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A Review on the Effect of Process Parameters on Different Output Parameters During Machining of Several Materials

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Abstract

It is important to view machining, as well as all manufacturing operations, as a system consisting of the workpiece, the tool and the machine. Machinability is the relative susceptibility of a material to the machining process. The ease with which a metal can be machined is one of the principle factors affecting a product's utility, quality cost. The usefulness of a means to predict machinability is obvious. Depending on the application, machinability may be seen in terms of tool wear rate, surface roughness, hardness, chip shape and several other benchmarks. In this paper an attempt has been made to consolidate some of the aspects of output parameters during machining of different materials.

Keywords: Machinability, Tool wear, Surface roughness, Hardness, Chip Shape.

Introduction

The cost of machining amounts to more than 20% of the value of manufactured products in industrialized countries. It is therefore imperative to investigate the machinability behavior of different materials by changing the machining parameters to obtain optimal results. The machinability of a material provides an indication of its adaptability to manufacturing by a machining process. Good machinability is defined as an optimal combination of factors such as low cutting force, good surface finish, low tool tip temperature, and low power consumption. Metal cutting is one of the most significant manufacturing processes in the area of material removal [1]. Black [2] defined metal cutting as the removal of metal chips from a work piece in order to obtain a finished product with desired attributes of size, shape, and surface roughness.

Machinability of materials plays an important role in its selection of material for commercial exploitation. In general, more than 80% of manufactured parts are machined before they are ready for use [3] (Pathak and Tiwari, 1995). Thus, machinability of a material determines its economy in various applications. One or more of the following criteria may be used to assess machinability of a material. However, relative importance of these parameters for evaluation of machinability varies according to the requirement [4] (Trent and Wright, 2000; Dwivedi, 2000a).

Tool life: The amount of material removed by a tool, under standardized condition, before tool performance becomes unacceptable or tool is worn out by a standard amount.

Cutting force: The forces acting on tool during the machining under specified condition.
Surface finish: The surface finish achieved under specified cutting condition.
Chip: The chip shape and size produced under standardized condition as this can affect chip disposability.

Machining requires attention to many details for a work piece to meet the specifications set out in the engineering drawings or blueprints. Besides the obvious problems related to correct dimensions, there is the problem of achieving the correct finish or surface smoothness on the work piece. Machining is a part of the manufacturing of many metal products, but it can also be used on materials such as wood, plastic, ceramics, and composites therefore the present paper summarizes the studies conducted by several investigators about the output parameters during machining of different materials.

Process Parameters

Cutting speed (V) is the largest of the relative velocities of cutting tool or work piece. In turning (Fig.1), it is the speed of the work piece while in drilling and milling, it is the speed of the cutting tool. In turning, it is given by the surface speed of the work piece, V = p D1N where D1 is the diameter of the work piece.

Depth of cut (d) is the distance the cutting tool penetrates into the work piece. In turning, for example, it is given by: d = (D1-D2)/2

2.3Feed (f) is movement of the tool per revolution. In turning, it is the distance the tool travels in one revolution of the work piece and is given the units of mm/rev or in./rev.

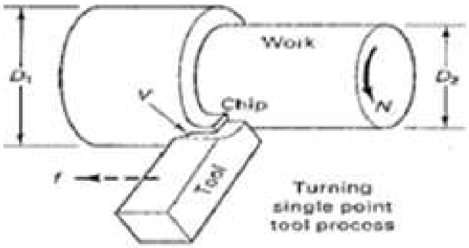


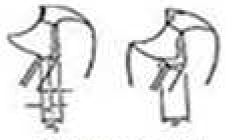
Fig.1 shows Process parameters during machining

Review on Different Output Parameters

Tool Wear

Tool wear describes the gradual failure of cutting tools due to regular operation. It is a term often There are basically two types of wear and they include:-

- **Flank wear** in which the portion of the tool in contact with the finished part erodes. Can be described using the Tool Life Expectancy equation.
- **Crater wear** in which contact with chips erodes the rake face. This is somewhat normal for tool wear, and does not seriously degrade the use of a tool until it becomes serious enough to cause a cutting edge failure.



