# Surface integrity of FC300 cast iron when machined with TiAlN ball end mill

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**ABSTRACT** – This paper presents the surface integrity of FC300 gray cast iron when machined with TiAlN Ball end mill. Machining trials were performed using CNC variaxis machine in dry condition at the cutting speeds of 66-99 m/min, feed rate of 5000 mm/min and depth of cut of 0.1 mm. The results shows that the surface roughness decreased as the cutting speed increased from 66 m/min to 88 m/min. Smooth and shiny surface profile appeared at the lower cutting speed of 66 m/min due to effect of lubrication layer that form from the small fragmented graphite flakes. When the cutting speed increased to 99 m/min, surface profile appeared with smeared and large graphite flaking probably due to higher rotational impact from the cutting tool.

## 1. INTRODUCTION

Metal stamping is a process where a sheet metal is stamped inside a closed die to form the required shape. Inside the die enclosure, the metal sheet was pressed, stretched or elongated according to the curvy design of the upper and lower dies. For accurate stamped product, the surface profile of the die must be as fine as possible to provide low friction of material sliding during stamping process [1].

Many dies available in the application of metal stamping. Among them, FC300 gray cast iron considered among most frequently used. FC300 is a ferrous metal which is less ductile, less toughness and tensile strength as compared to the steel [2]. Therefore, the die made from FC300 normally applied to stamp thin and medium size of car components such as doors, bonnet, fenders and roof. FC300 normally supplied in cast condition before machined in various shapes and patterns. Typically, between 50 to 80% of the workpiece weight is machined into a component. The die is then further polished manually in order to get a final surface finish.

Since the final die surface being prepared from the manual polishing technique, the evaluation of the surface quality examined by touch sensitivity by operators. If the cutting parameters applied correctly, the surface finish after machining should be ready in fine conditions. Hence, the operator may spend minimum polishing time to finish the die. In contrast, the operator may require longer polishing time if the surface finish not adequately prepared. Lack of documentation to observe the surface of die right after machining resulting the characteristics that occurred along machined surface still not well understood.

This research presents surface integrity of FC300 gray cast iron when machined with TiAlN coated carbide ball end mill. Series of machining trials were performed with the cutting conditions were selected based on the similar situation at industry. For each machining trial, surface roughness was evaluated to correlate with the effect on cutting parameters. Further observation through scanning electron microscope was employed to examine the damage that occurred along machined surface.

## 2. METHODOLOGY

FC300 gray cast iron was prepared within the size of 80mm x 50mm x 15mm (width x length x thickness) as shown in Figure 1(a). The cutting tool selected was SRFT 30 VP15TF TiAlN coated ball end mill as showen in Figure 1(b). The cutting speeds were set at 66 m/min to 99 m/min with constant 5000 mm/min feed rate and 0.1 mm depth of cut. The machining trials was set by using DECKEL MAHO DMU 60 monoBLOCK, high-speed CNC milling machine as shown in Figure 2. To monitor the morphology of surface profile, scanning electron microscope was employed to observe the area that demonstrate interested phenomena that related to the machining characteristics.

Figure 1 (a) FC300 gray cast iron and (b) SRFT 30 VP15TF TiAlN coated ball end mill.

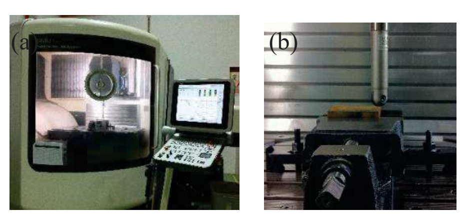

Figure 2 (a) DECKEL MAHO DMU 60 milling machine and (b) machining setup.

## 3. RESULTS AND DISCUSSION

Figure 3 shows the results of surface roughness with varying cutting speeds. The graph generally shows decline of surface roughness as cutting speed increased, especially from 66 m/min to 88 m/min. However, as the cutting speed increased to 99 m/min, the surface roughness started to deteriorate up to 0.69µm. The surface roughness generally increased as the cutting time increased due to tool wear.

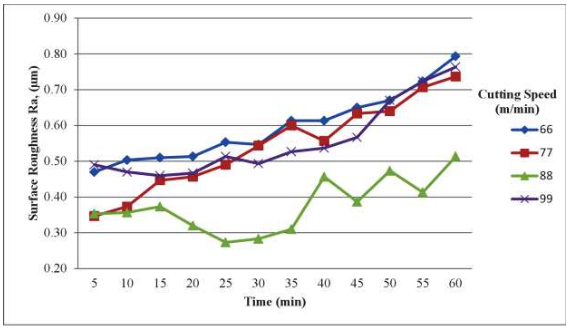


Figure 3 Surface roughness against cutting time at a feed rate 5000 mm/min.

Figure 4 shows some of surface profile that occurred during machining FC300 at various cutting condition. At a lower cutting speed of 66 m/min, the surface profile looks smoother and shiny with less surface damage. As the cutting speed increased to 88 m/min, the high repetition movement between the nose radius and workpiece material, generated more sliding contact and frictions, apparently generated high cutting temperature. As the cutting temperature increased, phenomenon such as graphitization of FC300 occurred. Graphitization is formed when the composition of carbon and silicon are mixed and produced a structure hat called graphite flake [3]. During machining, graphite flake can be pulled out by the shearing force from cutting tool and formed small fragmented particle debris. This fragmented debris can trapped between cutting tool and workpiece and formed a film formation when reacted with high temperature. Such film layer can react as a lubricant to protect the machined surface from thermal effect and frictions. This resulting better surface finish under parameters investigated.

As the cutting speed increased to 99 m/min, higher cutting speed that generated at the contact interfaces providing faster chip velocity which slides away the graphite debris. This restricting the access of fragmented debris to the contact interfaces, hence unable to provide protective layer to the machined surface. In addition, higher shearing force from rotational cutting tool may create a larger graphite pull out, leading to significant surface smearing along the machined surface [4]. Higher shearing force also facilitate more friction, resulting in early worn cutting tool. Machined surface tends to deteriorate due to inherent rubbing from worn cutting tool.

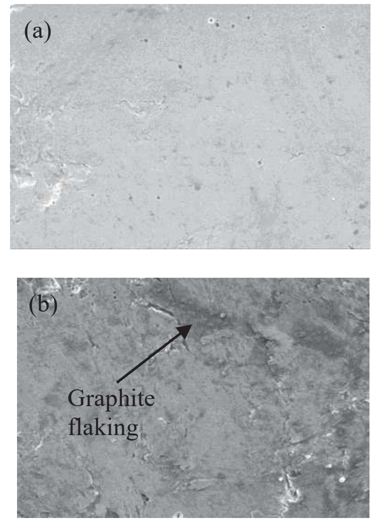


Figure 4 (a) Surface profile at 66 m/min and (b) surface profile at 99 m/min.

## 4. CONCLUSION

From the surface integrity of FC300 assessments, the surface roughness decreased as the cutting speed increased from 66 m/min to 88 m/min. At the lower cutting speed, small pull out graphitization particles that trap between cutting tool and workpiece provided lubrication when react with heat. This consequently facilitate better surface finish with smooth and shiny appearance. The surface roughness however demonstrated higher value of when cutting speed increased to 99 m/min. Higher shearing force from rotational cutting tool may promote early tool wear and create a larger graphite pull out, leading to significant surface smearing along the machined surface.

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