool geometry because it is more negative than the machined material properties. For materials with a huge grain size (ASTM 4), the burr formation was relevant; on the other hand, the materials with fine grains (ASTM 9) practically did not show burr formation. The grain size of the material used in this paper experiments is rated at 3.5 ASTM E112-10. As it can be considered as a coarse grain material, it may confirm the hypothesis that the notch wear presented by ceramic inserts is related to the burr formation. This burr occurs due to the machined material condition and null geometry of the ceramic inserts.

The use of cutting fluid controls the temperature and may decrease the wear rate, but it can bring some environmental issue and other costs with cleaning, transportation, and the operator's health risk. For this reason, the study of the available types of cutting fluids as well as the methods to apply them, in order to maximize the efficiency of cutting fluids in all machining processes, is suitable. It may significantly reduce the heat generation in machining and improving the surface roughness. Surface roughness and tool wear are always used as a quality indicator of a finished or semifinished product.

This discussion around the advantages and disadvantages of the use of cutting fluid led to the study of the ceramic tool use during turning Inconel 718 in dry condition, in order to check if this condition can improve environmental issues, reduce costs, and raise the safety in relation to the operator's healthy. These factors are unsolved problems so they are

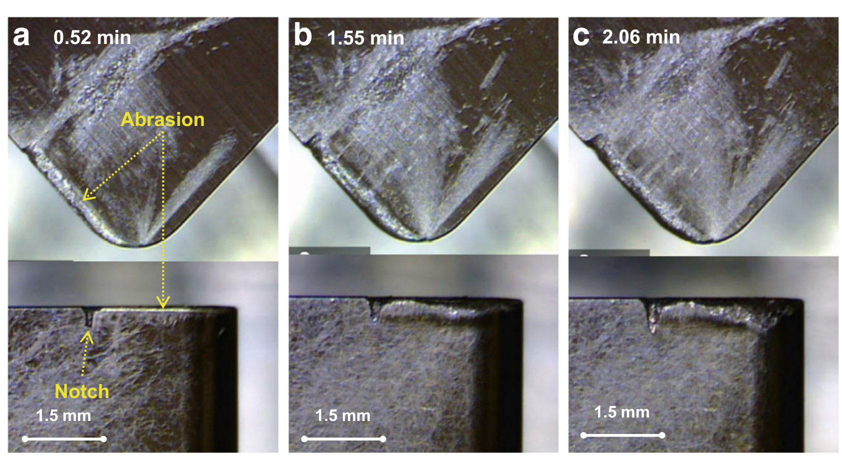

Fig. 3 **a**, **c** Tool wear (SiAlON) during turning with fluid application

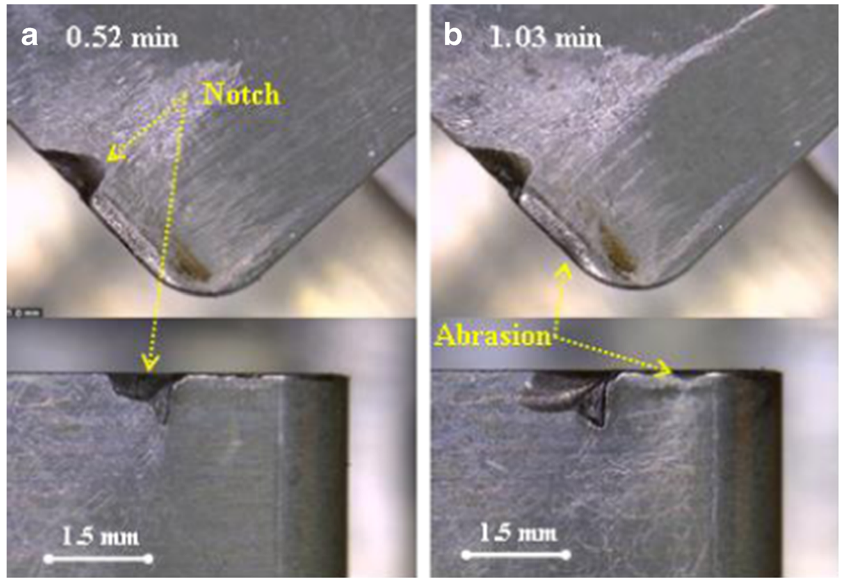

Fig. 4 **a**, **b** Tool wear (Al_2O_3 + $SiC_{whisker}$) during turning with fluid application

discussed in a day-to-day basis in the companies as they affect people and costs.

