Influence of melt treatments and turning inserts on cutting force and surface integrity in turning of Al–7Si and Al–7Si–2.5Cu cast alloys

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Abstract The microstructures, machinability and surface characteristics of Al–7Si and Al–7Si–2.5Cu cast alloys were studied after various melt treatments like grain refinement and modification. Results indicate that combined grain refined and modified Al–7Si–2.5Cu cast alloys have microstructures consisting of uniformly distributed α-Al grains, eutectic Al–silicon and fine $CuAl_2$ particles in the interdendritic region. These alloys exhibited better machinability and surface characteristics in the cast condition compared with the same alloy subjected to only grain refinement or modification. Performances of the turning inserts (Un-coated, PVD and Polished CVD diamond coated) were evaluated in machining Al–7Si and Al–7Si–2.5Cu cast alloys under dry environment using a lathe. The Polished CVD diamond coated insert outperformed the Un-coated or PVD-coated cutting inserts which suffered from sizeable edge buildup leading to higher cutting force and poor surface finish. The Polished CVD diamond coated insert shows a very small steady wear without flaking of the diamond film during cutting. This paper attempts to investigate the influence of grain refinement, modification and combined action of both on the microstrutural changes in the Al–7Si and Al–7Si–2.5Cu cast alloys and their machinability and surface finish when different turning inserts used.

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Introduction

The reason for the wide acceptance of the Al–Si alloys can be found in the attractive combination of physical properties and generally excellent castability, mechanical properties, corrosion resistance, machinability, hot tearing resistance, fluidity and weldability [1–2]. Hence Al–Si alloys are widely used in automobile, aerospace, defense and general engineering industries.

At present the cemented carbide inserts alone or with TiN, TiC or TiN + TiC, or PCD coatings are used for turning applications. The high hardness, wear resistance and chemical stability of these inserts with proven benefits in terms of tool life, good surface finish and reduced cutting force are well known. However, cutting tool performance is found wanting, in machining materials like Al–Si alloys, whose use is increasing in the expanding automobile industry. The cutting tools suffer from rapid wear because of strong adhesion and chemical reaction with Al–Si alloys [3–9]. In contrast, diamond coating can provide anti-welding characteristics because of chemical inertness towards Al–Si alloys. This can also offer remarkable abrasive wear resistance because of its super hardness. CVD diamond insert is an outstanding candidate for dry machining due to its unique properties such as low coefficient of friction, high thermal conductivity, high-temperature hardness and chemical stability. Further surface modification of diamond coated tools by polishing helps in further reducing cutting forces and improving surface finish of the dry machined components [10–14].

The present state of the technology for material cutting is characterized by the high productivity of precise components achieved by computer-controlled high-power machines. The success of this operation depends in no less degree on the proper choice of cutting tools.

A very important finding is that alloys with the same chemical composition can have different microstructures and mechanical properties due to variations in the casting process, the use of a grain refiner, modifier, or both grain refiner and modifier and also by heat treatment. This means that different processing techniques can result in a range of mechanical properties, which affect the cutting process [15].

A particular characteristic of the two-phase and multi-phase microstructures of Al–Si alloys is the fact that one phase is soft and highly ductile whereas the second is considerably harder. For a good surface finish, it is important that the particles of the hard phase are very fine and uniformly distributed within the soft, aluminum base [16].

Because the surface roughness achieved during turning depends on the shape, size distribution and morphology of the silicon particles, which, in turn, depends on the soft-phase deformation in the surface layer. Studies showed a relation between the microstructure of the alloy and the roughness of the machined surface, i.e. a relation with the magnitude of the variation of the cutting force after turning. It was found that an increase in the size of the soft matrix grains produced an increase in the cutting force and the roughness of the machined surface [17, 18].

Machinability and surface characteristics of Al–7Si and Al–7Si–2.5Cu cast alloys mainly depend on the shape, size and size distribution of the ά-Al grains, eutectic morphology and CuAl$_2$ particles in the interdendritic region. The microstructure of Al–7Si and Al–7Si–2.5Cu cast alloys consists of large primary ά-Al grains, the eutectic silicon (plate like) and massive CuAl$_2$ particles in the interdendritic region showing poor ductility in the casting. Unmodified acicular silicon acts as internal stress risers in the microstructure and provides easy path for fracture. With the addition of grain refiners and modifiers converts large elongated primary ά-Al grains into fine equiaxed ά-Al grains, eutectic silicon (plate like) into fine particles and fine CuAl$_2$ particles in the interdendritic region resulting in the improved machinability and surface finish characteristics.

Several experimental results have been reported describing the use of grain refiners and modifiers to obtain a fine-grained microstructure of hypoeutectic Al-Si alloys [3–5]. The effect of grain refinement and/or modification and combined addition of both on the machinability and surface characteristics of Al–7Si and Al–7Si–2.5Cu cast alloys have not yet been sufficiently elucidated, except for hardness, and tensile properties. The purpose of the present study was to improve the machinability of Al–7Si and Al–7Si–2.5Cu cast alloys using grain refiner and/or modifier, combined addition of both and different turning inserts (Un-coated, PVD-coated and Pol. CVD Diamond coated).

Experimental details

Al–7Si alloy was prepared by melting commercially pure aluminum (99.7%) with Al–20%Si master alloy in clay graphite crucible in a pit type resistance furnace under a cover flux (45%NaCl + 45% KCl + 10% NaF) and the melt was held at 720 °C. After degassing with 1% solid hexachloroethane, master alloy chips duly packed in aluminum foil were added to the melt for grain refinement. For modification Al–10%Sr master alloy was used with addition level being kept constant at 0.02 wt%Sr [3]. The melt was stirred for 30 s after the addition of grain refiner and/or modifier. Melts were held for 5 min and poured into a cylindrical graphite mould surrounded by fireclay brick. The details of the alloys, grain refinement and modification treatment and mechanical properties of various alloys are given in Table 1. The chemical compositions of the cast alloys and master alloys assessed using atomic emission spectroscopy are given in Table 2. The microstructures of the samples that had been cut in the longitudinal direction were studied. Grain size analysis was carried out by the linear intercept method after etching the polished surface with Keller's reagent (2.5% HNO$_3$, 1.5% HCl, 1% HF and 95% H$_2$O). Samples for optical microscopy were electro polished using in an electrolytic bath comprising of 80%

