CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

Coated abrasive belt grinding is different from traditional machining of parts of identical materials. The difference is in the way of chip production, the order of specific cutting pressure encountered and surface integrity of machined parts. For better understanding, a detailed literature survey has been carried out. A resume of the same is presented in this chapter. The literature survey has been grouped into three subgroups as analysis of material, wear behavior of coated abrasives and evaluation of abrasive belt on different work pieces and coolants.

2.2 BELT WEAR, SURFACE FINISH AND MATERIAL REMOVAL PROCESS IN BELT GRINDING

Abrasive belt grinding is a common finishing process in the metal and wood working industries. Coated abrasive belts are used in the same speed range as bonded wheels, but they are not generally dressed when the abrasive becomes dull (Ernest et al 1990). The wide spread application of coated abrasive belts and long standing operating practices have led to different kinds of quality requirements. The abrasive belt machining technique is more significant for precision machining and finishing, also used for roughing. They have reported that the performance difference between sol gel alumina grain and fused grains, it was observed, similar trend on material
removal and belt wear for different workmaterials. Though the trend found to be same but the solgel grain gives more material removal, this is due more cutting points per grain. Precision grinding gives considerably lower material removal rates, but can engage large workpiece volume in view of large workpiece engagement areas possible. Thus wide belt machines can be used at infeed ranging between 5 and 10μm for economical machining of workpiece having a width of more than 2000mm (Christian, 1990).

Jourani et al (2005) have reported that the belt grinding improves the surface finish that was obtained by hard turning. Three dimensional numerical model developed by them finds that the real contact area and contact pressure are smaller than the nominal contact area and contact pressure. This could be due to flexibility in contact. This model was developed by considering the abrasive grains as distribution of indenters with various rake negative angles. They have observed that the local normal and tangential force increase with negative angles. The surface topography and material ratio are improved with successive processes of hard turning and belt grinding. They have also reported that the geometrical accuracy reached is similar to that those obtained using a grinding process. It has been claimed that it is important to have an idea on the contact pressure, normal, friction forces and local friction coefficient distribution, to assess the belt wear.

Shibata et al (1979) investigated on wear characteristics of the abrasive cutting edges on coated abrasive belts by microscopic observations. The heights of most grain cutting edges on coated abrasive belts gradually decrease from the tips owing to attritious wear. Therefore, except for a short initial period when the belt is new, grinding is performed mainly by abrasive cutting edges with worn grain flats at their tips. The effects of these flats on belt grinding characteristics were investigated theoretically and experimentally. A metal removal model was proposed to explain the belt
grinding characteristics and their changes with respect to time. The shape and distribution pattern of the grain cutting edges have more effect on the performance of an abrasive belt. Hugh Dyer (1955) investigated the dependency of certain controllable grinding conditions on the wear of abrasive grains. It was reported that belt speed influences the attritious and fragmentation wear. They have concluded that high belt speed leads to higher temperatures at the abrasive grain-metal contact. At low belt speeds fragmentation wear of the abrasive belt is promoted. It was concluded that the effective use of abrasive belt was related to the balance between attritious wear and fragmentation/spalling wear. The wear pattern of coated abrasive would be different from that of the bonded abrasives. The individual grains were subjected to unique load. Since the shape of the abrasive grains used for belt grinding is acicular and also friable, at higher belt speed grain may getting fragmented.

Mcgibbon et al (1976) have stated that, in high-rate grinding applications, it was possible to achieve uniform abrasive wear on the coated abrasive belt. This uniformity of wear permits efficient usage of available coated abrasive area and aids in producing good flatness tolerance on the work pieces. In this study, abrasive belts were tested under selected operating conditions and test results were correlated with predictions.

A abrasive wear of coated abrasives can be compared with the single grain evaluation. Hamdi et al (2003) have investigated on the cutting power in a high-speed scratch test device in order to understand the grain behavior and the wear mechanisms. They have presented two useful and complementary experimental approaches for understanding the interface physics. An approach for the specific abrasion energy computation was also presented. It was reported that the high-speed scratch test for the study of the grain behavior yield the nearest to the actual results and gives more qualitative
information of the grinding process. The experimental results of the grain behavior presented in the paper were compared with numerical simulation of the scratch test.

Date et al (2001), have studied on effect of grit size on the initial performance of fresh coated abrasives and the deterioration of coated abrasive performance with continued usage. Abrasion tests were performed on pin-on-cylinder set up which had removable segments for observing the coated abrasive surface in the scanning electron microscope (SEM). This shows direct correlation between measurements of coated abrasive performance and SEM observations of coated abrasive morphology. With coated abrasives containing finer grit sizes, numerous adhesive wear particles were found on the coated abrasive surface; this supports the theory that the smaller initial abrasion rate with finer grits is due to abrasive grains making “elastic” contact with the metal specimen at loads insufficient for cutting. With continued usage, the rapid deterioration in performance with finer grits was accompanied by a buildup of metal caused by capping of the abrasive grain tips with metal chips and by clogging due to metal chips and adhesive wear particles becoming stuck between the grains. Coarser grits, were found to experience extensive grain fracture followed by some grain capping and flattening but virtually no clogging, the deterioration in coated abrasive performance was very much less.

