CHAPTER 2
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2.1. INTRODUCTION:

In every manufacturing process, machining is vital since it directly or indirectly, involves in the manufacturing of nearly every product. Manufacturers around the world constantly strive for lower cost solutions in order to maintain their competitiveness, on machined components and manufactured goods producers of which are continually challenged to reduce cost and improve quality in order to remain competitive. Researchers seek the solutions with the new technology. Such is the case with the grinding operations, which involves expensive machinery and comparatively long manufacturing cycles. The newer solution could be a hard turning process that may be used in a pre-grind operation or in sequences that are followed by super finishing. So the study of hard turning is of the great importance and hence attracted many researchers, scientists and investigators to develop scientific approach in solving problems encountered in hard turning.

Hard turning, possibly, is a profitable alternative to finish grinding. The ultimate aim of hard turning is to remove workpiece material in a single cut rather than a lengthy grinding operation in order to reduce processing time, production cost and setup time and to remain competitive. Since a large number of operations are required to produce the finished product, if some of the operations can be combined or eliminated or can be substituted by the new process, product cycle time can be considerably reduced and productivity can be improved. The traditional method of machining the hardened materials includes rough turning, heat treatment, and then grinding process. Hard turning eliminates the series of operations required to produce the component product and thereby reducing the cycle time and hence resulting in productivity improvement.
A machining process is defined by the independent and dependent process variables, among which different relations exist. Independent process variables are the process input variables which include tool geometry, cutting tool material, cutting conditions, capacity and rigidity of the machine tool, properties of the work piece material. Dependent process variables are the process output variables and include surface roughness, tool wear, cutting forces, specific power consumption, dimensional accuracy, temperature, vibration etc.

The optimum combination of parameters for the successful machining operation is still the subject of research. The optimum cutting conditions greatly depend upon the availability of reliable machining performance relating to the output parameters such as surface roughness, tool wear etc. The complexity of the multi-constrained optimization for turning operations has been demonstrated in a number of publications.

2.2 BRIEF HISTORY OF WORK:
2.2.1 Hard Turning:

Soroka (1) proposed that hard turning is a viable process that has real and measurable economic and quality benefits which is particularly true for a machine tool with high level of dynamic stiffness and the necessary accuracy performance; more emphasis should be laid on the characteristics of the machine tool.

Tamizharasan et.al. (2) described the various characteristics in terms of component quality, tool life, tool wear, and effects of individual parameters on tool life and material removal and economics of operation. In the study, the hardened material selected for hard turning was commercially available engine crank pin and with three different grades of polycrystalline cubic boron nitride (PCBN). This has shown that hard turning is a profitable alternative to finish grinding.

C.Ezilarasan, et.al. (3) presented the experimental investigation and analysis of the machining parameters while turning the nimonic C-263 alloy which is extensively
used in the fields of aerospace, gas turbine blades, power generators and heat exchangers because of its unique properties. However, the machining of this alloy is difficult due to low thermal conductivity and work hardening characteristics. The feed rate was found to influence the cutting force and surface roughness more significantly than the cutting speed and depth of cut, thus indicating the importance of feed rate control in the machining of the nimonic C-263 alloy while turning, using a whisker reinforced ceramic inserted tool.

The experimental investigations conducted by Dilbag Singh and P. Venkateswara Rao (4) with mixed ceramic inserts made up of aluminum oxide and titanium carbide (SNGA) exhibited the effect of cutting conditions and tool geometry on surface roughness in finished hard turning of bearing steel (AISI 52100). The primary influential factors that affect the surface finish are cutting velocity, feed, effective rake angle and nose radius; dominant factor being feed followed by nose radius and others. Mathematical model for the surface roughness was developed by using response surface methodology which would be helpful in selecting the tool geometry and cutting conditions for the required surface quality.

S.K. Choudhury, I.V.K. Appa Rao (5) presented a new approach for improving the cutting tool life by using optimal values of velocity and feed throughout the cutting process. The experimental results showed an improvement in tool life by 30%. For the experiments, two sets of tool-work combination were used (i) a carbon steel with a HSS tool having no cobalt and (ii) an EN24 steel with a HSS tool having 10% cobalt.

