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# Analyses of roughness, forces and wear in turning gray cast iron

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## ABSTRACT

**Purpose:** Purpose of this research was to analyze the surface roughness, cutting tool forces and tool wear in machining casted gray iron.

**Design/methodology/approach:** The methodology adopted was turning process from other machining process. The turning is the widely employed manufacturing process. The tests were conducted by designing various cutting speed, feed and a constant depth of cut. In turning casted gray iron, flank wear, crater wear and built up edge are the common phenomenon.

**Findings:** from the tests were the formation of flank wear, crater wear while machining the casted gray iron. Further research is possible in the direction measuring the residual stresses and the vibration of the cutting tool.

**Research limitations/implications:** There are some limitations in carrying the tests namely vibration of the tool, tool wear and length of work piece. The constraint in measuring depth of crater wear was due to non availability of technology devices and equipments. However, the length of crater wear was measured for analyzes.

**Originality/value:** The value of the work lies in the utility of the results obtained to researchers and users of the casted gray iron material for their components.

**Keywords:** Machining; Casting; Surface roughness; Technology devices and equipment

## 1. Introduction

The challenge of modern machining industries is mainly focused on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact. Cast iron has been used in large quantities for years because of desirable properties as good castability, good machinability and low cost. This is brittle, weak and it is not malleable. This is soft in nature and readily machinable. Charles wick reported that the hardness and abrasion resistance of CBN tool is second only to diamond [2]. Wear resistance of PCBN tools is up to 50 times that of uncoated tungsten carbide tools , 30 or more times that of coated carbide tools and up to 25 times that of ceramic tool, but only about one-half that of diamond tools. The wear pattern of CBN cutting inserts is characterized by crater and flank wear, as well as small cracks on the edge, depending upon the cutting conditions [3]. Konig et al [4] reported that the wear of CBN tools in machining of hardened gray cast iron is very similar to that of ceramics. Narutaki et al [5] indicated that in case of turning steels less than 44 HRC with low CBN tools, the flank wear land is almost constant and smaller than that of high in CBN tools. They also reported that low CBN tools show excellent performance in machining hardened steels and case hardened steels that do not contain much ultra hard carbide.

## 2. Experiments

### 2.1. Work piece

The chemical composition of the material is shown in the table1. The work piece was cut from a 50 mm diameter bar having 1000 mm length to 300 mm length. The work piece was centered on both sides to accommodate and skin turned. The both ends of the work piece were divided in to four segments to measure the surface roughness and then arrive at the average. The surface roughness and tool wear was immediately measured by Mitutoyo surf test and Olympus tools maker's microscope. The SEM was used to measure micro structure of the various tool wear.

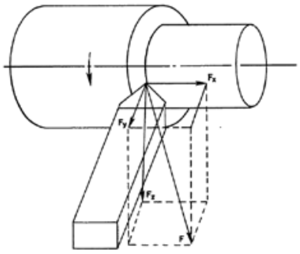

Fig.1. 3 Cutting forces acting on a tool.

The equipments used in the experiments are shown in the Table 1. The Table 2 shows the operating parameters. Depth cut 0.5 mm was kept as constant through out the tests and by varying the cutting speed and feed tests was carried out.

Table 1.
Shows the list of equipments used

| |
|---|
| Harrison Alpha 400 N.C. Lathe |
| Olympus Tool Maker's Microscope STM 6 |
| Mitutoyo Surface Roughness –SJ-301 |
| Scanning Electron Microscope-Joel- JSM – 6380 L.V. |
| Kistler Force measurement Type 9265B, Multi channel charge amplifier Type -5019A and data acquisition System |

Table 2.
Shows the operating parameters

| | |
|---|---|
| Cutting speed m / min. | 35, 45, 100,135 |
| Feed mm / rev. | 0.08, 0.10, 0.125, 0.16 |
| Constant depth of cut (DOC) mm | 0.50 |
| Lubrication | None |