Kazuhisa et al (1992), have studied the topography assessment of coated abrasive tape for distinguishing its functional performance. The three-dimensional distribution of projecting abrasive grains on a tape surface was presented and the related geometrical parameters for classifying the coated abrasive tapes were proposed. A comparison was made between those parameters of the tape surface and the generated surface textured on the aluminum alloy substrate. The topographical parameters of textured substrate
surface which are based on the profile amplitude. Micro geometry near the valley bottoms and their number were correlated fairly well with the spatial distribution of the effective coated abrasive grains in conjunction with working fluid or coolant.

The individual grain contact with work piece is influenced by the machine and product parameters. Khellouki et al (2005), have discussed on the wear mechanism of the abrasive film and its influence on surface roughness. A theoretical model was developed from the contact conditions between abrasive film and the surface. Abrasive grains were considered as cones and wear of the abrasive grain was compared as height reduction of the cone. The effective contact duration between grains and machined surface and average contact pressure, were considered as key parameters. The correlation of key parameters with surface roughness and material removal were discussed. It was concluded that the effective contact duration and number of active points are the most important parameters. This model also revealed the existence of an optimum belt finishing duration depending on the force and the hardness of the contact wheel. They have reported that material removal has direct correlation with effective contact duration and hardness of the contact wheel.

John et al (1985) have studied the coated abrasive belt grinding through profilometer. The wear characteristics of an alumina and silicon carbide abrasive were studied. The heights of the abrasives were studied with respect to time and surface finishes of the workmaterial were compared. It was concluded that alumina grinds and wears larger than the Silicon carbide.

Shah et al (1977) have described making of computer-controlled profilometer to describe the quantitative characterization of extremely rough surfaces such as grinding wheels and coated abrasives. The use of the system is illustrated by showing the effects of grit size on coated abrasive
topography. Duwell et al (1961) has studied the resistance of abrasive grits to wear and reported that aluminium oxide grits would develop sub surface crack owing to low hardness and better toughness and these cracks lead to small fragments of the grit, successive conversion leads to delamination mode of wear.

Van et al (2010) have studied a new method to evaluate roughness parameters considering the scale used for their evaluation. Application is performed for grinding hardened steel with abrasive belts. Seven working variables are considered through a two-level experimental design. For all configurations, 30 surface profiles were recorded by tactile profilometry and rectified by a first degree B-spline fitting before calculating a set of current roughness parameters. The relevance of each roughness parameter, to highlight the influencing process parameters, is then estimated for each scale by variance analysis. The results show that each influent input parameter is characterized by a related relevant evaluation length.

Khellouki et al (2007), studied the effect of abrasive film and grinding parameters on the surface roughness. The abrasive film was applied on work piece with oscillating pad. It was concluded that the belt finishing did not influence on the waviness parameters and also on the form parameters. Its action influences only the roughness parameters. Moreover, among the parameters of belt finishing, it was shown that the granulometry of abrasive films is the most influential parameter on surface roughness. However, after the strategic choice of the granulometry, the most influential parameters of belt finishing are, the applied force, the film feed rate, the hardness of the contacting roller and the belt finishing duration. The oscillation’s frequency, oscillation’s amplitude and tangential speed of work piece were shown as secondary influencing parameters.
Mohamed El Mansori et al (2007) have discussed on the belt finishing process. The influence of the working variables in belt finishing process like cycle time and axial oscillation frequency on surface finish of hardened steel was studied. It was concluded that angle of contact, cycle time and oscillation frequency were significant factors. Axial oscillation of abrasive band decreases the friction at the grain-microchip interface and increase in cutting ability by frequent evacuation of microchips and leading to minimum load.

Meghani et al (2008), have studied the effect of grit sizes on the surface finish of different workmaterial. A set of parameters was defined which describe the aluminium oxide resin-bonded belt characteristics including active grits density, cutting edge dullness, chip storage space and mean effective indentation. A parametric study was made on the effects of coated belt characteristics on surface finish performance with different grain sizes for grinding different workpiece materials. Experimental results are discussed in relation to the prevailing mechanisms of the process at the belt-work interface which can be separated into cutting and ploughing components.

In coated abrasives, the mineral wear is more critical for a given bonding system. The abrasive minerals particle size follows a distribution pattern and the coating process follows the same. The area covered by the abrasives also should follow a distribution pattern. Burney et al (1975), have discussed a statistical model for wear of coated abrasive. Statistical model was created based on the profile height studies. The difference between new and worn out profiles was evaluated based on auto correlation function, standard deviation of heights, and standard deviation of profile shape, number of peaks per unit area in contact and ratio of real to apparent area of contact. It was also reported that model was developed with the assumptions of coated abrasive surface as isotropic, contact peaks as circular and heights of the grains were following Gaussian distribution. It was concluded that abrasive
wear in the belt grinding resulted in slower decay in auto correlation, continuous reduction in the standard deviation of profile heights, profile slope and profile curvatures. It was reported that belt wear showed reduction in the number of peaks per unit contact area. This means that abrasive wear is relatively controlled.