Tugrul Ozel et al. (6) investigated the effects of cutting edge geometry, work piece hardness, feed rate and cutting speed on surface roughness and resultant forces in the finish hard turning of AISI H13 steel by CBN inserts which show the effects of these parameters on surface roughness are statistically significant. The effects of two factor interactions of the edge geometry and the work piece hardness, the edge geometry and the feed rate, and the cutting speed and feed rate also appeared to be important. Especially honed edge geometry and lower work piece surface hardness resulted in better
surface roughness. Cutting-edge geometry, work piece hardness and cutting speed are found to be affecting force components. The lower work piece surface hardness and honed edge geometry resulted in lower tangential and radial forces.

Grzesik (7) reported an extensive characterization of the surface roughness generated during hard turning operations performed with conventional and wiper ceramic tools at variable feed rate and its changes originated from tool wear. Moreover, this research contributed to practical aspects of hard turning technology due to exploring the relations between the tool state at different times within the tool life and the relevant surface roughness characterization. The work piece material was AISI 5140 (DIN 41Cr4) and cutting tool as Sandvik CC650.

Ilhan Asiltürk, Harun Akkus (8) focused on optimizing turning parameters based on the Taguchi method to minimize surface roughness by using hardened AISI 4140 (51 HRC) with coated carbide cutting tools. Results of this study indicate that the feed rate has the most significant effect on surface roughness. In addition, the effects of two factor interactions of the feed rate-cutting speed and depth of cut-cutting speed appear to be important. The developed model can be used in the metal machining industries in order to determine the optimum cutting parameters for minimum surface roughness.

D.I. Lalwani, N.K. Mehta (9) made an attempt to investigate the effect of cutting parameters (cutting speed, feed rate and depth of cut) on cutting forces (feed force, thrust force and cutting force) and surface roughness in finish hard turning of MDN250 steel (equivalent to 18Ni(250) maraging steel) using coated ceramic tool. The machining experiments were conducted based on response surface methodology (RSM) and sequential approach using face centered central composite design. The results show that cutting forces and surface roughness do not vary much with experimental cutting speed in the range of 55–93 m/min. A linear model best fits the variation of cutting forces with feed rate and depth of cut. Depth of cut is the dominant contributor to the feed force, accounting for 89.05% of the feed force whereas feed rate accounts for 6.61% of the feed force. In the thrust force, feed rate and depth of cut contribute 46.71% and 49.59%,
respectively. In the cutting force, feed rate and depth of cut contribute 52.60% and 41.63% respectively, plus interaction effect between feed rate and depth of cut provides secondary contribution of 3.85%.

Radhakrishnan et.al. (10) presented the detailed experimental investigation on turning Aluminum Silicon Carbide particulate Metal Matrix Composite (Al-SiC –MMC) using polycrystalline diamond (PCD) 1600 grade insert Using ANOVA and Grey Relational Analysis. The grey relational analysis of the experimental results of surface roughness and specific power can convert optimization of the multiple performance characteristics in to optimization of the single performance characteristic called the grey relational grade. As a result, optimization of the complicated multiple performance characteristics can be greatly simplified through this approach. It is shown that the performance characteristics of the Al-SiC machining process such as surface roughness and specific power are improved by using the method proposed by this study.

Y.Yao and X.D.Fang (11) showed that grooved wear at the minor cutting edge, once formed, dominates the finishing tool life, while in the case of no groove formation at the minor cutting edge, the minor flank wear reaches its critical point earlier than the major flank or crater wear does. The results also show that the method derived from the dispersion analysis is a feasible approach to online tool wear estimation in finish turning.

B.Chennakesavarao et.al. (12) have studied optimization of parameters for machining aluminum and silicon carbide metal matrix composites by using K20 and P40 grades of carbides. The results show that the forces increased with cutting velocity and feed rate. The tool wear was lesser while machining work piece materials obtained by VHP (vacuum hot pressed) route when compared to that of cast route.

S.N. Mukharjee and S.K.Basu (13) pointed out tool wear or tool wear rate is more sensitive to cutting speed rather than the feed or depth of cut. Also multiple regression analysis serves as a useful tool in designing and processing metal cutting experiments.
S.N. Mukharjee and S.K. Basu (14) tried to found the most rational approach for a single generalized relationship connecting all the variables and useful parameters. They have analyzed these parameters by using Latin square and Complete Randomized Design. The results showed that surface finish is more sensitive to feed than the relative cutting speed or nose radius. Also depth of cut has no influence on the surface finish.

S. Hagglund (15) suggested a new procedure for optimizing cutting parameters i.e. speed, feed and depth of cut for general turning. A new target function, better related to process cost was suggested, which has resulted in higher optimum feed and lower optimum cutting speed. The productivity index \( (I_p) \) introduced was truly related to the process cost and should therefore considered as the target function.