Outer corner wear

Flank wear

Margin wear

Crater wear

Chisel wear

Chipping wear

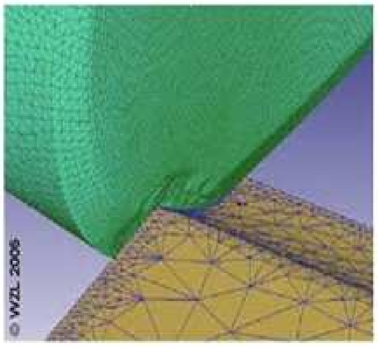


Fig.3 shows SEM image of tool wear

Some General effects of tool wear include:

- Increased cutting forces.
- Increased cutting temperatures
- Poor surface finish
- Decreased accuracy of finished part
- May lead to tool breakage

Reduction in tool wear can be accomplished by using lubricants and coolants while machining. These reduce friction and temperatures, thus reducing the tool wear.

Tool Life Expectancy

The **Taylor's Equation for Tool Life Expectancy** [5] provides a good approximation.

$$V_cT^n = C$$

A more general form of the equation is

$$V_cT^n \times D^xS^y = C$$

Where

- V_c=cutting speed
- T=tool life
- D=depth of cut
- S=feed rate
- x and y are determined experimentally

- n and C are constants found by experimentation or published data; they are properties of tool material, work piece and feed rate.

Caroline J.E. Andrewes [6] reveled that a faster rate of flank wear on the CVD diamond insert than on the PCD insert. The faster wear rate of the CVD diamond insert can be reduced by securing stronger adhesion between the diamond coating and the carbide substrate. Their experiment was carried out on a Baxter CNC lathe by using work piece material. Duralcan composite F3D.20S, which was essentially an A380 aluminum alloy matrix reinforced. They found that crater wear may not be a main concern to the diamond inserts due to the very low coefficient of friction and the high thermal conductivity of diamonds. Xiaoping Li [7] concluded that the main mechanism of tool wear in cutting of Al-SiC MMC using tungsten carbide is abrasion, including two-body and three-body abrasion. The abrasive wear of the tool is accelerated when the percentage of the reinforcement in the MMC exceeds a critical value. All the cutting tests were performed on a Leblond Makino15 Inch Regal Precision Lathe. In the cutting tests for tool wear mechanisms, coated carbide inserts (CNMG N308) with a tool holder of 6ºrake angle and 95ºapproach angle was used.H.A. Kishawy [8] reveled that due to the high content of silicon in the A356 alloy, the main wear mechanisms encountered were abrasive wear at the tool tip region, and adhesive wear on the flank and rake faces away from the tool tip. The degree of the wear severity is function of both insert coating and coolant environment. Kýlýc¸kap [9] reveled that increasing cutting speed produced a faster tool wear. When cutting speed increased from 50 to 150 m/min, tool wear value doubled. The tool wear mechanism was abrasion. After conducting their experiment they had observed that tool wear occurred on the flank face of the cutting tool. S.Kannan[10] concluded that the tool wear was accelerated mainly due to abrasive wear mechanisms, it is desired to have a cutting fluid that can form a lubricating layer/film and can reduce the friction effects at the flank contact region. Their objective was to investigate the processes occurring in the narrow contact zone between the cutting tool and the work piece. The different temperature zones were shown as in Fig-4.

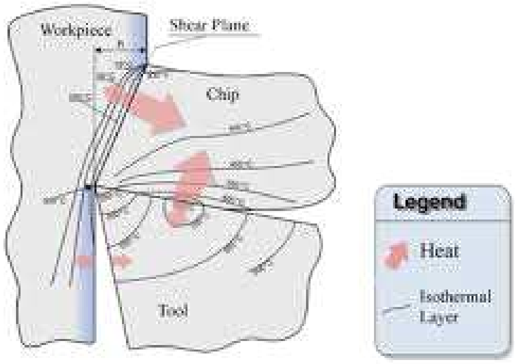


Figure-4 Shows Different temperature Zones at the time of Chip Formation.