Phadke et al (1975), have studied the coated abrasive profiles using second order continuous autoregressive model. Expressions were derived from the geometry of the average grain size. These models were developed to understand the abrasive wear. It was concluded that the average grains become shaper as its size reduces. As per the model, it was observed that apex angle increases with the increase in grain wear out.

The distribution of abrasive grits in grinding tool plays a critical role in deciding the surface finish. Andreas et al (2003) studied the feasibility of using engineered abrasives for consistent surface finish. Recent advances in engineered abrasives have allowed replacement of the random arrangement of minerals on conventional belts with precisely shaped structures uniformly cast directly onto a backing material. This allows for abrasive belts that are more deterministic in shape, size, distribution, orientation, and composition. A computer model based on known tooling geometry was developed to approximate the asymptotic surface profile that was achievable under specific loading conditions. Outputs included the theoretical surface parameters, $R_q$, $R_a$, $R_v$, $R_p$, $R_t$, and $R_{sk}$. Experimental validation was performed with a custom-made abrader apparatus and using engineered abrasives on highly polished aluminum samples. Interferometric microscopy was used in assessing the surface roughness. It was concluded that the individual parameters like pyramid base width, pyramid height, attack angle, and indentation depth on the surface have quite a strong relation with surface roughness.

Mulhearn et al (1962) have discussed on the abrasive finishing technology which employs a soft coated belt as a tool; an attempt was made to
identify the simultaneous influence on the process efficiency of two working parameters: the contact pressure and the abrasive particle size. Their effects were mainly studied by considering the most important achievements of the belt finishing process which is to reduce the workpiece surface irregularities and to improve its geometrical quality with a lower wear of the abrasive belt. Chang et al (2003) have discussed on the finishing tests done in wet conditions with various contact pressure and average size of Al₂O₃ abrasive particles. With all other working parameters kept constant, five values of contact pressure (between 0.3 and 0.8MPa) and six abrasive belts of different grains size (9, 15, 30, 40, 60 and 80 µm) have been considered. It was concluded that contact pressure range has effective correlation with the rough super finishing range.

Grzesik et al (2007) studied the process of hard turning followed by the abrasive machining. This is because, many transmissions parts, such as synchronizing gears, crankshafts and camshafts require superior surface finish along with appropriate fatigue performance. Belt finishing process was performed with pressure and oscillation. In this investigation, 2D and 3D surface roughness parameters, as well as profile and surface characteristics, such as the amplitude distribution functions, bearing area curves, surface topographies and contour maps were monitored and analyzed. Experimental data collected during measurements indicate that each of the finishing abrasive processes provides a specific set of surface topologies. The transformation of bearing properties of surfaces, generated through two optional hard turning-BG and MC HT-SF machining sequences, were highlighted. As a result, the modifications of surface profiles achieved by means of special abrasive machining operations, distinctly improved the bearing properties of previously hard turned surfaces, and exemplarily, they shorten the running-in period. It was concluded that elastic belt modifies the valleys and peaks of the surface. The modification of hard turned surfaces by abrasive finish, changes the partition of height and spacing roughness parameters in the total profile height Rz. They have found that hard turned
surfaces treated with belt finishing give better bearing properties than by rigid abrasive stone.

Hong et al (1975) have studied the effect of contact wheel on centerless belt grinding. Different kinds of contact wheel and its impact on output parameters were studied. It was concluded that metal base contact wheel gave better belt efficiency and dimensional accuracy on the finished part. Mineral utilization was found to be higher for metal contact wheel whereas the rubber contact wheel resulted in 35 -65% utilization owing to enhanced elasticity and elastic contact area.

Recha et al (2008), studied on the methodology on AISI 52100 work material. Belt grinding process was performed to reduce the residual stresses generated in the hard turning. It was shown that the belt finishing process improved very significantly the surface integrity by the induction of strong compressive residual stresses in the external layer with significant improvement of the surface roughness. A two stage process was discussed for belt finishing and in the first step belt eliminates very quickly the peaks of the surface texture until abrasive grains reach the lower part of the surface texture. Further to reach of lower part, the shape of the surface texture remains constant. Second step was defined as rubbing phase where the abrasive grains are rubbing the work material. Work material was ploughed on each side of the grains. It was of the effect on subsequent layer was influenced by the pressure on unit grain. concluded that the compressive layer affected by the belt finishing was influenced by the lubrication and lack of lubrication would induce tensile stress.