Table 1 Test specimens and analyzed mechanical properties of Al–7Si and Al–7Si–2.5Cu alloys

Sl No	Alloy Designation	Alloy Composition	Addition level of GR (wt%)	Addition level of Modifier (Wt%)	UTS (MPa)	Hardness (HB)
1	HP-1	Al–7Si	–	–	149	60
2	HP-2	Al–7Si-1M13	1.0	–	160	66
3	HP-3	Al–7Si-0.02Sr	–	0.02	168	70
4	HP-4	Al–7Si–2.5Cu	–	–	163	73
5	HP-5	Al–7Si–2.5Cu-1M13	1.0	–	184	85
6	HP-6	Al–7Si–2.5Cu-0.02Sr	–	0.02	194	90
7	HP-7	Al–7Si–2.5Cu-0.02Sr-1M13	1.0	0.02	200	98

GR: Grain refinar [M13 = Al–1Ti–3B] Modifier [(Sr-Strontium)]

Table 2 Chemical analysis of cast alloys and master alloys

Alloy	Composition (Wt%)					
	Si	Fe	Sr	Ti	B	Al
Al	0.11	0.16	–	–	–	Balance
Al–7Si	6.98	0.17	–	–	–	Balance
Al–10Sr	0.12	0.17	10.0	–	–	Balance
Al–20Si	20.13	0.18	–	–	–	Balance
Al–1Ti–3B	0.16	0.17	–	1.13	2.25	Balance

Table 3 Detail data of turning inserts for machining

Insert Code-CCGT 09T304 FL K10	
C	Shape of Insert—80°
C	Clarence angle—7°
G	Tolerance
T	Type
09	Cutting edge length mm
T3	Thickness 3.97 mm
04	0.4 mm
FL	Chipbraker
K-10	Carbide grade
Un-Coated Insert—K-10: 94%WC + 6%CO	
PVD—Monolayer of Ti N (Tempreture-400–600°C)	
Polished CVD diamond Coated—R_a-0.14 µm	

methanol and 20% HNO_3 by volume. Selected samples were subjected to SEM and XRD analysis.

Machinability tests were carried out on Al–7Si and Al–7Si–2.5Cu cast alloys (cylindrical rods) using lathe under dry environment with constant feed rate (0.2 mm/rev), constant cutting speed (226 m/min) and constant depth of cut (0.4 mm) for Un-coated, PVD and Polished CVD Diamond coated turning inserts. The details of turning inserts data for the present work and geometry of the inserts are given in Table 3. Tangential cutting force, P_z (N), and axial force, P_x (N) were measured at suitable intervals using a Kistler Piezoelectricity lathe tool dynamometer, mounted together with the cutting-tool handle on a transverse support of the experimental lathe. Surface roughness of machined alloys under different conditions were evaluated using R_a (µm) and R_z (µm) parameters with the help of surface roughness tester (Mitutoyo SJ-301, Japan) under the following conditions:

Standard:	ISO 1999
Profile:	R
Cut off length:	0.8 mm
Range:	Auto
Speed:	0.25 mm/s
R_a:	Average roughness
R_z:	Maximum peak height

Tensile testing of the specimens was carried out in Universal Testing Machine (AG-5000G, Shimadzu, Japan) in accordance with ASTM B-557-84 procedure.

Results and discussion

The microstructures of Al–7Si and Al–7Si–2.5Cu cast alloys treated by grain refiner and modifier

The microstructures of the Al–7Si and Al–7Si–2.5Cu cast alloys before and after grain refinement, modification and combined addition of both refiner and modifier are shown in Fig. 1a–g. It is observed that grain refinement; modification and combined addition of both refiner and modifier have profound influence on microstructures of the Al–7Si and Al–7Si–2.5Cu cast alloys. Figure 1a and d shows the microstructure of un treated alloys consisting of large primary ά-Al grains (soft phase), the plate like eutectic silicon and massive $CuAl_2$ particles in the interdendritic region. Figure 1b and e shows the microstructures of treated (1 wt% Al–1Ti–3B grain refiner) alloys consisting of fine equiaxed ά-Al grains (soft phase), un modified eutectic and $CuAl_2$ particles in the interdendritic region. Figure 1c and f shows the microstructure of treated (0.02 wt% Sr modifier) alloys consisting of few primary ά-Al grains (soft phase), uniformly distributed fine eutectic mixture and fine $CuAl_2$ particles in the interdendritic region. Figure 1g shows the microstructure treated by the combined addition of both grain refiner and modifier (1 wt% Al–1Ti–3B grain refiner and 0.02 wt% Sr modifier) alloys consisting of fine equiaxed ά-Al grains (soft phase), uniformly distributed fine eutectic mixture and fine $CuAl_2$ particles in the interdendritic region.

The present experimental work confirms that, addition of grain refiner (1 wt% Al–1Ti–3B) to Al–7Si and Al–7Si–2.5Cu alloy significantly refines the coarse columnar primary ά-Al grains to fine equiaxed ά-Al grains due to the presence of AlB_2/TiB_2 particles present in the master alloy which are nucleating agents during the solidification of ά-Al grains (soft phase), while the eutectic silicon particles appear to be unaffected as