Kremer [11] concluded by experimenting on aluminum alloy reinforced with different level of particles (0, 15, 25 and 35% of SiCp). Airborne particles were measured in situ with a spectrometer and sorted in 15 size channels each six seconds that PCD tools had higher significant wear resistance than CVD (PCD tools were three times more resistant than the best CVD tool). The good resistance to abrasive wear of PCD tools increased the importance of tool chip interface on dust emission. Friction at contact area chip/rake face seems to be the dominant dust generator with PCD tools. Their objective was to investigate their wear resistance and their impact on particle generation. J. Paulo Davim [12] concluded that the flank wear was the most important type wear observed in diamond cutting tools. This kind of wear determines the tool life. The mechanism of abrasive wear was predominant in machining these composites. The CVD diamond inserts have quickly reached (4.5 min) the credible flank wear imposed.Saad Hameed Najem[13] reveled that addition of B_4C as reinforcement to the master alloy produces higher tool wear. When machining the master alloy and MMCs with high speed causes rapid tool wear due to generation of high temperature in the machining interface. The rate of flank wear was high when machining with a higher depth of cut. An increase in feed rate also increased the flank wear. A.K.Sahoo [14] concluded that the flank wear evolution with increase of feed was steady. Flank wear accelerated at higher cutting speed (180 m/min) compared to low cutting speed (60 m/min). At higher parametric ranges, flank wear was higher because of abrasive reinforcement element but within recommended limit of 0.3mm. Abrasion was found to be the dominant wear mechanism.

Surface Roughness

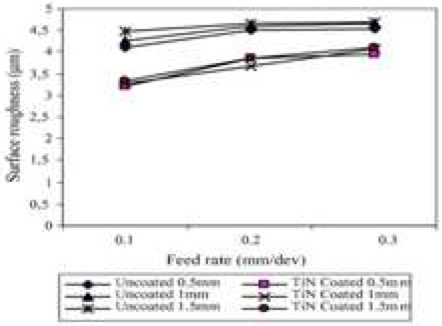
Surface roughness, often shortened to roughness, is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion. Although roughness is often undesirable, it is difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase exponentially its manufacturing costs. Roughness is typically measured in "RMS" micro inches and is often only measured by manual comparison against a "surface roughness comparator", a sample of known surface roughnesses.The roughness average, R_{a}, is the most widely used one dimensional roughness parameter.

Parameter	**Description**	**Formula**
R_a, R_{aa}, R_{yni}	Arithmetic average of absolute value	$R_{\mathrm{a}} = \frac{1}{n}\sum_{i=1}^{n} \lvert y_i \rvert$
R_q, R_{RMS}	Root mean squared	$R_{\mathrm{q}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} y_i^2}$
R_v	Maximum valley depth	$R_{\mathrm{v}} = \min_i y_i$
R_p	Maximum peak height	$R_{\mathrm{p}} = \max_i y_i$
R_t	Maximum Height of the Profile	$R_{\mathrm{t}} = R_{\mathrm{p}} - R_{\mathrm{v}}$
R_{sk}	Skeweness	$R_{\mathrm{sk}} = \frac{1}{nR_{\mathrm{q}}^3}\sum_{i=1}^{n} y_i^3$
R_{ku}	Kurtosis	$R_{\mathrm{ku}} = \frac{1}{nR_{\mathrm{q}}^4}\sum_{i=1}^{n} y_i^4$
R_{zDIN}, R_{tm}	Average distance between the highest peak and lowest valley in each sampling length, ASME Y14.36M - 1996 Surface Texture Symbols	$R_{\mathrm{zDIN}} = \frac{1}{s}\sum_{i=1}^{s} R_{\mathrm{t}i}$, where s is the number of sampling lengths, and $R_{\mathrm{t}i}$ is R_{t} for the i^{th} sampling length.
R_{zJIS}	Japanese Industrial Standard for R_{z}, based on the five highest peaks and lowest valleys over the entire sampling length.	$R_{\mathrm{zJIS}} = \frac{1}{5}\sum_{i=1}^{5} R_{\mathrm{p}i} -$, where $R_{\mathrm{p}i}$ and $R_{\mathrm{v}i}$ are the i^{th} highest peak, and lowest valley respectively.