Fine grit abrasive belts are used in the finishing process. The material removal in the finishing process is very low. The scratch pattern on the surface decides the finish, hence the shape and size of the abrasive plays critical role. Any grinding parameter which decides the contact points between work piece and abrasive should influence the finishing process. Mezghani et al (2009), have studied the effect of grit size on the finishing of
cast iron and steel components. Geometrical and superficial variations of the workpiece samples were measured in 2D surf scan and surface profile of the abrasive grain morphology were measured after removing the superficial microchip layers. It was reported that predominant mechanism for finishing depends on the size of abrasive grains and the wear state of abrasive belt. Height reduction in the grit changes the shape and morphology of the grit which changes the attack angles of finer abrasive grits. It was reported that these changes were favoring the plowing mechanism. Junji Sugishita et al (1978), have discussed the wear process of silicon carbide paper. Results were obtained in the investigation of 600 and 100 grade water proof papers. Abrasive paper was studied in different pressure and reciprocating load. The rate of detachment of grits, the material removal rate and the mean sizes of the detached grits were investigated under various conditions. Experimental results were reported that reciprocating frictional action created more abrasive wear, possibility due to stress attributed over the peaks of abrasives. It was concluded that the mean sizes of the detached grit were independent of load differences and speed differences in the strokes and the wear of cutting points was high at the initial stage of the testing.

Ren et al (2007), have discussed the process model to estimate the material removal rate in the robotic belt grinding. Finite element analysis was used to simulate the belt grinding process. Abrasive grit size and shape were included as one of the parameters. Model was developed by considering three dimensions namely contact situation, force distribution and removal computation. The contact situation was related to geometric intersection between grinding belt and workpiece. This was used to calculate the force distribution. The proposed model included the geometry of the work piece as the one of the parameters.

Xiang Zhang et al (2004) have discussed new model based on support vector regression (SVR). This model was relating the nonlinear relation between the local contact situation and force distribution. Xiang Zhang et al (2005) have developed a local grinding model to simulate the
robot-controlled belt grinding processes, especially for grinding free-form surfaces. A new force model to estimate the grinding forces is also put forward as an alternative to the conventional FEM model. Instead of handling the problem in pure physical way, the new model indicates the nonlinear relationship between local contact situation and force distribution. Bigerelle et al (2009), have discussed on surface finish by belt grinding process. Scaling analysis was used for roughness characterization. It was concluded that roughness amplitude has direct correlation with scan size and belt finishing process creates a fracture structure on tooled surfaces until a critical length which is related to the profile autocorrelation length. It is informed that larger contact area and enhanced uniform compatibility in belt grinding results in the above findings. Yuko et al (2005) studied on the surface finish. The surface finish of the samples as shown in Figure 2.1 were sanded using various grades of coated abrasives and the roughness parameters, such as reduced peak height (Rpk), core roughness depth (Rk), and valley depth (Rvk), were estimated on the material ratio curves, which were obtained from roughness profiles determined using robust Gaussian regression filter.

![Figure 2.1 Average peaks to valley vs material removal](image-url)
Li Na Si et al (2009), have carried out a study on optimization of belt grinding of fiberglass reinforced plastic. Experiments were performed on wet abrasive belt grinding of glass reinforced plastic, the reasons for belt slipping was analyzed. It was concluded that the hardness of the contact wheel plays a significant roll. Abrasive belt grinding technology has been applied in most material machining processes with its high machining efficiency low grinding temperature and high machining precision. Zhi Huan et al (2009), have studied on abrasive grain granularity, belt speed and workpiece feed. Speed plays an important role in grinding for magnesium alloy tube surface, magnesium alloy tube surface roughness ($R_a$) ranging between 0.22 um to 2.93 um. The belt grinding was studied as pre treatment process for magnesium alloy which decides on the surface texture /pattern of magnesium alloyed components. It was concluded that increasing belt speed and workpiece feed deteriorates roughness.

Kayaba et al (1986) have discussed on the effect of contact pressure in belt finishing operation. It was reported that applied contact pressure modified the abrasive efficiency of coated belt. It was concluded that wear rate of abrasive grits were depends Workpieces/tool contact conditions and significance of the contact pressure varies with abrasive grains size. Visser et al (1981) have reported that in belt finishing process, under wet condition, the adhesion between aluminium oxide abrasive and workpiece microchips is negligible. Zhi Ming Lv et al (2009), have discussed on the coated abrasive belt finishing of slender piston rod. The belt grinding process was compared against conventional grinding wheel process. It was concluded that surface finish in belt grinding was improved surface compatibility due to elastic contact point of belt grinding.

Hyunsoo Kim et al (1990) had devised an equation based on Euler formula and investigated the normal and tangential belt force distribution in a
flat belt grinding. The belt force equation presented in this paper has a constant coefficient of friction. Analytical results showed good agreement with the experimental results and the authors' previous work, which was based on a surface model of the belt friction force with a varying coefficient of friction. The equation developed from the Euler formula was suggested for practical design due to its sufficient accuracy and simplicity.