Fig. 1 Optical
microphotographs of Al–7Si
alloy (**a**) un-treated, (**b**) with
grain refiner (1% of M13),
(**c**) with modifier (0.02% Sr)
and Al–7Si–2.5Cu alloy
(**d**) un-treated, (**e**) with grain
refiner (1% of M13), (**f**) with
modifier (0.02% Sr) and (**g**)
with grain refiner (1% of M13)
and modifier (0.02% Sr)
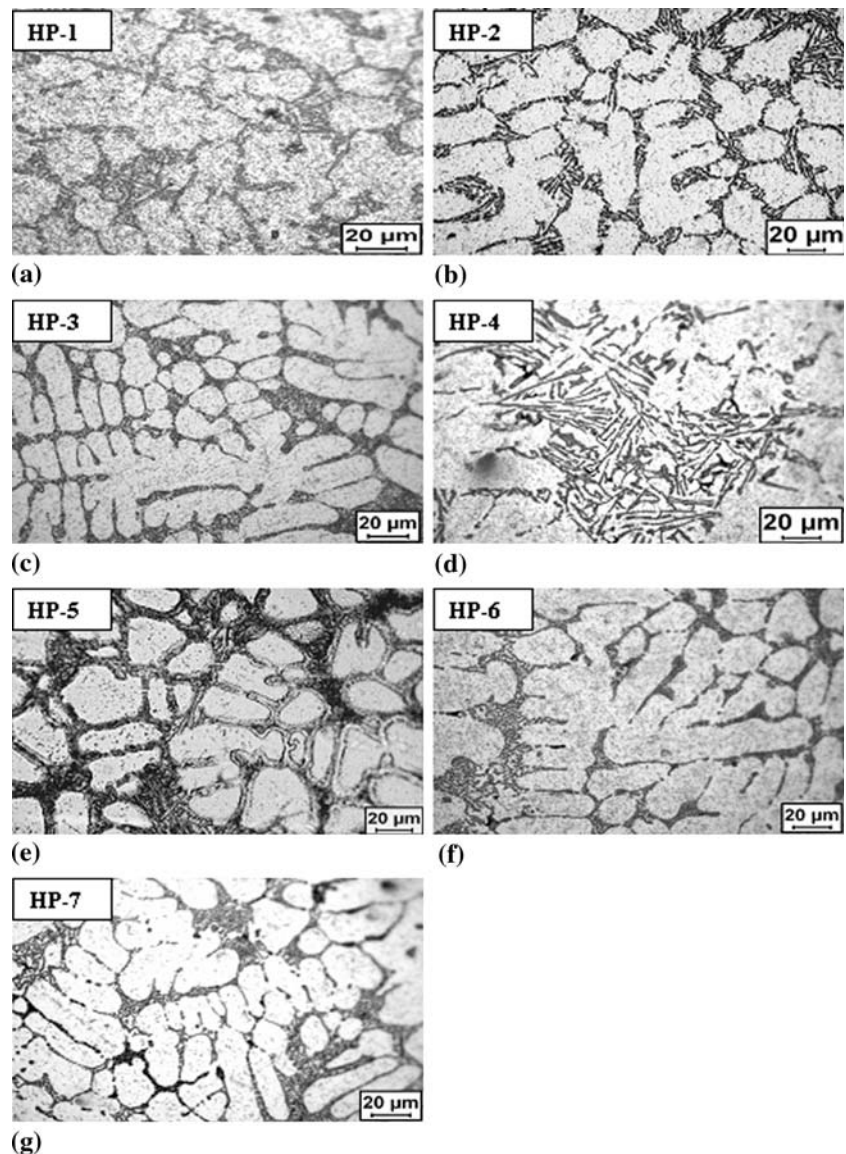
expected. Also the addition of modifier (0.02 wt% Sr) to
Al–7Si and Al–7Si–2.5Cu alloy changes the plate like
eutectic silicon to uniformly distributed fine particles
(eutectic) and fine $CuAl_2$ particles in the interdendritic
region [3]. The results also suggest that, the addition of
Al-1Ti-3B master alloy along with Sr modifier to Al–7Si
and Al–7Si–2.5Cu cast alloys shows more uniformly
distributed á-Al grains, fine silicon and $CuAl_2$ particles in
the interdendritic region compared to the individual
addition of grain refiner or modifier. It is important to
note that the alloys have been cast in a graphite mould
surrounded by fireclay brick (slow cooling). Thus, further
Improvement in the machinability and surface character-
istics can be expected for fast cooled castings, as this can
lead to further refinement of the microstructures.

Figure 2a shows the distribution of the intercept lengths
Lá measured for the grains of soft phase for untreated
Al–7Si–2.5Cu alloy. On the basis of measurements of the
longest length and shortest length, 15 classes were deter-
mined, with the width of a single class being 10 μm. From
the data in the column chart, it is clear that the fraction of
grains of solid phase Lá with the size up to 90–100 μm is as
high as 80%. The microstructure also shows a few large
primary coarser grains with intercept lengths between
130 μm and 150 μm. The size distribution of the measured
intercept lengths for the eutectic constituent of the
untreated Al–7Si–2.5Cu alloy is shown in Fig. 2b. In the
size class up to 60–70 μm there are as many as 80% of the
eutectic, which means that the eutectic of the untreated
hypoeutectic alloy is coarse and plate like particles.