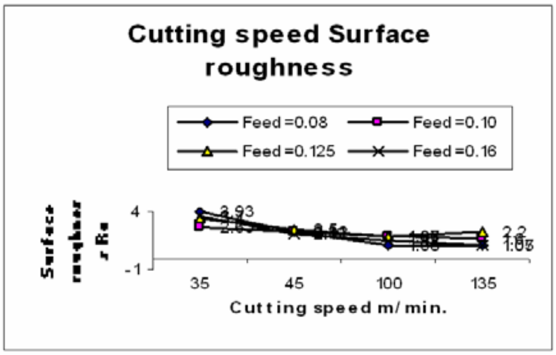


Fig. 2. Shows Cutting speed Vs Roughness at 35, 45, 100 and 135 cutting speeds

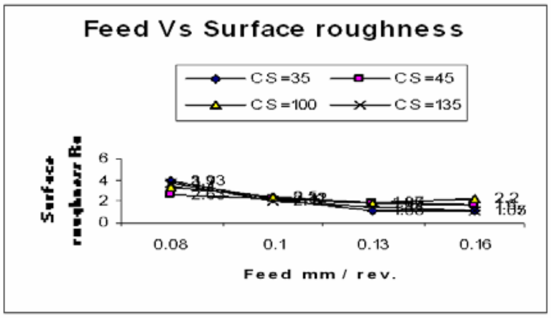


Fig. 3. Shows feed Vs roughness at 0.08, 0.10,0.125 and 0.16 feeds.

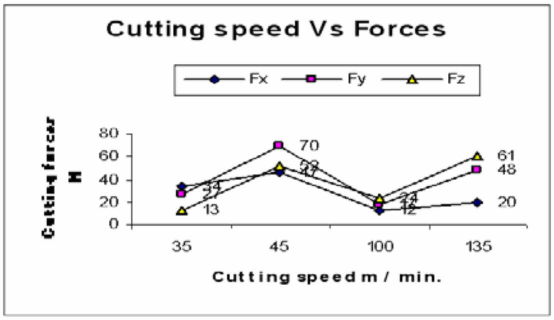


Fig. 4. Cutting speed Vs Forces at 0.08 feed.

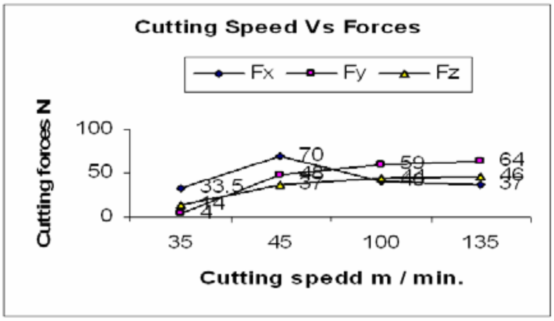


Fig. 5. Cutting speed Vs Forces at 0.10 feed.

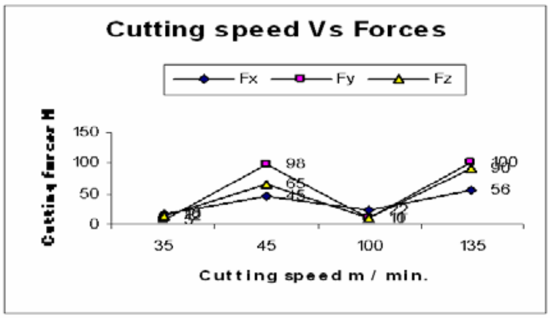


Fig.6. Cutting speed Vs Forces at 0.125 feed.

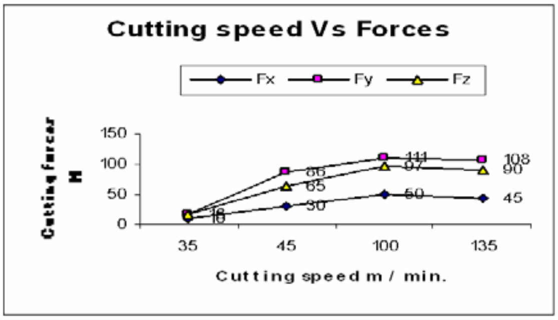


Fig.7. Cutting speed Vs Forces at 0.16 feed.