Robert et al (1980) have discussed on the wear and performance characteristics of two abrasive minerals used in two different modes of belt grinding. The modes are low pressure contact-load and high pressure constant rate. The abrasives such as alumina and alumina-zirconia were compared for their wear characteristics. The belt caliper, surface profile were studied to understand the grinding performance with respect to pressure. It was reported that profile of the grains on a new coated abrasive was distributed over a wide range of heights. They have reported that at mild constant load test only a few high grains were participating in the material removal and at severe constant-rate test more number of grains was contacting the work pieces. Belt caliper curves for different mineral type for same grinding mode are more alike than curves for belts of the same mineral type used in different grinding modes. The amount of minerals consumption changed with respect to loading pattern. It was concluded that alumina zirconia abrasive removes ten times more material than by alumina at constant load test. This is possibly due to enhanced friability or toughness of the abrasive grain.

In coated abrasive, it is possible to change the wear pattern based on the product design. A protective layer shall create the differences in the wear mechanism. Billingham et al(1974) studied the grit failure mechanism in coated abrasives belt grinding on a wide variety of engineering materials. Study was related to the effect of additional “size” layer on the product with “anti-glaze” property. Scanning electron microscopy was used to both
characterize and monitor the incidence of the various grit failure mechanisms for a standard aluminium oxide resin-bonded belt and a similar belt containing a grinding aid additive. The two predominant wear mechanisms were discussed, namely capping, where swarf becomes firmly attached to the grit surface preventing any further grinding action and by dulling, which is a combination of attrition by chemical degradation or plastic flow and small-scale grit fragmentation, which leads to the formation of flats on the grit surfaces. It was reported that antiglaze layer has reduced the belt wear. Wear due to capping was reduced due to the antiglaze layer. The effect of antiglaze found to be the same for different work pieces like stainless steel, super alloys and high carbon steel.

The wear of coated abrasive shall be correlated with single grit grinding. Doyle et al (1978) reported that delamination of the surface layers of brass work pieces was observed during single-grit grinding. In most instances, complete delamination did not occur and the delaminated material was still attached to the workpiece. Transmission electron microscope examination of the ground surface layers showed that they had a fine sub grain structure; no evidence of a dislocation free surface layer was obtained. Delamination was found to occur in the fine grained surface layers, and it is suggested that this occurred by a process of shear separation within the fine sub grain structure. The manner in which the delaminated sheets were observed to lift away from the workpiece surface seems to indicate the presence of both residual tensile and compressive stresses within the surface layers.

Desa et al (2001) stated that in machining of ceramic materials subsurface damage and low material removal rates was observed, owing to their high hardness, low thermal conductivity and brittle behavior. With this in mind, the subsurface damage and material removal in single point
scratching and abrasive machining of alumina and silicon nitride were studied. The lubricants were selected based on the potential for high material removal rates and low subsurface damage as determined from an earlier study. A Vickers pyramidal indenter with a linear transverse motion was used for scratch tests while abrasive machining was done under controlled load conditions in a modified belt sander. The material removal rates in scratch tests were determined by profilometry and in abrasive machining by gravimetric measurements. The subsurface damage was studied by scanning electron microscopy (SEM). It was found that the subsurface damage in both processes was greater in alumina than in silicon nitride. Compared to alumina, silicon nitride is tougher and able to resist delamination and related damage. The lubricants were found to contribute to higher material removal rates and lower subsurface damage as compared to the dry condition. X-ray photoelectron spectroscopy (XPS) analysis of the abrasively machined surfaces of alumina revealed that the compounds such as Al(OH)₃ and MeSiO₅ were generated on the cutting surfaces. These compounds contributed to the above effects by making the cutting conditions less aggressive.

Masatoshi et al (1983), have discussed on the surface characterization of coated abrasive grinding of carbon steel. It was concluded that the distribution of the cutting edges could be represented as limited parabolic type. Average mean value of the grain size has exponent relation with surface finish. Bhattacharyya et al (1975) have discussed on the topography of the coated abrasives. The surface profiles were tested with stylus measurement technique with subsequently analyzed with statistical model for output signal. Leggett et al(1978) discussed on the process parameters for belt finishing and recommended that power source, drive or contact wheel, an idler for tensioning, tracking the belt, and properly selected coated abrasive belt were important factors to get good surface quality. These components differ for all the methods but in general the workpiece is pressed.
between the grinding head and the rest support. The objective of the regulating head is to coordinate the belt pressure. Wang et al (2008), have discussed on the selection of belt grinding axis on finishing of turbine blades. Blade grinding was realized by two liner control axes and two rotation control axes. The kinematic model was developed and reported that belt grinding as a suitable process for turbine blade finishing. Konig et al (1986), have discussed on the belt grinding parameters like contact wheel and surface qualities of the workmaterial. They have concluded that for high surface qualities the contact wheel hardness, axial accuracy and area of contact are critical parameters. It was reported that axial accuracy decreases with increase in the hardness of the contact wheel. Harder contact wheel reduces flexibility over the contact region.