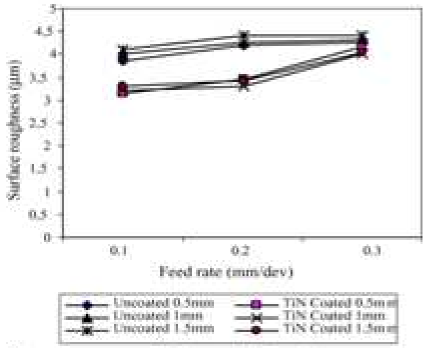
Practical effects

In most cases, roughness is considered to be detrimental to part performance. As a consequence, most manufacturing prints establish an upper limit on roughness, but not a lower limit. Roughness is often closely related to the friction and wear properties of a surface. A surface with a large R_a value, or a positive R_{sk}, will usually have high friction and wear quickly. The peaks in the roughness profile are not always the points of contact. The form and waviness must also be considered.

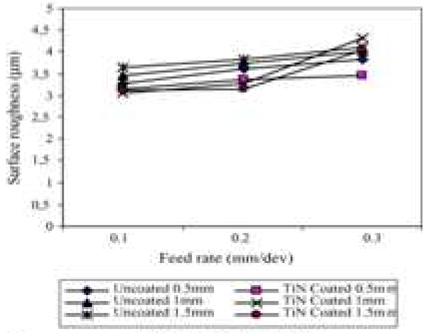
Manna [15] reveled that high speed, low feed and low depth of cut are recommended for better surface finish. Experimental results showed that both the surface roughness heights *R*a and *R*t increase by increasing feed. From their test results from experiment they concluded that when feed is tripled, i.e. from 0.25 to 0.75 mm/rev the value of surface roughness height *R*a increases by 40% whereas when cutting speed is tripled, i.e. from 60 to 180 m/min the value of surface roughness height *R*a decreased by 46%. Hence, it indicated that the cutting speed and feed has equal influence on the surface finish if both are increased simultaneously. Kýlýc¸kap [16] concluded after their experimental study on MMC which was carried out in MKE brand lathe machine (6.5kW power) by taking cutting tool was titanium carbide K10 grade (ISO code), that Surface roughness again mostly affected with cutting speed. Higher cutting speed produced better surface finish. The influences of cutting speed, feed rate, and depth of cut, uncoated and coated cutting tool were determined on tool wear and surface finish. The experimental feed rate was an effective machining parameter on surface roughness. Higher feed rates produced poor surface quality. They plotted the graph between input parameters feed vers surface roughness.



(a) Cutting speed : 50 m/min



(b) Cutting speed : 100 m/min

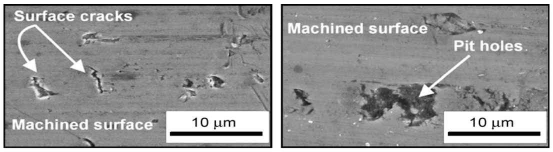


(c) Cutting speed : 150 m/min

(Figures 5 (a), 5 (b), 5(c) shows the effect of feed rates on surface roughness)

Yusuf Ozcatalbas [17] reveled that at high cutting speeds that improves the quality of surface roughness.