Fig. 2 Frequency of the intercept lengths of (**a**) Soft phase L á for the untreated hypoeutectic alloy, (**b**) Eutectic for the untreated hypoeutectic alloy, (**c**) Soft phase L á for the treated hypoeutectic alloy, (**d**) Eutectic for the treated hypoeutectic alloy, (**e**) Soft phase L á for the combined treated hypoeutectic alloy and (**f**) Eutectic for the combined treated hypoeutectic alloy
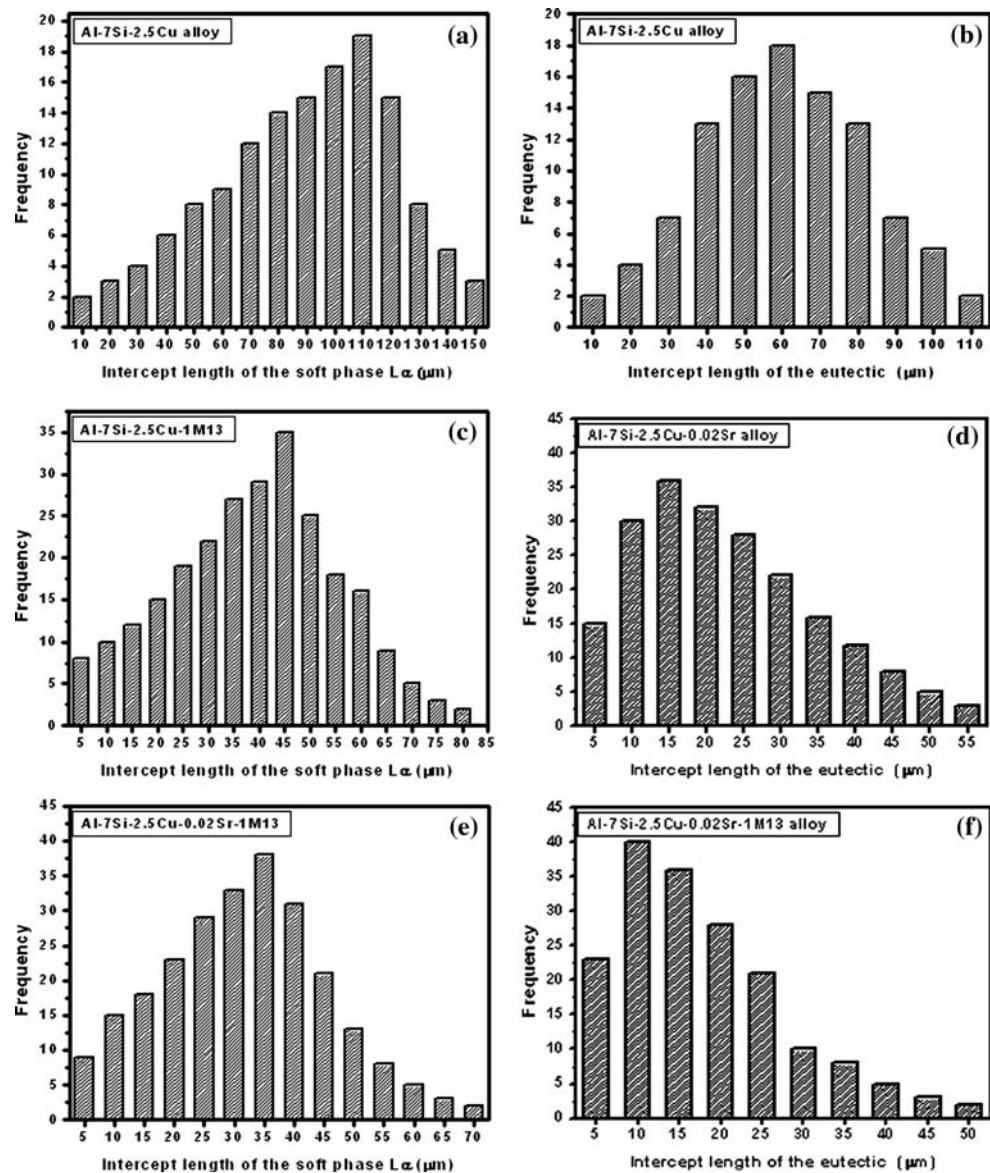

Figure 2c shows the distribution of the intercept lengths Lá measured for the grains of soft phase for grain refined (1 wt% Al–1Ti–3B) Al–7Si–2.5Cu alloy. The bandwidth of a single class is only 5 μm. In the size class up to 40–45 μm there are as many as 85% of all grains measured, which means that the soft phase of the hypoeutectic alloy is fine and equiaxed.

The size distribution of the measured intercept lengths for the eutectic of the modified (0.02 wt% Sr) Al–7Si–2.5Cu alloy is shown in Fig. 2d. In the size class up to 10–15 μm there are as many as 85% of all measured intercept lengths for the eutectic, which means that the eutectic of the treated hypoeutectic alloy is fine and uniformly distributed.

Figure 2e and f shows the distribution of Lá measured for the grains of soft phase and eutectic for the combined

grain refined and modified (1 wt% Al–1Ti–3B and 0.02 wt% Sr) Al–7Si–2.5Cu alloy. It is clear that, the fraction of grains of soft phase Lá with the size up to 35–40 μm is as high as 80% and the fraction of eutectic with the size up to 10–15 μm is as high as 85%, which means that, the Fig. 2e and f clearly reveals fine equiaxed grains (soft phase) together with fine modified eutectic.

Influence of the microstructural changes on cutting forces

During turning there are two processes occurring simultaneously in the cutting zone: material cutting that produces a chip, and plastic deformation of the chip and the workpiece material in the surface layer. Both processes have a synergic influence on the formation of the chip and of the

new workpiece surface, which can be described by changes of the cutting force. Although all the Al–Si alloys involved differ a little in their mechanical properties, they show a distinct difference in the cutting force under identical cutting conditions. The differences may arise from different cutting conditions, increased wear, changes in the tool geometry, and differences in the alloy microstructures. The behavior of the hypoeutectic alloy in the cutting zone and the changes in the component of the cutting force depend on the changes and size of the ά-Al grains (soft phase) and the eutectic.

Un treated alloys

Un treated Al–7Si and Al–7Si–2.5Cu alloys consist of longest lengths of both soft and eutectic will produce changes in the periodic variations of the cutting force. It is known that an increase in the fraction of the solid-solution grains in the alloy will significantly increase the probability of the formation of deposits produced by the workpiece material at the cutting face of the tool. The solid solution is soft and plastic; therefore, in the course of turning it will adhere to the cutting face of the tool. The deposit will gradually increase in size and, when it exceeds a critical size, it will separate from the cutting face and adhere to the lower surface of the chip. Thus, in the course of cutting, material will gradually accumulate to a certain thickness at the cutting face. The deposit at the cutting face will produce a change in the tool geometry, which is indicated by an increase of the cutting-force Fig. 3. It is assumed that at the moment when the deposit reaches the critical size it will slide, under the action of a sufficiently strong transverse force, completely or partly from the cutting face and be eliminated with the chip. It can be assumed that at this moment the measured cutting-force will attain its peak value. Due to the turning conditions another case may occur when a deposit from the tool face slides over the cutting nose and imprints into the already-machined workpiece surface. Immediately after the elimination of the existing deposit, a new deposit will form on the tool, and will gradually grow and change the tool geometry, which will show in further increase of the cutting force.