2.3 BELT GRINDING WITH COOLANTS

One of the important advances in the coated abrasive field since development of the synthetic abrasive has been the development and utilization of special grinding aids. These in the form of fluids and waxes which permit the use of coated abrasives for economical grinding and polishing. The difficult to grind materials such as plastics and super alloys finished by belt grinding and by the addition of grinding aids. Since the effective contact area of the coated abrasives and heat generation in the grinding process are small, it needs more optimization to create effect of external atmosphere in the belt grinding process. Amundson et al (1975) have studied the influence of aqueous solution of K$_3$P$_4$O$_7$ on material removal rate in coated abrasive machining. It was reported that 10% aqueous solution of K$_3$P$_4$O$_7$ buffered with NaH$_2$PO$_4$, act as grinding aid. In grinding of 1095 and AISI 304 stainless steel the material removal rate decreases with increase in the cut per path. The maximum power drawn in grinding was found to be low in dry grinding compared to wet grinding. It also concluded that abrasive
wear was decreased due to wet grinding which inturn reflected as increase in material removal. Reduction in wear was related with adhesion between mineral grains and metal. It was also reported that mineral metal interaction creates micro fracture in the mineral and mineral pullout from the backing. It was referred that $K_3PO_4$ solution worn down the grain attritably to a less sharp.

Mercer et al (1988), have discussed on the influence of atmospheric composition such as air, inert gas, on the abrasive wear of coated abrasive paper on grinding of titanium and Ti-6Al-4V. Wear and frictional behavior of metals on silicon carbide and alumina were studied in pin-on-disc method. The abrasive wear observed was grit blunting and build-up-edge or capping. Yu Fu Wang et al (2009), have discussed about grinding of titanium alloys. These alloys are sensitive to heat generated at grinding zone. Grinding process creates, heat affected zone and burn marks which result in degradation of mechanical and metallurgical properties. It was stated that belt grinding has more sharp cutting points and pointed grains give sufficient chip clearance. This paper attempts to retain the pointed structure of belt and improve the material removal rate by coolants. They have recommended the green cooling technology by liquid Minimum quality level (MQL). It was reported that liquid nitrogen MQL significantly influences belt wear and material removal rate. Liquid nitrogen acts like a grinding aid which reduces the friction coefficient and toughness of the work materials. Liquid nitrogen easily access to grain-workpiece interface and reduces the coefficient of friction, and hence less damage, reduced build-up.

Heat sensitive materials can be finished with coated abrasive belt grinding. The wear pattern changes with grinding time. Cadwell et al (1961) have studied the factors affecting the performance of fully and conventionally coated abrasive belts in grinding of the Ti-6Al-4V. The decline of
volumetric stock removal by attritional wear of the abrasive wear was studied by an automatic sensing and plotting methodology. It was reported that the effect of lubrication varies with respect to surface speed of the belt. Experimental studies on lubricants such NaNO$_2$ and K$_3$PO$_4$, showed that greater mobility of nitride ions made the effect of belt speed less significant on wear. Axinte et al (2005), have worked on optimization of belt polishing for Ti-6Al-4V alloy. Belt polishing was employed subsequent to milling process. The belt speed, pressure and table speed were used as variable parameters. The structured abrasive belt was used in a finishing operation. The structured abrasive was considered as belt with uniform height of the cutting points. It was reported that belt finishing of Ti-6Al-4V generated very less heat. The surface integrity of the workpiece found to be same for dry or air lubricated, air cooled grinding. The life of the belt was evaluated against the optimal measures such as surface roughness, material removal and machining time. Axinte et al (2009), have discussed on the polishing of Ti-6Al-4V heat-resistant alloy. Two types of polishing methods namely belt and bob polishing methods with various media/grades (Al$_2$O$_3$, SiC, polycrystalline diamond) of the abrasive materials in conjunction with three cutting media have been tested to address the overall finishing of components. It was discussed that both polishing methods are capable to meet the requirements of minimum workpiece surface coverage. When considering surface roughness criteria, Al$_2$O$_3$ belts and SiC bob tools were found appropriate. Furthermore, surfaces obtained with these tools when employing cooling media (chilled air for belt polishing and minimum quantity of lubricant (MQL) for bob polishing) showed compliance with the tight requirements of industrial standards for workpiece surface integrity (metallurgical damage and residual stresses). This proved that belt and bob polishing methods can be employed to enable automated overall finishing of complex geometrical components.
Mamoru et al (1987), have reported the optimization study on belt grinding of stainless steel. In this study on formulation or selection of an optimum oil-based grinding fluid with which stainless steels can be successfully ground, an optimum base oil was first experimentally selected, and then additives were evaluated for their effect in improving abrasive-belt grinding performance. Chemical grinding oil additives were found markedly effective in improving the abrasive-belt grinding performance for both 19Cr-2Mo ferritic stainless steel and SUS 304 austenitic steel, with those containing sulphur or chlorine being superior to those containing phosphorus, fatty acid or alcohol. Among all the additives tested, chemically active oils, such as sulphurized mineral oil, exhibited the best performance.