Mohammed T. Hayajne [18] objective was to develop a better understanding of the effects of spindle speed, cutting feed rate and depth of cut on the surface roughness. They experimented on a Bridgeport end-milling machine. Eight ¾-inch four-flute high-speed steel cutters were used. The cutting parameters were set as: four levels of spindle speed (750, 1000, 1250, 1500 rpm), seven levels of feed rate (150, 225, 300, 375, 450, 525, 600 mm/min), and three levels of depth of cut (0.25, 0.75, 1.25 mm). At last they conclude that the factors like spindle speed, feed rate, depth of cut affect the surface roughness.Y.F. Ge[19] revealed that the issue of the effect of cutting parameters, cooling conditions, cutting tool material and geometries, work piece material and reinforcement on the type of surface/subsurface damage during diamond turning of SiCp/Al composites. At last they achieved the Surface roughness *R*a = 20-30nm can be attained using SPDT or PCD tools. Surface quality debased with increasing feed rate or using of high volume fraction material. Dry cutting would deteriorate the surface finish.S. Kannan[20] with the turning test which was carried out on A356 MMC using coated tungsten carbide cutting tools on a 10HP standard modern lathe concluded that the surface roughness was slightly deteriorated due to the application of cutting fluid. This was largely due to the effective flushing away of the partially or completely debonded particulates, thus, forming large pit holes and voids. The machining forces were collected using a three component piezoelectric dynamometer (KistlerTM type 9251A). The surface roughness measurements were conducted using a Mitutoyo SJ-201 surface roughness tester.



Dry cutting Wet cutting

Figure-6 shows Influence of coolant on the nature of defects on the machined surface (7075 MMC, orthogonal cutting, *V*= 60m/min,*h* = 0.1mm, *b* = 3 mm).

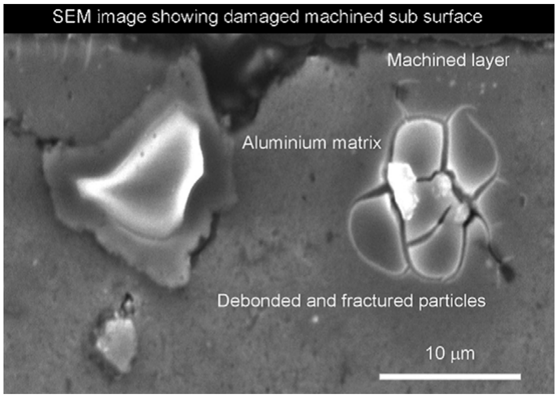


Fig.7 Shows SEM Image showing Damaged machined Sur.

Effect of wet cutting on integrity of 7075 MMC machined subsurface (orthogonal cutting, V= 60m/min, h = 0.1mm, b = 3mm, coated carbide tool).

A.Pramanik[21]concluded that at low feeds, the surface roughness of the MMC was controlled by particle fracture or pull out but at higher feeds, it was controlled by the feed. On the other hand, surface roughness of the non-reinforced alloy was mainly controlled by the feed.Rabindra Behera [22]reveled that that the surface roughness of MMCs increased on increasing the weight percentage of SiCp in the matrix metal and it increases on increasing the depth of cut at constant feed rate and different cutting speed.

A.K.Sahoo[23]concluded that Surface roughness increases with increase of feed but at slower rate upto 0.1mm/rev.At 0.15mm/rev feed, the surface quality deteriorated rapidly.

Hardness

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behavior of solid materials under force is complex; therefore, there are different measurements of hardness: scratch hardness, indentation hardness, and rebound hardness. Hardness is dependent on ductility, elastic stiffness, plasticity, strain, strength, toughness,visco elasticity, and viscosity.