E.J.A. Armarego and D. Ostafiev (16) presented multi-constraint optimization analysis and computer aided strategies for selecting the optimal speeds and feeds in single pass rough turning operations while using 5 TiN coated carbide tool-steel work piece combinations and 5 TiN coated carbide tool-cast iron work piece combinations. The study also highlighted the increased benefits of using optimal cutting conditions in turning operations in modern computer controlled and automated manufacturing where the non-productive times and costs are continually being reduced.

S.K. Basu (17) presented a new approach to optimize the values of major metal cutting parameters using simplex technique of linear programming. The study aimed at obtaining maximum rate of metal removal under a given condition of tool life and surface finish. The results showed that the surface finish that we can expect is 7.3 microns.

D.E. Dimla Snr (18) investigated into the development of the tool wear monitoring system for metal turning operations by using double coated carbide inserts to cut EN24 alloy steel. Tool wear is increased with the increase in cutting conditions. Also it was found that flank and nose wear were better indicators of tool wear than notch wear.

M. Murugan and V. Radhakrishnan (19) attempted a new tool wear sensing technique for turning ASTM 1040 steel by using SNUN 120408 (TTS) inserts. The monitoring of acoustic emission (AE) voltage level was found to be suitable for the
detection of the flank wear reaching the designed limit. The proposed method is suitable irrespective of the work material or the cutting conditions. The change in the insert design doesn’t affect the life of tool or the surface finish of the machined surface as there is no change or damage to the cutting edge.

S. Seshan and A.J. Sadiq Babu (20) concluded that cast irons have desirable machinability when turning cylindrical test castings by using indexable tungsten carbide tip. The machinability of ductile irons lies between gray iron and steels. Assessment of cutting force has proved to be a reliable method for measuring and comparing the machinability of different metals and alloys.

Yan Luo (21) presented an algorithm to visualize chip geometry for ball end tool. Tool management will affect the production time and cost to change tool for high speed cutting.

Y.S. Negi and P.P. Marwaha (22) studied the effect of machining parameters on surface finish of nonferrous materials (Aluminum alloy, Magnesium Alloy, Brass, Ecosorb) using polycrystalline diamond cutter in finish turning. They observed that surface finish improves when the feed rate and depth of cut is reduced and cutting speed is increased. The improvements in surface finish values were observed near lapping region at low feed rates.

S.V. Dravid and L.S. Utpat (23) investigated the machinability rating of EN8 and EN24 based on surface roughness produced on the work piece in comparison to mild steel. The results showed that though the carbon content is same in EN8 and EN24, EN24 shows more machinability than EN8. As micro- constituents of ferrites are present in large quantities, the metal is soft and cutting process does not produce good surface quality. As the carbon percentage is medium or high the pearlite increases causing discontinuity and more strength.

P.T. Mativenga and K.K.B. Hon (24) examined the effect of increased spindle speeds on surface finish while using Physical Vapor Deposition (PVD) coated carbide tools for milling of AISI H13. The results showed that axial force has a very strong
correlation with surface finish and that increased spindle speeds lead to far superior surface finish. Multilayer coated carbides were found to generate the best surface finish while the uncoated tool and lubricant coating led to severe degradation of surface finish at increased spindle speeds.

M.S. Chua et al. (25) developed mathematical model for TiN coated carbide tools while turning T4 medium carbon steel. It was found that the tool life model was independent of the depth of cut as compared with the cutting force and power consumption models which were independent of depth of cut feed rate and cutting speed.

Tugrul Zel, Yigit Karpat (26) utilizes neural network modeling to predict surface roughness and tool flank wear over the machining time for variety of cutting conditions in finish hard turning of AISI 52100 steel with CBN tools. Regression models are also developed in order to capture process specific parameters. The results indicate that CBN inserts with honed edge geometry performed better both in terms of surface roughness and tool wear development. Neural network models with cutting force inputs and a single output yielded better results than neural networks with two outputs, which predict surface roughness and tool wear together.

Ravindra Thamma (27) focused on comparing multiple regression models by collecting data pertaining to depth of cuts, nose radii, feed rates, surface roughness, and cutting speeds during the turning operation for an Aluminum 6061 work pieces. A non-ferrous grade, carbide tipped cutting tool was used to turn the work piece material. The carbide tipped tools have a multiphase coating with Ti (C, N), Al₂O₃, and TiN (Carboloy grade TP200). The results show that cutting speed, feed rate, and nose radius have a major impact on surface roughness. Smoother surfaces will be produced when machined with a higher cutting speed, smaller feed rate, and nose radius. Depth of cut has a significant impact on surface roughness only in an interaction.