Nakayama et al (1988), have studied the effect of blended paraffin base oils of the same viscosity on the abrasive belt grinding of stainless steel. The base oils are varying in specific gravity, viscosity and sulphur content. Oil was applied through pressurized cylinder. The effect of viscosity and blending ratios on material removal and belt wear were reported. The following conclusions were reported in the study. Stock removal was decreasing with increase in oil viscosity. Abrasive belt wear was decreasing with increasing viscosity. Fracture wear was observed at low viscosity and abrasive wear at higher viscosity. At low viscosity oil film was easy to penetrate hence, more wear was reported. The optimum lubricant was measured based on grinding ratio i.e. the maximum material removed at minimum belt wear. Maximum Grinding ratio was reported with blended oil lubricant.

Hugh (1955) studied the the life of abrasive belt in different lubrication environment in grinding of carbon steel 1020 and stainless steel 304. Figure 2.2 shows the results of tests using aluminum oxide of grit size 50, resin bonded, cloth backed, belts to grind both low carbon steel (1020 hot
rolled) and stainless steel (Type 304) under the same conditions of high unit work pressure. The belt speed was 25m/s, and the metal test piece was oscillated across the belt at a speed of 0.35m/s under a constant pressure of 5kg.

![Graph showing metal removed over time for different conditions](image)

**Figure 2.2 comparative stock removal-accelerated shedding tests**

It was reported that reduction of belt life was often the result of changes in one or more of the above listed variables. They have concluded that it was required to adjust the appropriate variables to reach the ideal situation for each job.

Wilke et al (1986), have studied the coated abrasive super finishing of metal roll surfaces. Coated abrasive tape was used as finishing tool, belt speed; oscillation and pressure were used as parameters. They have studied the effect of grinding atmosphere dry, water and oil on the performance of coated abrasive belt finishing. The water soluble synthetic lubricant used to flush debris from the interface was found to enhance abrasive action. Plain water, mineral seal oil and other lubricants were tested. Use of mineral oil
resulted in coarse surface finish on hard workmaterial. It was reported that coated abrasive super finishing conducted in the absence of lubricant caused the abrasive tape surface to become loaded.

2.4 GRINDING OF BRITTLE MATERIAL

Hard and brittle materials like alumina, silicon carbide, refractory materials are finished only with super abrasive grinding wheels. Since grinding forces are high and abrasive wear rate is also high. There is only few research works have been carried out on coated abrasive belt grinding of ceramic materials. Wang et al (2003) have studied the platen belt grinding of brittle materials like ceramic tile, granite and marble. They have conducted the tests with silicon carbide and zirconia base abrasive belts on vertical loading conditions. The effect of belt speed, type of abrasive, force and coolant on abrasive belt grinding at constant pressure were discussed. It was reported that abrasives were able to grind granite and marble in reciprocating and rotating worktable. It was concluded that belt grinding had no significant effect on ceramic tiles. This could be due the glazed surface of the ceramic material. The grinding conditions were optimized, with grinding pressure, worktable rotation, belt speed and coolants. It was reported that worktable rotation had greater influence on material removal and surface finish. It was concluded that belt speed reduce the cutting force at higher belt speed.

Yoangsheng et al (2003), studied the abrasive belt grinding of granite. Based on analysis of action of surfactant in granite grinding with diamond disk, the effects of the grinding coolant with different surfactant and concentration were studied in belt grinding. The influences of different parameters like grit size, cationic, anionic and non ionic surfactants on belt grinding were reported. It was reported that material removal rate improved greatly using grinding coolants with surfactant. Addition of Surfactant is leading to reduction in the surface formation energy and hence increases in
material removal. The grinding speed, grit mesh size and rotating table speed were affecting the function of surfactant. The belt speed 15 mps and the work table rotation of 50 rpm was reported parameters. Addition of surfactant leads to reduce the surface formation energy and consequently increases material removal. Anne venu gopal et al (2004) investigated that the chip-thickness model, used to assess the performance of grinding process, plays a major role in predicting the surface quality. They have concluded that the effectiveness of the existing chip-thickness model has been enhanced by incorporating elastic properties of the wheel and the workpiece. This model exhibits the importance of incorporating the material properties of the wheel and workpiece apart from other traditional grinding parameters. The new chip-thickness model was more accurate in predicting the surface roughness.

Sanjay Agarwal et al (2007) reported that it was often desired to increase the machining rate while maintaining the desired surface integrity. The success of this approach, however, relies on the understanding of mechanism of material removal on the micro structural scale and the relationship between the grinding characteristics and formation of surface/subsurface machining induced damage. In this paper, grinding characteristics, surface integrity and material removal mechanisms of SiC ground with diamond wheel on surface grinding machine have been investigated. The surface and subsurface damage have been studied with scanning electron microscope (SEM). The effect of grinding conditions on surface/subsurface damage has been discussed. This research links the surface roughness, surface and subsurface damages to grinding parameters and provides valuable insights into the material removal mechanism and the dependence of grinding induced damage on grinding conditions.

Gowri et al (2006) have investigated on “Modeling and Optimization of super abrasive grinding of alumina ceramics”. It is stated that
super abrasive grinding of advanced ceramics requires effective selection of process parameters to control the surface integrity and to maximize the material removal rate. Grinding of advanced ceramics such as alumina is difficult due to its low fracture toughness and sensitivity to cracking.