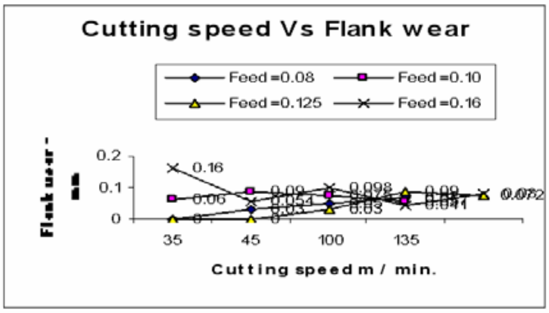


Fig.8. Cutting speed Vs flank wear.

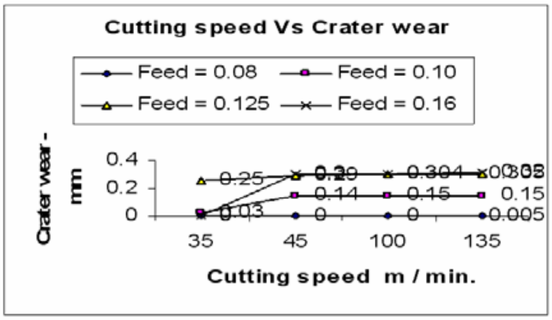


Fig.9. Cutting speed Vs Crater wear.

## 3. Results and discussion

### 3.1. Surface roughness

The surface roughness of the cast iron surface is discussed through figures 2-3. Surface finish is one of the most stringent requirement placed on finishing operations, its degradation is usually due to the tool wear [6]. The lubrication –cooling does not significantly affect tool wear, where as wet cutting produces worst surface finish [7]. During the experiments it was determined by increasing the cutting speed and feed rate, the Ra value was encouraging and reduced. At 35 m / min cutting speed having feed rate of 0.08 mm / rev the roughness value was 3.93 µm and reduced to 2.92 µm. At 135 m / min cutting speed and feed of 0.16 mm / rev, Ra value obtained was 1.03 µm and minimum value obtained during the tests.

E.O.Ezugwu and S.H.Tang reported that it is possible to get the surface finish improved and surface damage when machining materials with round inserts [8].

### 3.2. Cutting forces

There are three cutting forces which are acting on a single point tool and shown in figure1. The Fx is the feed force which is acting on the X direction, the Fy is cutting force acting of on Y direction and Fz is the radial force acting on the Z direction. The cutting forces were measured using 3 component dynamometer (Kistler, Type 9265B, a multi channel charge amplifier type 5019Aand a data acquisition system). The figures 4-7 show the various cutting forces measured during turning. The feed force Fx was low when cutting at feed of 0.08 and 0.10 where as the cutting force Fy low at the start and increased when the cutting speed increased. However, the radial force was low in all the experiments. The vibration will be more in the direction of cutting force Fy than that in the radial direction. Shintani et al [9] With the increase of feed or depth of cut, vibration increase the tool wear When machining at feed of 0.125 mm/ rev. the cutting force Fy was low and almost equal to Fx and Fz and gives better results at higher cutting speed. These are shown in the figure 6. During machining at 0.16 mm / rev feed force Fx was high and shows increasing trend. Ulvi Seker and Hasan Hasirci [10] stated that cutting forces remained at about 20 % when machining austempered ductile irons and considerable improvement in surface quality.

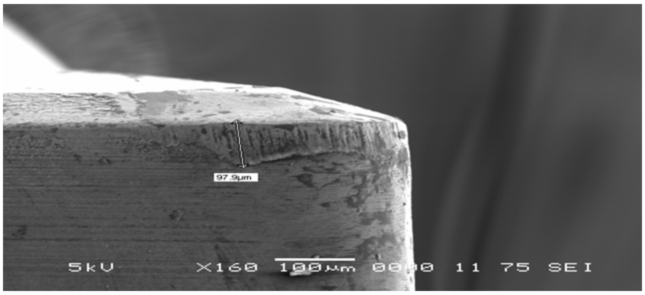


Fig 10 shows the flank wear and nose combined.