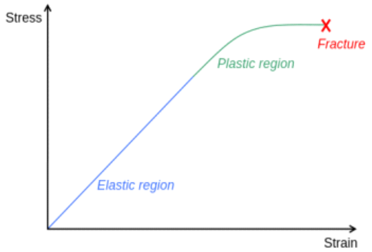


Figure-8 shows Stress and strain curve

S. Kennan's [24] objective was to determine the effects of process parameters on the matrix hardness alteration on the machined surface and Sub surface layer. The different aluminum matrices along with the levels of particulate volume fraction and average sizes were used in their experiments. Cutting tests were performed on a 10HP standard lathe using uncoated tungsten carbide cutting tools with rake angle of 0 degree and Clearance angle of 7degree. The cutting tools were ultrasonically cleaned in 10% NaOH and then thoroughly in acetone. After conducting experiment they concluded that the initial matrix hardness greatly influences the extent of subsurface damage. The lower the matrix micro hardness, the higher will be the depth of plastic deformation zone beneath the machined layer. Application of coolant to some extent affects the matrix micro hardness at the tested cutting conditions. Y. Zedan[25]their objective was to determine the Specimens were cut from the waffle-plate casting having the overall dimensions of 300mm length, 175mm width and 30mm thickness, with ribs approximately 25mm wide, separated by gaps of 16mm. Hardness measurements were carried out on the heat-treated samples using a Brinell hardness tester, employing a steel ball of 10mm diameter and a load of 500 kg applied for 30 s. Four blocks were used for each alloy condition. The reported hardness values in each case represent the average of at least 160 indentation readings, namely, 40 indentations per block, made on the top and bottom surfaces, as well as the sides of each waffle-plate casting block. They concluded that the addition of iron and manganese, which had originally been expected to reduce the tool edge build-up tendency through the abrasive action of hard inter metallic phases.

Chip Shape

In cutting and abrasive processes, the cutting edge penetrates into the work piece material, which is thus plastically deformed and slides off along the rake face of the cutting edge. This is called chip formation. Depending on the deformation behavior of the work piece material, there are different mechanisms of chip formation with either continuous or discontinuous chip flow.

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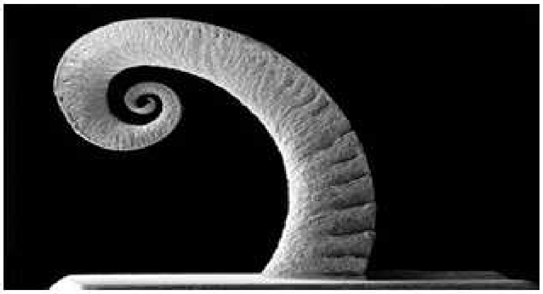
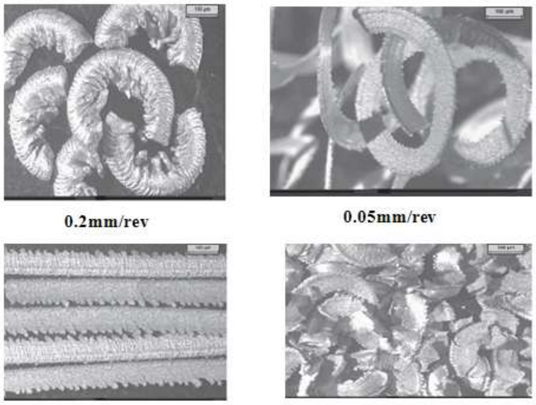


Fig.9 shows SEM photo graph of chip

D.K. Dwivedi [26] reveled that, Presence of hard and brittle coarse non-metallic silicon crystals in LM28 alloy acts as A.Pramanik [28] reveled that Chip breakability was found to improve due to the presence of the reinforcement particles in the MMC. Short chips were formed under almost all conditions. With the non-reinforced alloy chips of almost similar shape (long and unbroken) were formed for all cutting conditions. They experimented on a CNC Turning Centre, Mori- Seiki MT2000a1s2, using a bar turning process under dry conditions using specimens non- reinforced 6061 aluminium alloy and MMC. At different feed and constant speed they had taken different shapes of chip which shown in below figs.



0.2mm/rev

0.05mm/rev

0.1mm/rev

0.025mm/rev

Fig. 10 shows different shape of chips obtained at different feed

The change in form of chips from partially C-type to washer C type and spring type chips as the cutting speed increases (from 40 to 120mmin−1) is due to increased ductility of the work material because of the high machining temperature at higher cutting speed. Continuous and semi-continuous type a120mmin−1 cutting speed generates the chips but, in coarser reinforcement composites; the length and number of chip curls are lower than finer chips generated during machining. stress raiser and discontinuity in metallic matrix. Therefore, fracture of such hard and brittle silicon particles promotes formation of large number of small fragmented chips in machining of LM28 as compared to LM13 alloy. After their experiment they concluded that Melt treatment and heat treatment of LM13 alloy increased the average number of chips per gm due to increase in ductility of the alloy. LM28 alloy produced higher number of chips per gm than the LM13 alloy due to higher hardness and lower ductility of LM28 alloy compared to LM13 alloys.Uday A. Dabade [27] concluded that, the effect of change in cutting speed and feed rate is more dominant on physical form of the 0.05mmrev−1 reinforcement composites. This trend is more prominent especially in finer reinforcement composites.