4.2 Ceramic tool in dry condition

For dry turning, the friction and heat are extremely high; for this reason, SiAlON insert did not show the same performance as in machining with fluid application. Figure 6 shows the tool wear generated in this process. The first image presents notch and abrasion wear and in the second image it is considerably higher than before.

During dry turning, the wear mechanisms are activated with high intensity. Once Inconel 718 presents high mechanical strength even at high temperatures and low thermal conductivity, the chip transportation during shear is difficult.

The tested cutting parameters presented tough conditions during dry machining. Tt resulted in numerous microchipping. They are possibly associated with the high thermal and mechanical tensions in the insert cutting edge. It changed its original geometry and the heat generated was sufficient to adhere the machined material over its edge, as shown in Fig. 7b.

The inserts, in both situations, presented a high wear rate. SiAlON reached the maximum wear before 0.75 min and presented a different wear behavior compared to the one proposed by Klocke [16]. However, the second situation, Al_2O_3 + $SiC_{whisker}$, behaves itself as expected by the author and its life ended before 1.25 min.

Al_2O_3 + $SiC_{whisker}$ insert presented excessive notch wear as in wet machining but had better results during dry turning, confirming the provider's indication. It can be confirmed by the wear evolution showed in Fig. 8. The first image shows notch and abrasion wear, and it turns worse as the cutting time gets higher.

Comparatively, dry machining with Al_2O_3 + $SiC_{whisker}$ insert showed a lower notch formation rate than that observed during wet machining. This is possibly due to high heat-generated sectional area of the material, which would not