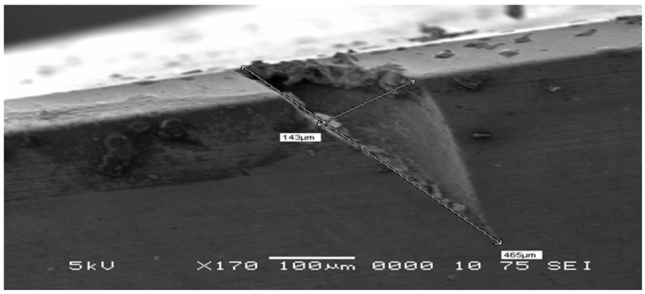


Fig.11. SEM view micro notch wear.

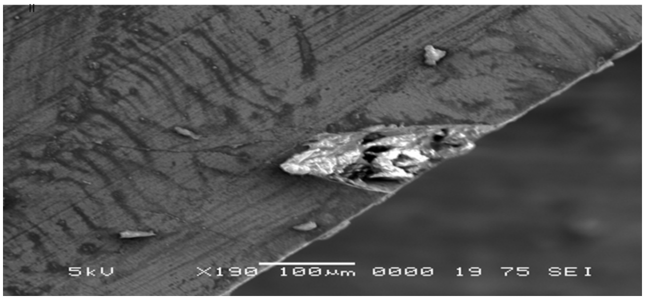


Fig.12. SEM view on micro cracks and chipping.

### 3.3. Tool wear

Konig et al [4] reported that the wear of CBN tools in machining hardened gray cast iron is similar to that of ceramics. They reported that CBN tools have poor thermal shock and that intermittent coolant applications resulted in rapid tool wear. The figure 8 cutting speed Vs flank wear and figure 9 shows cutting speed Vs Crater wear. Flank wear is produced mainly by the abrasion of carbides, sand inclusions and harder chilled skins. Hard particles plough grooves into the cutting tool material [1]. The crater wear occurs when hard particles grind the tool material off the chip face, or when diffusion between the chip face and tool material occurs. Excessive notch wear affects surface finish and weakens the cutting edge. The flank wear is a widely used criterion for evaluating tool life because of its importance in most applications [11]. The flank wear in this experiment was not present when machining at 35 m / min cutting speed and at 0.08 mm / rev feed, then increased to 72.3µm at 135 m / min speed having same feed rate. But flank wear 150 µm observed at speed 35 m / min having feed of 0.16 mm /rev. In other experiments, the flank wear was less than 150 µm. The figure 10 show flank wear and nose wear combined. The crater wear was as low as 5 µm and increased to 280µm. The notch wear occurred during experiment and shown in the figure 11. The notch wear may be possible while machining with inclusions and other surface particles [1] and at end of the experiment, micro cracks were noticed. The micro crack and chipping occurred shown in the figure 12. Shintani et al [10] reported that initial wear stage; frequent chipping of the cutting edge strongly influenced the tool life. The hardness value of surface layer was also increased by prolonged machining [8]. Gastel et al [12] found that two main effects are responsible for tool wear, namely oxidation of the tool and interdiffusion of the constituting elements between tool and compacted graphite iron.

## 4. Conclusions

### 4.1. The following conclusions are arrived from this experiment

The surface roughness from various tests shows a decrease in value at higher cutting speed and feed rate. The cutting tool has produced micro chipping and has not affected the surface finish Micro cracks were obtained from the edge of micro chipping. The notch wear might have been caused due to hard particles and other impurities present in the material. There is no formation of built- up- edge that is usually occurring during machining cast iron at lower cutting speed.

Further work can be carried in the direction of measuring the residual stresses by turning and formation of built- up edge under high speed machining.

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