Combined influence of grain refiner and modifier

Given the statistical data on the microstructure of the Al–7Si–2.5Cu cast alloys treated by the combined addition of both Fig. 2e and f, it can be assumed that the conditions for the formation and the shaping of a chip in the cutting zone will be completely different from those occurring in the case of the untreated alloy. With the combined addition of both, the behavior of the workpiece material in the
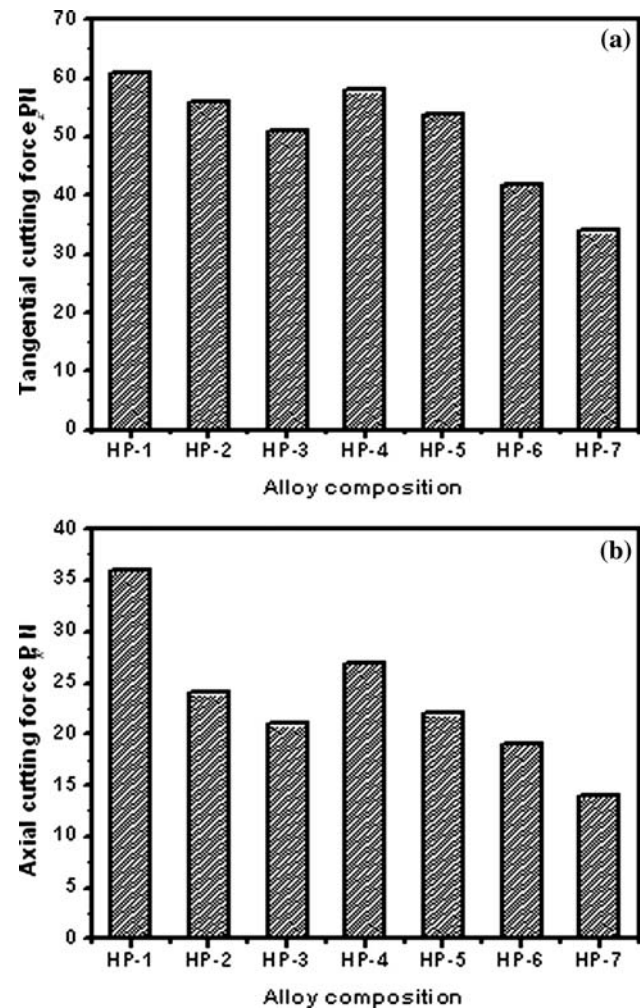
Fig. 3 Variations of (**a**) Tangential cutting force Pz and (**b**) Axial cutting force Px with alloy compositions for pol. CVD diamond coated insert

cutting zone and the changes in the main cutting force will depend on both constituents of the soft phase and eutectic. Due to the addition of both grain refiner and modifier, both phases are very fine and uniformly distributed. The average intercept lengths for the soft phase and eutectic are approximately 35–40 μm and 10–15 μm. This means that the alloy microstructure in the cutting zone is very fine grained and shows periodic stacking, i.e. a homogeneous and alternating distribution of the fine lamellae of the eutectic silicon and of the soft solid solution. Consequently, during cutting there are very favorable conditions for the formation of a chip. Figure 3 shows the cutting force during the turning of the treated alloy. A simple visual assessment of the signal of the cutting force indicates that there are no individual, distinct maximum amplitudes, i.e. they are considerably lower and uniform than those measured for the untreated alloy. The effect of other additions like only grain refiner (Al–1Ti–3B) and only

modifier (Sr) on machinability properties of hypoeutectic alloys is also shown in Fig. 3, Single additions have limited effect only.

Influence of the microstructural changes on surface roughness

In the course of turning, the microstructure in the cutting zone of the thin surface layer changed because of a pronounced micro plastic deformation of the soft phase when a new surface was being formed. A microstructure analysis of the surface layer of the individual specimens confirmed that when the new surface was being formed a number of processes occur in the cutting zone, like

- Micro plastic deformation of the Al-base soft phase;
- Adhering of the soft phase to the cutting face of a tool;
- Adhering of the soft phase to the already machined surface;
- Gradual removal of the built-up edge fragments by chips; and
- Crushing of the brittle eutectic constituents.

Pronounced changes in the newly formed surface and in the microstructure of the subsurface layer occur after turning of the untreated alloys. In the course of turning the soft Aluminum deformed excessively and adhered to the cutting face of the tool. During turning the built-up edge fragment at the cutting face increased. Consequently, the tool geometry changed. When the built-up edge fragment has grown to its critical size, it will slip away with a chip or adhere to the machined workpiece surface increasing the roughness of the new surfaces. For a description of the surface quality after turning, it is common to select the mean arithmetic surface roughness R_a (μm) and R_z (μm). In the technical literature the surface roughness is most often related only to influences of machining conditions. Consequently, influence of the microstructure on surface formation during turning was considered in the present study. The column charts in Fig. 4 show the average roughness R_a (μm) and R_z (μm) as a function of the alloy compositions. For the same machining conditions, the roughness was the highest value with untreated Al–7Si and Al–7Si–2.5Cu alloys than grain refined; modified and combined grain refined and modified alloys. Because of pronounced plastic deformation of the soft phase in the cutting zone and build-up at the cutting tool edge resulting in increased roughness of the new surface formed. The surface roughness, i.e. $R_a = 7.8$ μm for pol. CVD diamond insert was twice as higher than that of the combined grain refined and modified alloy. Combined grain refined and modified alloy characterized by the shortest intercept lengths of the soft and eutectic phases in the matrix. The effect of other additions like only grain refiner (Al–1Ti–3B) and only
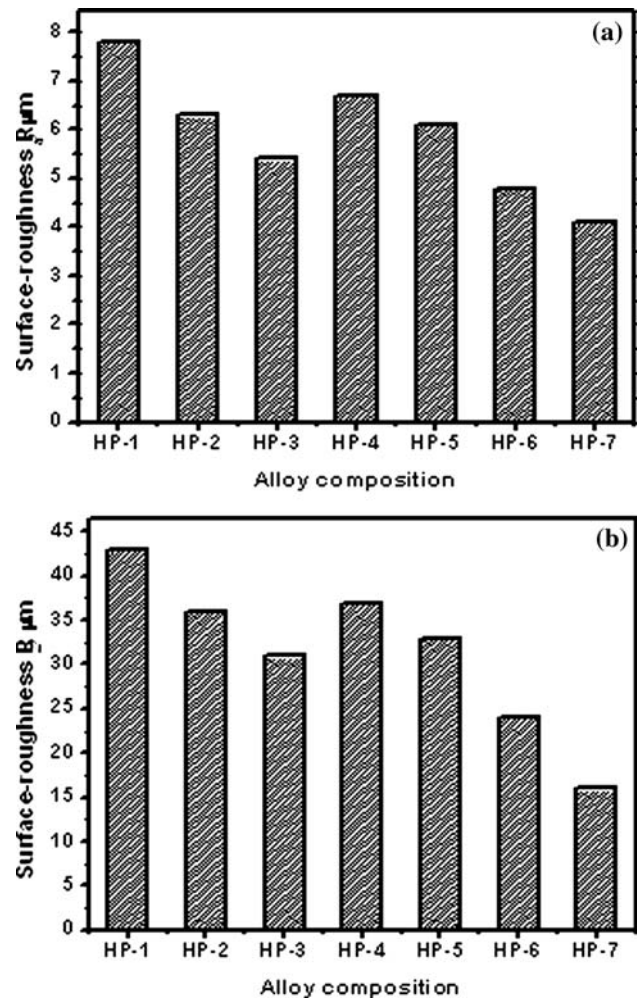