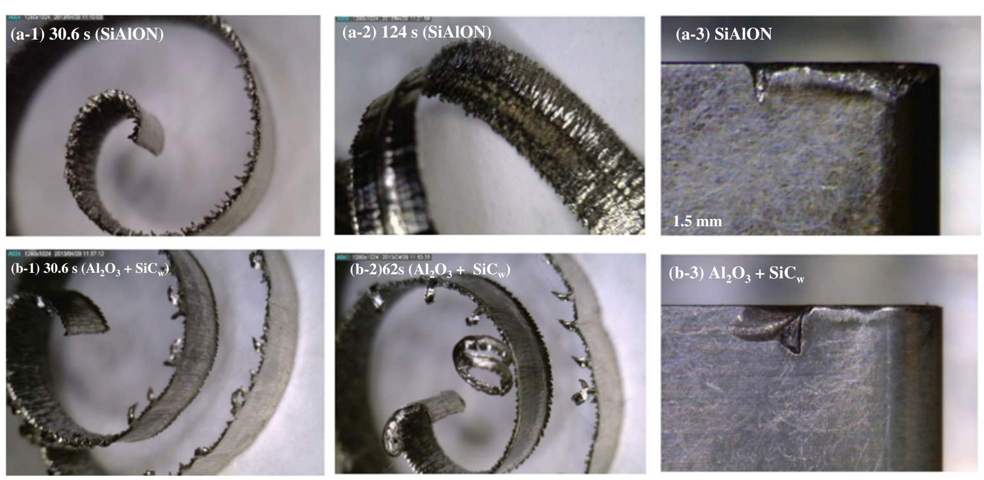

Fig. 5 Generated chip during turning with ceramic insert and fluid application

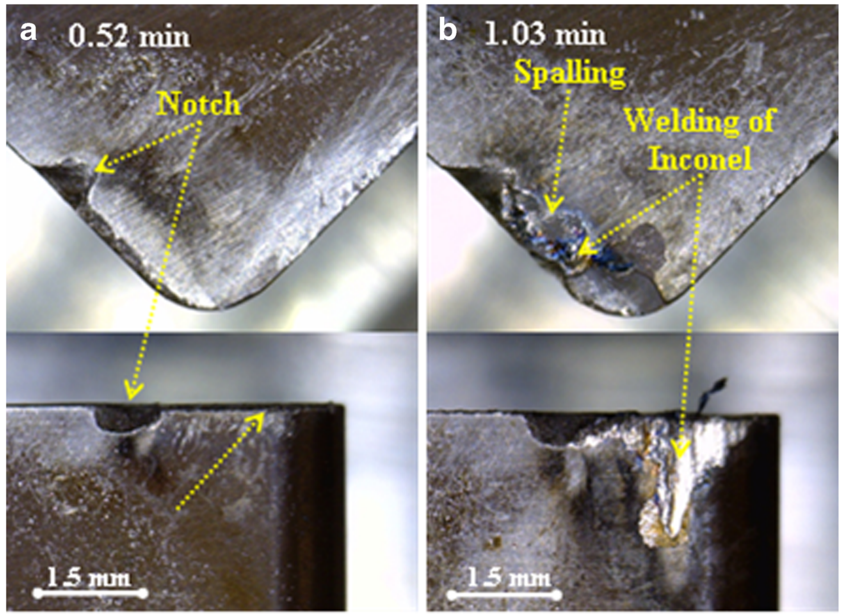

Fig. 6 **a**, **b** SiAlON wear during dry turning

allow the same to increase their hardness by work hardening, thereby reducing the abrasive action of the chips generated on the cutting edge of the insert [19].

The workpiece of heat-resistant superalloy tends to form a work-hardened layer due to the machining-induced deformations on the subsurface therefore the work hardening tendency of nickel alloys under excessive strain loading; thus, a highly hardened surface layer is created and it becomes difficult to cut [22].

The $SiC_{whisker}$ addition to the Al_2O_3 matrix raises the material thermal conductivity and hardness, and it gives excellent toughness to the insert. On the other hand, it decreases the chemical stability and it can induce the wear rate [23].

The cutting fluid use can bring some disadvantages related in environmental issues, worker's health, costs, and other significant questions about its application. A possible better solution to reach the machining manufacturers goals is moving towards dry cutting by eliminating or minimizing the cutting fluid use.

There are other advantages in dry machining, such as the reduction of skin and respiratory diseases, other health problems, environmental benefits, and no residue on machining components, which reduces or eliminates the cleaning costs and the cutback of disposal costs and associated energy consumption [3]. The author also says that in dry machining is necessary to find another way to insure the positive effects of coolants, because the removal of chips from cutting zone and heat evacuation must occur. In order to get an acceptable surface integrity tools with high hot hardness, high refractivity, low adhesion, and low friction properties are required [3].

Comparing carbide and ceramic tools in dry conditions and different cutting speed, they could conclude that tool wear in high speed cutting. The major wear mechanisms of nickel-based alloys are interactions of abrasive wear, adhesion wear, micro-brake out, and chipping [13].

Carbide and ceramic inserts were compared during machining Inconel 718 in dry condition with focus on cutting speed, and it was possible to conclude that force and average surface roughness in ceramic tools are lower than in carbide tools [24].

The effects of machining parameters such as cutting speed, feed rate, and depth of cut on machining forces were investigated. These forces include feed force, thrust force, and cutting force. In addition, surface roughness was examined.