Kamely, M.A. et al. (28) studied important characteristics such as the tool life, wear mechanism and surface roughness produced in the turning of a hardened cold work tool steel AISI D2 (60 HRC) using mixed (Al₂O₃ + TiCN) ceramic coated with TiN cutting tools as a low cost alternative cutting tool to address these concerns. In the tool
life testing, it shows that mixed (Al$_2$O$_3$ + TiCN) ceramic coated with TiN performed better than CBN cutting tools. The wear mechanism of mixed ceramic cutting tools coated with TiN is subjected to not only abrasion, adhesion, chipping and notching, especially when machining at high cutting speed. Generally, hard turning with mixed ceramic tools with TiN provide the lowest surface finish for all cutting conditions.

S. Ranganathan, T. senthlevelen and G. Sriram (29) developed a new mathematical modeling for process parameters on hard turning of AISI 316 stainless steel by tungsten carbide inserts. Regression analysis and ANOVA theory was used to predict surface roughness and tool wear. Among different process parameters during hard turning, effect of cutting speed is more and combination of feed rate and depth of cut influences only lesser extent.

M.Y. Noordin, D. Kurniawan (30) studied the performance of wiper coated carbide insert in hard turning with respect to tool life and surface finish. AISI 420 stainless steel hardened to 47–48 HRC was hard turned at various speeds and feeds ranging in finish turning parameters. Results showed that the maximum tool life of 18 min was achieved and the tool life decreased at higher cutting speeds and feeds. The combination of high cutting speed and high feed was found to be unfavorable for hard turning of stainless steel. High local temperature generated at some distance from the tool edge was probably the cause of the crater. The substrate plastic deformation and discrete plastic deformation (of the coating) were evidenced. Cracks also occurred at both tool faces. Wear occurred at both the rake and flank faces with crater formation exposing the carbide substrate indicating more severe wear on the rake face. The wiper coated carbide tool resulted in very fine surface finish, much better than the theoretical values.

S. Thamizhmanii et.al. (31) analyzed the surface roughness produced by turning process on hard martensitic stainless steel by Cubic Boron Nitride cutting tool. The work piece material was hard AISI 440C martensitic stainless steel. Low surface roughness was produced at cutting speed of 225 m/min with feed rate of 0.125 mm/rev and 0.50 mm depth of cut. However, moderate cutting speed of 175 m/min under above feed rate and depth of cut is an ideal operating parameters taking flank wear in to account. It is always
advisable to turn the hard martensitic stainless steel at medium level cutting speed, high feed rate and high depth of cut. Turning at this parameter would also produce generation of heat and intensity may not be high which in turn affect flank wear.

N.R. Abburi, U.S. Dixit (32) developed a knowledge-based system for the prediction of surface roughness in turning process. Neural networks and fuzzy set theory are used for this purpose. The concise set of rules helps the user in understanding the behavior of the cutting process and to assess the effectiveness of the model. The performance of the developed knowledge-based system is studied with the experimental data of dry and wet turning of mild steel with HSS and carbide tools.

Dhiman, et. al. (33) studied effect of cutting parameters (feed, speed, depth of cut) of AISI 1018 steel on various factors (tool tip temperature, surface roughness, and cutting forces) that account for machining costs. A cylindrical bar of AISI 1018 steel (length 125 mm, diameter 25 mm) was used to carry out experiments on lathe by HSS single point cutting tool without using any coolant. Among the cutting parameters affecting machining variables for AISI 1018 steel, speed has maximum effect and depth of cut has minimum effect. Tool tip temperature increases with increase in cutting speed. At high speeds, surface finish is least affected. Surface finish deteriorates at high feed rates; hence to obtain good surface finish, feed rate may be kept low. At low speeds cutting force are high and tendency of work material to form a built up edge is also stronger. At lower speeds, surface roughness increases with increasing feed but at higher speeds surface roughness is less dependent on feed.