Fig. 4 Variations of (**a**) Surface roughness R_a and (**b**) Surface roughness R_z with alloy compositions for pol. CVD diamond coated insert

modifier (Sr) on surface roughness of eutectic alloys is also shown in Fig. 4, these have limited effect only.

Influence of the turning inserts on cutting force and surface roughness

The existence of diamond coating (CVD insert), TiN coating (PVD insert) have been confirmed with X-ray diffractograms shown in Fig. 5a, b. Figure 5c is the diffactogram of uncoated tool showing only WC. The faint peaks of diamond and TiN peaks as compared to WC peaks are due to the thinness of the coatings. Table 4 gives the initial roughness of the inserts. The flank wear of the inserts were measured using optical microscope (MG Olympus Tokyo-Japan). The influence of grain refinement and modification on the machinability and surface finish characteristics of Al–7Si and Al–7Si–2.5Cu cast alloys with different turning inserts (Un-coated, PVD and Polished CVD diamond

Fig. 5 X-ray diffraction spectra of (**a**) Diamond coated W C insert, (**b**) TiN coated W C insert and (**c**) W C insert
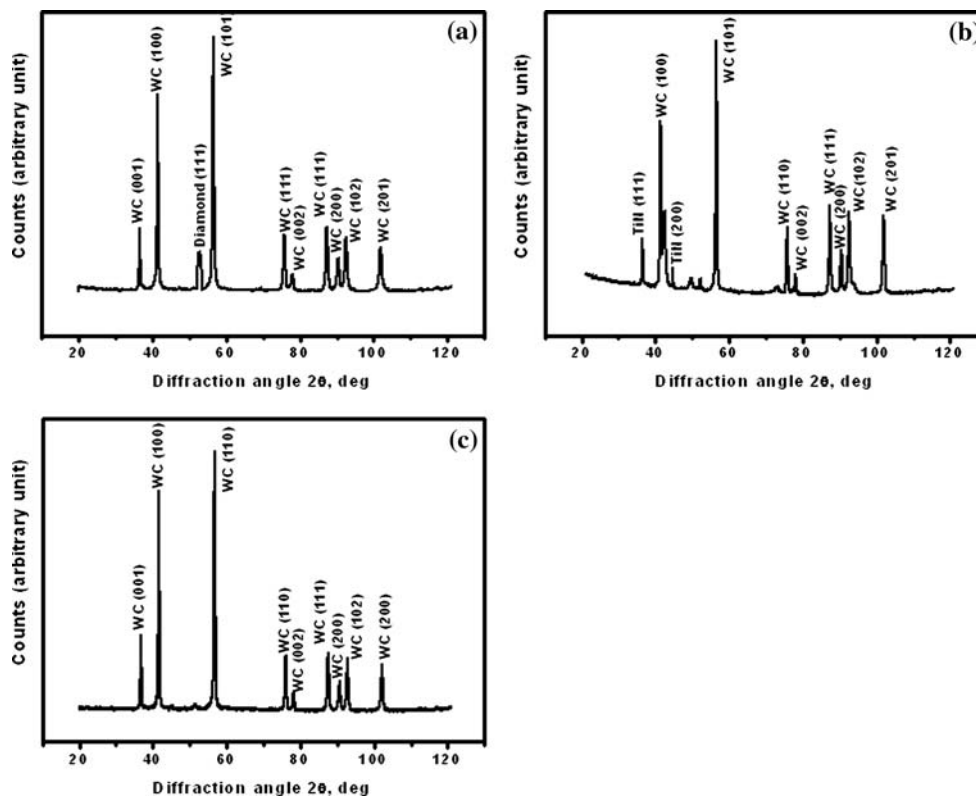
Table 4 Initial roughness of the inserts

| Sl. No	Insert	Roughness R_a, µm	Roughness R_z, µm
1	Un-coated	0.17	0.82
2	PVD-coated	0.73	4.6
3	Pol. CVD diamond	0.14	0.19

coated) with constant cutting speed (226 m/min), feed rate (0.2 mm/rev) and depth of cut (0.4 mm) are shown in the Fig. 6a and b. It is noticeable from Fig. 6a and b that the tangential cutting forces (P_z) and axial cutting force (P_x) for PVD and Un-coated inserts appear to be high. In contrast, the cutting forces for Polished CVD diamond coated insert were substantially low as shown in Fig. 6a and b. Such low cutting forces for polished diamond coated insert could be attributed to the poor affinity of diamond to materials like Al–Si alloys.