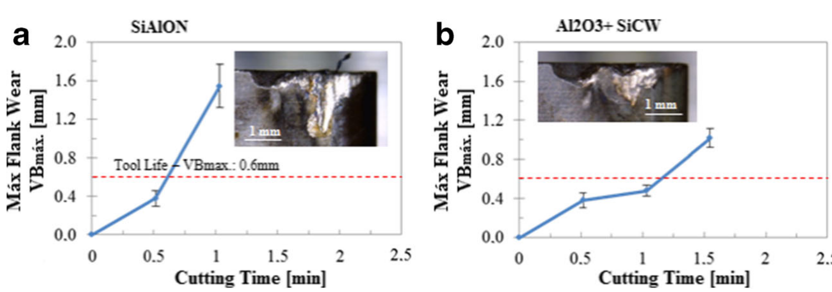

Fig. 7 **a**, **b** Wear behavior graphic VB × cutting time

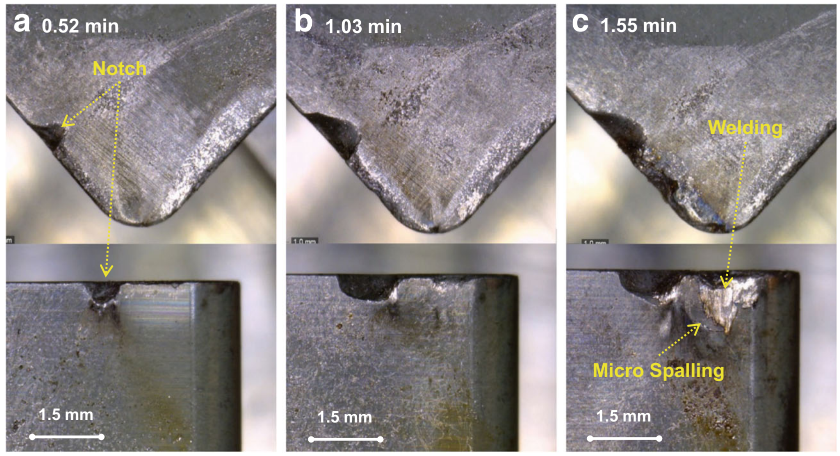

Fig. 8 **a**, **c** Al_2O_3 + $SiC_{whisker}$ wear in dry turning

Results showed that in contrast with conventional machining processes, cutting speed and coating are the most important parameters in removing cutting fluids [25].

After the wet and dry turning of Inconel 718 with ceramic tool evaluation, it is possible to realize that, due to the low machinability of Inconel 718, the tools are easily affected, leading to excessive tool wear during machining operations. To ensure good results, not only in tool wear decrease but also in good surface quality, special care must be taken when choosing cutting conditions and other important factors to the process. To minimize these problems, hard turning, in some situations, requires a large amount of cutting fluid.

In contrast, the cutting fluid application involves high costs and it is not truly accepted because of environmental issues. When it comes to environmental concerns and growing regulations over contamination and pollution, the search for renewable and biodegradable cutting fluids is increasing. It is necessary to consider green machining in every condition, even when the cutting fluid is appropriate.

Besides these differences, during the experiments, the most noticeable wears were notch wear and flank wear. This wear is associated with a combination of high temperature, high strength of the machined material, plastic deformation followed by hardening of the surface layer, high voltages on the chip-tool interface, chemical reaction of the cutting tool material with the components in surrounding area, and forming abrasive chip [16].

Some researchers have studied the machining of Inconel 718 with ceramic cutting tools. The main wear mechanisms reported were abrasion and diffusion as can be seen in a recent work on tool wear characteristics in machining of nickel-based superalloys [12, 26]. The friction in machining of nickel-based superalloys is seen as the key for rapid tool wear, mainly the notch wear. It is the predominant type of catastrophic failure mechanism for the round type ceramic cutting tools. The author also presented a notch wear model considering work-hardened layer used to establish the depth of notch wear. Series of cutting tests are used to validate the proposed

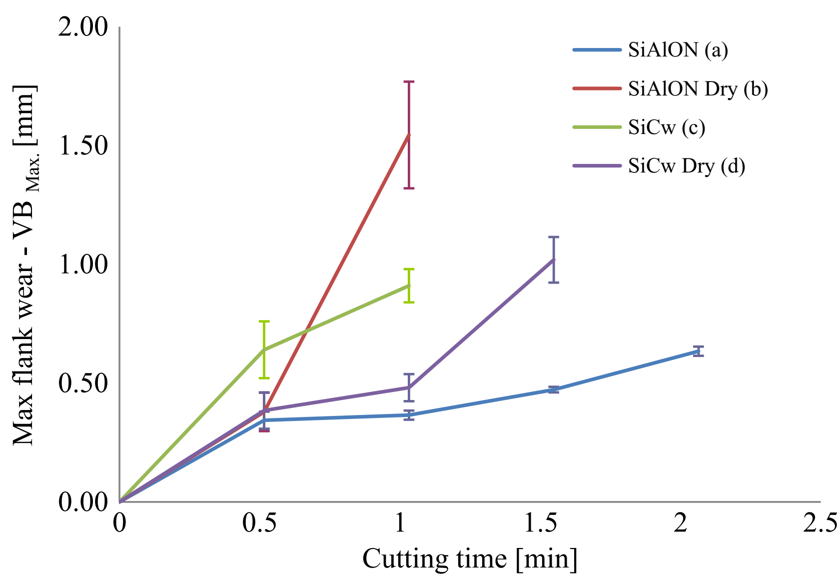

Fig. 9 Wear behavior graphic VB × cutting time

Table 4 2^2 data

N test	Fluid	Insert	×1	×2	Wear
1	Flood	SiAlON	−1	−1	0.38
2	Flood	SiAlON	−1	−1	0.35
3	Dry	SiAlON	1	−1	1.77
4	Dry	SiAlON	1	−1	1.32
5	Flood	$SiC_{whisker}$	−1	1	0.84
6	Flood	$SiC_{whisker}$	−1	1	0.98
7	Dry	$SiC_{whisker}$	1	1	0.54
8	Dry	$SiC_{whisker}$	1	1	0.42

model [9]. In other research, it was showed that the sensitive strain rate and easy work hardening characters would cause upward tool wear [3]. Notch wear formed at the depth of cut line was the mainly wear noticed, while turning Inconel 718, because of severe thermal processes, abrasive particles, high work hardness and high strength of the workpiece [27].