Singh, et al (34) adopted a design of experiments approach to obtain an optimal setting of turning process parameters (cutting speed, feed and depth of cut) that may yield optimal tool wear (flank wear and crater wear) to titanium carbide coated carbide inserts while machining En24 steel (0.45% C). The effects of the selected process parameters on tool wear and subsequent optimum settings of the parameters have been accomplished using Taguchi’s Parameter Design Approach. The results indicated the selected process parameters affect significantly the tool wear characteristics of TiC coated carbide tool.
Chelladurai, et al (35) made an attempt to create artificial flank wear using the electrical discharge machining (EDM) process to emulate the actual or real flank wear. The tests were conducted using coated carbide inserts, with and without wear on EN-8 steel, and the acquired data were used to develop artificial neural networks model. Empirical models have been developed using analysis of variance (ANOVA). In order to analyze the response of the system, experiments were carried out for various cutting speeds, depths of cut and feed rates. To increase the confidence limit and reliability of the experimental data, full factorial experimental design (135 experiments) has been carried out. Vibration and strain data during the cutting process are recorded using two accelerometers and one strain gauge bridge. The magnitude of strain and amplitude of vibration depend upon various machining parameters and it is observed that they increase with depth of cut and feed rate, and decrease with cutting speed. Power spectral analysis was carried out to test the level of significance through regression analysis. Experimental results were analyzed with respect to various depths of cut, feed rates and cutting speeds.

Sai (36) found that an increase in cutting speed causes a higher decrease of the time of the second gradual stage of the wear process. This is due to the thin coat layer which is rapidly peeled off when high-speed turning. The investigation included the realization of a wear model in relation to time and to cutting speed. An empirical model has also been developed for tool life determination in connection with cutting speed. On the basis of the results obtained it is possible to set optimal cutting speed to achieve the maximum tool life.

Zhang, et al (37) used the development of an in-process surface roughness adaptive control (ISRAC) system in turning operations. An artificial neural network (ANN) was employed to establish two subsystems: the neural network-based, in-process surface roughness prediction (INNSRP) subsystem and the neural network-based, in-process adaptive parameter control (INNAPC) subsystem. The two subsystems predicted surface roughness and adapted feed rate using data from not only cutting parameters (such as feed rate, spindle speed, and depth of cut), but also vibration signals detected by an accelerometer sensor.
Tosun (38) made an investigation on the optimization and the effect of cutting parameters on multiple performance characteristics (the tool life and the work piece surface roughness) obtained by hot turning operations. A plan of experiments based on the Taguchi method was designed. M20 sintered carbide as tool and the high manganese steel as work piece material were used in experiments. The work piece material heated with liquid petroleum gas flame was machined under different settings of feed rate, depth of cut, cutting speed and work piece temperature on a lathe. The results showed that cutting speed and feed rate were the dominant variables on multiple cutting performance characteristics. An optimum parameter combination was obtained by using statistical analysis.

Aramcharoen, et al (39) determined the effect of CrTiAlN and high cutting speeds on white layer formation in machining tool steel. H13 tool steel (57 HRC) was examined after turning at a conventional and high cutting speed. Coated tools resulted in lower work piece and tool temperatures. Hence coated tools resulted in reduced and also more homogeneous hardening effects compared to the uncoated tool. In addition, the higher cutting speed produced negligible white layers. Thus, the paper elucidates on the benefits of coatings on surface hardening in conventional and high speed machining.

Chih-Cherng Chen, et al (40) presented the mathematical models for modeling and analyzing the vibration and surface roughness in the precision turning with a diamond cutting tool. Machining parameters including the spindle speed, feed rate and cutting depth were chosen as numerical factor, and the status of lubrication was regarded as the categorical factor. An experimental plan of a four-factor’s (three numerical plus one categorical) D-optimal design based on the response surface methodology was employed to carry out the experimental study. A micro-cutting test is conducted to visualize the effect of vibration of tool-tip on the performance of surface roughness. With the experimental values up to a 95% confidence interval, it is fairly well for the experimental results to present the mathematical models of the vibration and surface roughness. Results show that the spindle speed and the feed rate have the greatest influence on the longitudinal vibration amplitude, and the feed rate and the cutting depth play major roles for the transverse vibration amplitude. As the spindle speed increases,
the overall vibration of tool-tip tends to more stable condition which leads to the results
of the best machined surface. The effects of the feed rate and cutting depth provide the
reinforcement on the overall vibration to cause the instability of cutting process and
exhibit the result of the worst machined surface.

2.2.2 Minimum Quantity Lubrication (MQL) Turning:

Hwang, et al (41) presented an investigation into the MQL (minimum quantity
lubrication) and wet turning processes of AISI 1045 work material with the objective of
suggesting the experimental model in order to predict the cutting force and surface
roughness, to select the optimal cutting parameters, and to analyze the effects of cutting
parameters on machinability. Fractional factorial design and central composite design
were used for the experiment plan. Cutting force and surface roughness according to
cutting parameters were measured through the external cylindrical turning based on the
experiment plan. The measured data were analyzed by regression analysis and
verification experiments were conducted to confirm the results. From the experimental
results and regression analysis, this research project suggested the experimental
equations, proposed the optimal cutting parameters, and analyzed the effects of cutting
parameters on surface roughness and cutting force in the MQL and wet turning processes.