Xipeng Xu et al (2003), have studied the mechanisms of abrasive wear in the grinding of titanium (TC4) and nickel (K417) alloys. The present investigation was dedicated to elucidate abrasive-wear mechanisms during surface grinding of a titanium alloy (TC4) and a nickel-based super alloy (K417) using silicon carbide (SiC), alumina (Al$_2$O$_3$), and cubic boron nitride (CBN) wheels. The temperature at the wheel–workpiece contact zone was measured using a workpiece–foil thermocouple. SEM and EDS were used to examine the morphological features of ground workpiece surfaces and worn wheel surfaces. It was shown that the grinding with either SiC or Al$_2$O$_3$ is characterized by the high temperatures reached in the grinding zone since either of them is easily worn during the grinding processes. Along with the presence of high temperatures, strong adhesion was found between the abrasives and workpieces, which might be attributed to the chemical bonding between the abrasives and workpieces at the elevated temperatures. Increasing ductile deformation of both TC4 and K417 at the elevated temperatures may also be a factor. Therefore, the wear of SiC or Al$_2$O$_3$ is both chemical and physical. In the grinding with CBN wheels, however, the wear of abrasive grits is mainly physical since CBN is more stable at higher temperatures. At extremely high temperatures, CBN was found to undergo dislodging prior to being gradually worn. In order to reduce the grinding temperature, a segmented wheel was incorporated into grinding with CBN wheels.

Kun Li et al (1996) reviewed the published works related to surface/subsurface damage and the fracture strength of ground structural
ceramics over the last 20 years. Consistent as well as conflicting experimental observations concerning grinding-induced micro cracks, residual stresses and the degradation of flexure strength are summarized. Special attention was shown on the quantified relationships between the grinding variables, machining damage and the flexure strength of ground ceramics because of the importance of these relationships for optimizing the ceramics grinding processes. Several issues such as non-uniformity of the grinding interface, crack measurement, thermal effects and micro structural features are discussed and highlighted as future research areas for better modeling and simulation of ceramics grinding operations.

Xipeng Xu et al (2003) in their study measured the temperature at the wheel–workpiece contact zone using a workpiece–foil thermocouple. SEM and EDS were used to examine the morphological features of ground workpiece surfaces and worn wheel surfaces. In order to reduce the grinding temperatures, a segmented wheel was incorporated into the grinding with CBN wheels. Duwell et al (1988), have studied the performance of coated abrasive lap covers with free abrasive lapping. The work materials studied were fused quartz, pyrex, alumina and silicon nitride. Above studies were conducted in dry conditions and with oil and water. It was concluded that water was highly beneficial to the performance of coated abrasive on all the materials. They have reported that conventional minerals in coated form may improve the surface integrity in the final finishing of glasses, ceramics by avoiding subsurface crack formation. They recommended that high normal load or coarse grades were to be avoided for finishing of ceramic workmaterial.

2.5 SCOPE AND OBJECTIVE OF THE PRESENT WORK

The literature survey on abrasive belt grinding mainly indicates the applications in the non-precision finishing processes. Figure 2.3 shows the
differences between belt grinding and finishing. There was considerable work done on belt finishing process. Most of the studies were restricted to the low pressure and low belt speed grindings. Studies conducted on final finishing were assisted with work pad oscillation vibrations and belt grinding was studied as one of the finishing process. In the belt finishing process, studies were oriented towards the reduction of residual stresses, created in the previous processes. Yet definite conclusions could not be arrived. Not much on belt properties and relative influence on machining parameters is reported. Regarding the influence of grinding environment no conclusive information can be arrived and role of lubricant and grinding fluids is yet to be understood. There are continuous developments in the abrasive mineral, bonding system, backing materials, manufacturing process and workpiece materials, which demand study on influence of belt characteristics and machining parameter on the output of belt grinding. Hence there is a need for further study in abrasive belt grinding for proper understanding of the parametric influence and also to develop useful data base.

Figure 2.3 Belt grinding and finishing methods.
2.5.1 Need and Scope

The literature survey on belt grinding shows certain limited understanding of material removal, wear and grinding process. The importance of belt related parameters in grinding and finishing of workpieces can be seen in the illustration on grinding Figure 2.3. Compared to the grinding with wheels, involving non rigid wheel with belt grinding is another way to enhance the flexibility. The aim is through systematic approach to optimize parametric setting to achieve the desired output and precision in coated abrasive belt grinding.

Accordingly the objectives of the study are to:

- Conduct a detailed study on grinding characteristics of coated abrasive belt grinding process and develop a methodology to maximize the output and usage of belt grinding.

- Conduct experiments to study the belt properties and grinding parameters to arrive a systematic process to select belt and grinding parameters.

- Analyze the data and develop statistical model considering individual and interactive parametric influence on performance indicator.

- Recommend the feasibility of optimizing parameters for custom specific applications.
2.5.2 Organization of Research Work

The organization of research work based on the objective is illustrated in Figure 2.4.

![Diagram](http://example.com/diagram.png)

**Figure 2.4** Organization of research work