The notch wear commonly occurs where the hardening layer is located. Based on this, it is noted that the notch wear might have been generated by the work-hardened layer resulting from the previous cutting process, and the friction between the workpiece and the cutting tool will increase the damage.

Figure 9 shows the results from all the experiments. It is possible to conclude that Al_2O_3 + $SiC_{whisker}$ in dry turning shows a better result in comparison to SiAlON in dry turning, and Al_2O_3 + $SiC_{whisker}$ with cutting fluid presents impracticable results. SiAlON also presents good results with cutting fluid, because it reached the tool life in the longest period and the wear behavior is according to Klocke [16].

The investigation shows clear results, which are organized and confirmed by 2^2 and ANOVA analyses. Table 4 shows details of the eight tests realized in the study and their results.

In the sequence, the data showed in Table 4 was used to calculate the total wear and its average. After that, the ANOVA analyses with 0.05 significance were used to determine whether there are any meaningful differences between the groups. It compared the importance between the groups of interested and determined if any of these are significantly different from each other. Table 5 displays the results and it is possible to conclude that the type of fluid application, in this case wet or dry, and the interaction between this and the type of the insert are significant. On the other hand, the type of the insert by itself makes no big difference in the results.

Following this further, it is noticeable the survey of existing works has revealed paucity studies published with focus on dry turning using ceramic inserts. Under these circumstances, it is important to discuss this process in an attempt to improve it in order to bring an environmentally friendly and economic option, which, in the future, may be applied on the shop floors.

After this discussion, it is possible to conclude that dry machining cannot be considered the best technical option during turning Inconel 718. However, it is relevant to study and improve the process. The results show SiAlON with cutting fluid as the best option to be applied when turning Inconel 718 with ceramic inserts. Under these conditions, other results were presented and this information can help decision makers to choose the best parameters to be applied in their companies considering the processes and its particularities.

Despite to the supposed excessive costs when using conventional lubricants, this condition continues to be the best when a production increase is required. This information was found in a study where characterizations and turning tests were carried out, varying cutting conditions and lubricooling systems to evaluate the machinability of Inconel 718 [12].

5 Conclusion

Rapid tool wear and short tool life are huge problems, which need to be improved. In this paper, the comparison among the use of cutting fluid and dry turning of Inconel 718 with ceramic tools showed that in both conditions, the main tool wear is notch and flank wear and it is extremely high. The main contribution of this research is to develop knowledge about dry machining and move towards an environmentally friendly, economic, and healthy process.

Experiments and machining simulation now have to work together to find a way to the dry cutting of Inconel 718 as the results presented have not been adequate yet. The objective is

Table 5 ANOVA results

Source of variable	Sum of squares	Degree of freedom	Mean square	F_0	F_c	P	Conclusion
A	0.1352	1	0.1352	4.56	7.71	9.9×10^{-2}	F0 < F tabela
B	0.2813	1	0.2813	9.48	7.71	3.6×10^{-2}	F0 > F tabela
AB	1.2961	1	1.2961	43.67	7.71	2.7×10^{-3}	F0 > F tabela
Error	0.1187	4	0.0297				
Total	1.8312	7					

to find a suitable tool and appropriate coating, to define the better geometrical tool configuration and the optimal cutting conditions in order to obtain a more acceptable surface integrity and the longer tool life.

In relation to tool life experiments, the best result was obtained by SiAlON, with cutting fluid application. This result converges with the results obtained by other nickel superalloy turning researches, with high cutting parameters. It is associated to its excellent toughness, abrasion resistance, and good chemical stability.

The predominant wears were notch wear and flank wear. The notch wear in the cutting depth was the main type observed for all tested conditions, and it was related to the hardened area.

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