Surface roughness values, R_a and R_z, for machined surface produced by PVD and un-coated inserts were observed to be high as shown in Fig. 7a and b. On the other hand, surface roughness of the work piece produced by the Polished CVD diamond-coated insert was very low as shown in Fig. 7a and b. Interestingly: (i) Polished CVD diamond coated insert continued to give a glossy surface till 12–14 min of machining after which it started giving few tear marks on the surface and (ii) Polished CVD diamond-coated insert shows smooth flank wear and no

flaking of the diamond film is observed at the cutting edge after 14–16 min machining. From Fig. 8a and b, the initial rapid wear of polished CVD diamond- coated insert is almost the same as that for the un-coated and PVD inserts but the increase in flank wear of the polished CVD diamond-coated substrate at the steady wear stage is very small and the difference in wear compared with the PVD or un-coated inserts shows remarkable increase with time. The result indicates that a polished CVD diamond-coated insert is expected to be superior for machining of Al–Si alloys.
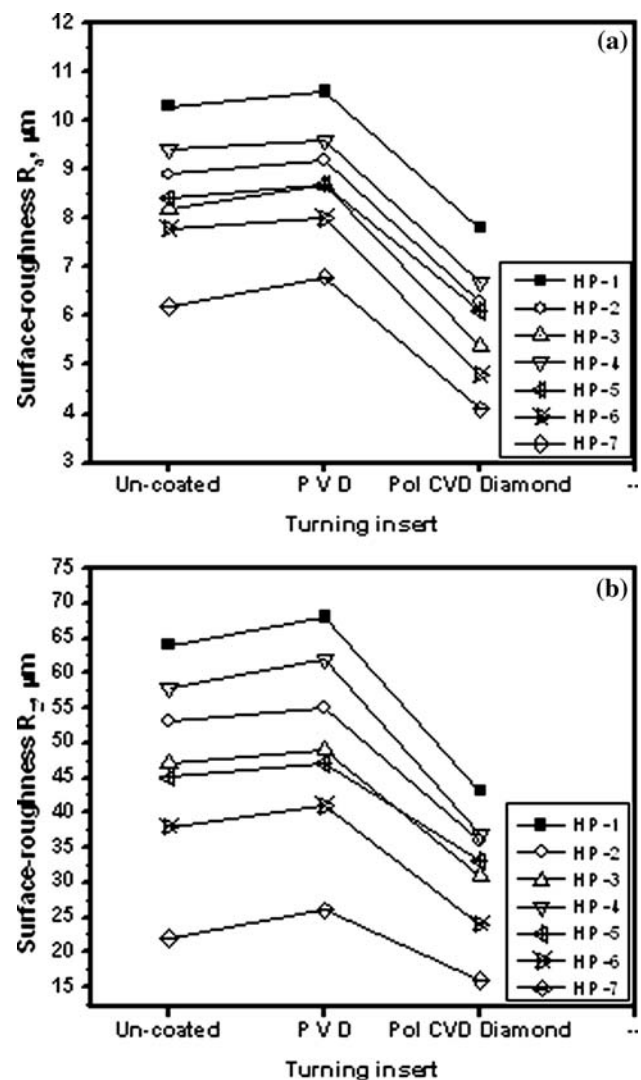
SEM micrograph Fig. 9a and b show heavy build-up of work-piece material on the face and flank of the PVD and uncoated inserts covering the cutting edge after machining. Such good adherent layer of the work material at the tool tip is responsible for high cutting force and poorer surface finish for PVD and uncoated inserts are seen in Figs. 6 and 7. As observed in the machining, the flowing chip moves across the rake surface and is trapped by the sharp crystallites. The trapped material build-up at and near the cutting edge would continue to grow as machining is continued, leading to the "caterpillar effect". At some point during cutting, enough material may sometimes be welded strongly to the PVD coating to break off a portion of the film. Alternatively, it may pile up to form a curling chip, which may be pushed back towards the work piece material at the trailing edge of the cut. If it comes in
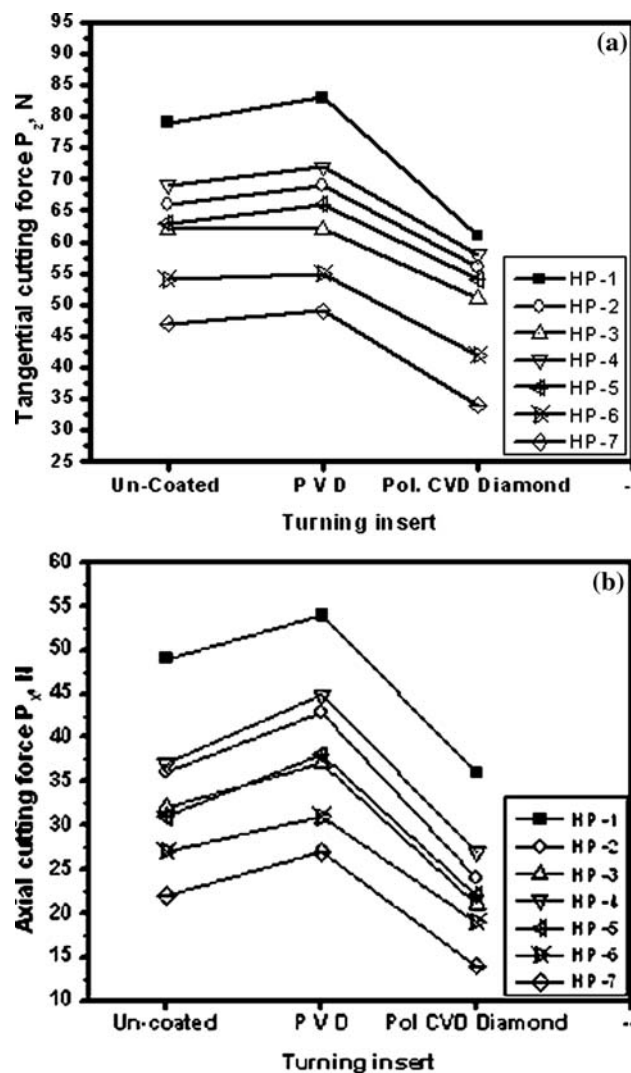
Fig. 6 Variations of (**a**) Tangential cutting force Pz and (**b**) Axial cutting force Px with different inserts for different alloy compositions

Fig. 7 Variation of (**a**) Surface roughness R_a with different inserts for different alloy compositions Variation of (**b**) Surface roughness R_z with different inserts for different alloy compositions

contact with the machined surface of the work piece, it may scratch and mar the surface finish. The SEM micrograph of Polished CVD diamond coated insert (Fig. 9c shows that even after machining, the tool tip experienced no built-up edge formation. One of the advantages of such a cutting edge is a clean cutting action and a reduction in cutting forces. The polished surface allows the metal chips to slide across and away from the cutting point with relative ease, thereby preventing a curl-back or build-up near the cutting edge. It is well known that the build-up of work piece material at the cutting edge has several disadvantages: (i) it increases the cutting force, (ii) it adversely affects the surface finish of the part and (iii) it can cause severe damage to the cutting edge when the built-up material is dislodged during cutting, leading frequently to the removal of the coating or micro chipping of the cutting tool. Thus

there are several potential advantages in using polished CVD diamond-coated cutting inserts especially when machining relatively soft materials, which have a tendency to build-up at the cutting edge.