Conclusion

The exhaustive literature survey presented above reveals that, extensive work has been reported to improve machining properties of different materials. This review presents the views, experimental results obtained and conclusions made over the years by numerous investigators in the field of machinability of several materials. A considerable amount of interest in Al-MMCs evinced by researchers from academics and industries has helped in conduction of various studies and has enriched our knowledge about the machining parameters like tool wear, surface roughness, hardness and chip shape etc.Cutting speed was the most influential machining parameter on tool wear. It increased tool wear with increasing cutting speed. Abrasion is found to be the dominant wear mechanism. Since the tool wear was accelerated mainly due to abrasive wear mechanisms, it is desired to have a cutting fluid that can form a lubricating layer/film and can reduce the friction effects at the flank contact region. As it was observed that addition of reinforcement to any materials changes its mechanical properties i.e material becomes harder so tool wear will be more in that case. Therefore the best increasing the weight percentage of SiCp in the matrix metal and it increases on increasing the depth of cut at constant feed rate. It was observed that at high cutting speed machining will minimize chip tool contact length and build-up edge formation, which reduce the cutting force and surface roughness. Feed is also an important machining parameters with affects the surface roughness. Generally solution to this problem is that we have use a tool which is harder than reinforced particle in order to reduce abrasive wear. Surface roughness increases with increase of feed. The surface roughness of different materials was found that with a very low feed the surface roughness of different materials were controlled by particle fracture or pull –out but at higher feeds, it was controlled by the feed. On the other hand, surface roughness of the non-reinforced alloy was mainly controlled by the feed. Sometime we use the cutting fluid to increase the cutting rate but the surface roughness was slightly deteriorated due to in effective flushing. Thus forming large pits holes and voids on work piece. The depth of subsurface plastic deformation and matrix micro hardness decrease with the application of coolant at the time of machining. The exhaustive literature survey presented above reveals that, extensive work has been reported to improve machining properties of different materials. This review presents the views, experimental results obtained and conclusions made over the years by numerous investigators in the field of machinability of several materials. A considerable amount of interest in Al-MMCs evinced by researchers from academics and industries has helped in conduction of various studies and has enriched our knowledge about the machining parameters like tool wear, surface roughness, hardness and chip shape etc.Cutting speed was the most influential machining parameter on tool wear. It increased tool wear with increasing cutting speed. Abrasion is found to be the dominant wear mechanism. Since the tool wear was accelerated mainly due to abrasive wear mechanisms, it is desired to have a cutting fluid that can form a lubricating layer/film and can reduce the friction effects at the flank contact region. As it was observed that addition of reinforcement to any materials changes its mechanical properties i.e material becomes harder so tool wear will be more in that case. Therefore the best increasing the weight percentage of SiCp in the matrix metal and it increases on increasing the depth of cut at constant feed rate. It was observed that at high cutting speed machining will minimize chip tool contact length and build-up edge formation, which reduce the cutting force and surface roughness. Feed is also an important machining parameters with affects the surface roughness. Generally solution to this problem is that we have use a tool which is harder than reinforced particle in order to reduce abrasive wear. Surface roughness increases with increase of feed. The surface roughness of different materials was found that with a very low feed the surface roughness of different materials were controlled by particle fracture or pull –out but at higher feeds, it was controlled by the feed. On the other hand, surface roughness of the non-reinforced alloy was mainly controlled by the feed. Sometime we use the cutting fluid to increase the cutting rate but the surface roughness was slightly deteriorated due to in effective flushing. Thus forming large pits holes and voids on work piece. The depth of subsurface plastic deformation and matrix micro hardness decrease with the application of coolant at the time of machining.

The length of chip and the number of chip curls increases with an increase in feed rate at given cutting speed and depth of cut. During finish turning operation, the coarser reinforcement particles themselves act as a chip breaker and produce both segmented and small curled chips and improve the machined surface roughness.

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