Conclusions

The effect of melt treatment and turning inserts on the machinability and surface characteristics of Al–7Si and Al–7Si–2.5Cu cast alloys were investigated and the following conclusions could be drawn:
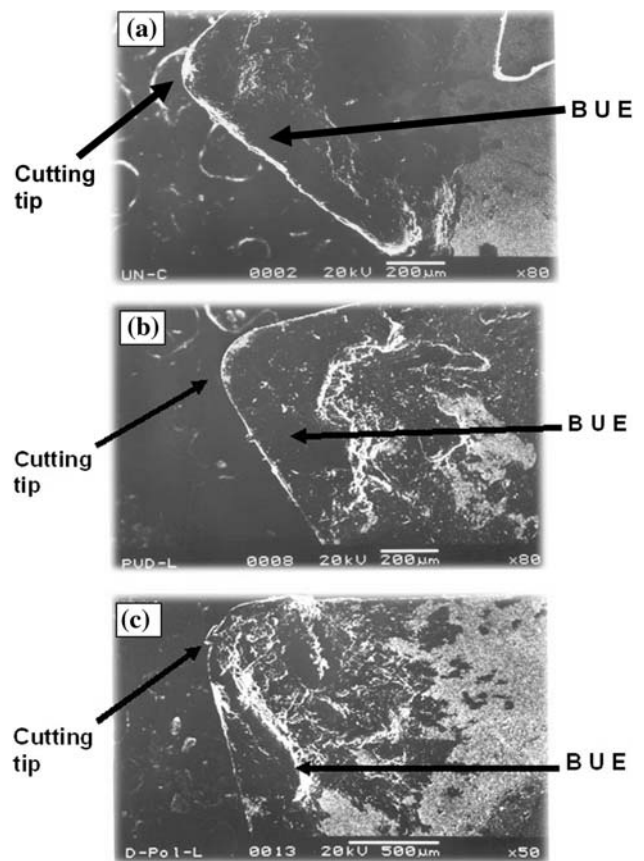
1. Combined addition of grain refiner and modifier (Al–1Ti–3B + Sr) to Al–7Si–2.5Cu cast alloy shows
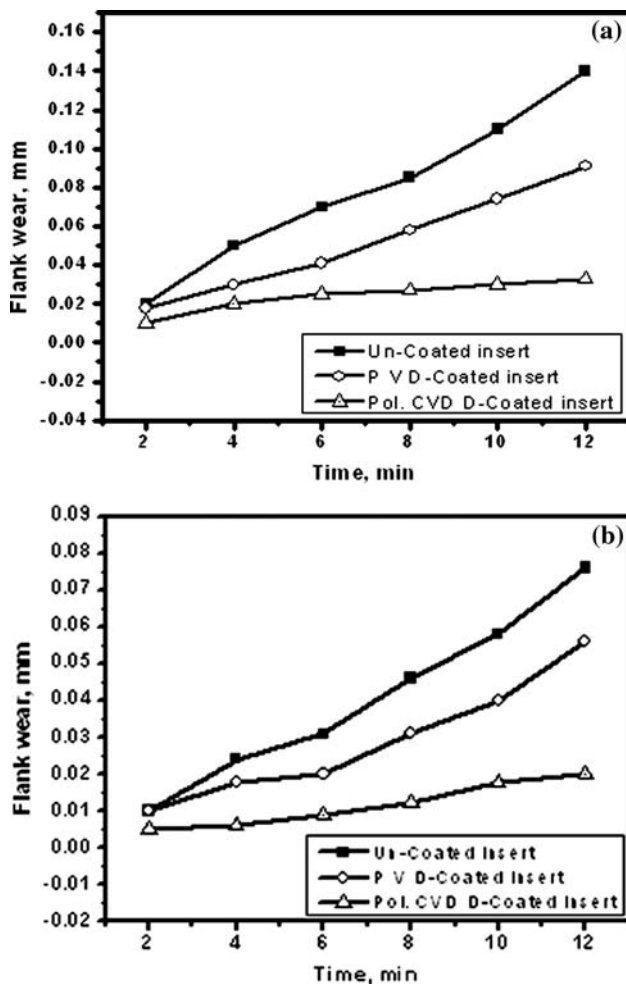
Fig. 8 Flank wears in (**a**) Machining of Al–7Si alloy and (**b**) Machining of Al–7Si–2.5 Cu–0.02 Sr–lM13 cast alloy

Fig. 9 SEM micrograph of the cutting tip after machining of Al–7Si alloy. (**a**) Un-coated insert (**b**) PVD coated insert (**c**) Polished CVD diamond-coated insert

remarkably low level of cutting forces and improved surface finish when compared with untreated alloys.

2. The measurements performed confirmed that the principal cutting forces (P_z and P_x) are mainly influenced by the sizes of the soft and eutectic constituents in the alloys.

3. The surface quality after turning was established by the measurement of roughness of the new surface formed. Average roughness R_a and R_z increased with an increase in the sizes of the soft and eutectic constituents in the alloys.

4. The performance of the polished CVD diamond coated insert (in comparison to PVD and uncoated inserts) in dry machining of Al–Si alloys was remarkable in that the cutting forces and the work piece surface roughness were significantly low.

5. The tendency for material build-up at the cutting edge is reduced when polished CVD diamond-coated insert is used.

6. Polished CVD diamond-coated insert shows very small steady wear without flaking of the diamond film in machining hypoeutectic Al–Si alloys.

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