J. Kundra k et. Al. (42) investigated that the most critical element in the accuracy
of hard turning is the generation of out-of-roundness. If the work piece is rigid enough
then the required out-of-roundness can still be achieved but in lower rigidities even
permissible values cannot be ensured. This is due to the highly concentrated
uncontrollable clamping force from the clamping mechanism. This problem could
probably be avoided if, instead of concentrated clamping force, a magnetic or vacuum
chuck working with distributed forces were applied. The hard turning was performed on
AISI 5115 by using PCBN CNGA 120408 BNC80 tools.

Y. Kevin Chou, Hui Song (43) studied Tool nose radius effects on finish turning
of hardened AISI 52100 steels by square type inserts (SNG43x-T, x = 2, 3, or 4) have
been investigated. Surface finish, tool wear, cutting forces, and, particularly, white layer
(phase transformation structures) were evaluated at different machining conditions.
Results show that large tool nose radii only give finer surface finish, but comparable tool wear compared to small nose radius tools. Specific cutting energy slightly increases with tool nose radius. For new tools, white layers only occur at aggressive feeds (0.3 mm/rev) and small nose radius results in deeper white layers. For worn tools, white layers appear even at mild feeds (0.05 mm/rev), but in contrast, large nose radius leaves deeper white layers. Smaller tool nose radius gives larger uncut chip thickness, and thus, greater shear plane heat source that may induce deeper white layers for new tool conditions. For worn tools, where the wear-land sliding is the major heat source, temperature analysis at machined surfaces reveals that the larger the tool nose radius, the deeper the temperature penetration due to a shorter transition-material zone from the cutting edge to the final machined surface.

M. L. Penalva et.al. (44) proved that, in the studied process, replication of tool tip on the work piece is acceptable. Therefore, the machined profile reveals tool wear state. It has also been seen that, for fixed tool and cutting conditions, information provided by roughness profile scan be helpful to estimate tool wear. Concretely, the average roughness and the skeweness of the profile are sensitive enough to discriminate different tool wear states, as well as to indicate when the tool should be replaced.

Tugrul(45) developed multiple linear regression models and neural network models for predicting surface roughness and tool flank wear in finish turning of AISI D2 steels (60 HRC) using ceramic wiper (multi-radii) design inserts. Experimental results indicate that surface roughness $R_a$ values as low as 0.18–0.2 can be attained with wiper tools. In general, low feed rates provided better tool life and better surface finishes was obtained at the lowest feed rate and highest cutting speed combination. Best tool life was obtained in lowest feed rate and lowest cutting speed combination as expected. Neural network based predictions of surface roughness and tool flank wear are carried out and compared with a non training experimental data. These results show that neural network models are suitable to predict tool wear and surface roughness patterns for a range of cutting conditions and can be utilized in intelligent process planning for hard turning.
R. Suresh (46) presented that hard turning with multilayer coated carbide tool has several benefits over grinding process such as, reduction of processing costs, increased productivities and improved material properties. The objective was to establish a correlation between cutting parameters such as cutting speed, feed rate and depth of cut with machining force, power, specific cutting force, tool wear and surface roughness on work piece. In the study, performance of multilayer hard coatings (TiC/TiCN/Al₂O₃) on cemented carbide substrate using chemical vapor deposition (CVD) for machining of hardened AISI 4340 steel was evaluated. An attempt has been made to analyze the effects of process parameters on machinability aspects using Taguchi technique. Response surface plots are generated for the study of interaction effects of cutting conditions on machinability factors. The correlations were established by multiple linear regression models. The linear regression models were validated using confirmation tests. The analysis of the result revealed that, the optimal combination of low feed rate and low depth of cut with high cutting speed is beneficial for reducing machining force. Higher values of feed rates are necessary to minimize the specific cutting force. The machining power and cutting tool wear increases almost linearly with increase in cutting speed and feed rate. The combination of low feed rate and high cutting speed is necessary for minimizing the surface roughness. Abrasion was the principle wear mechanism observed at all the cutting conditions.

Ashok Kumar Sahoo, Bidyadhar Sahoo (47) presented machinability studies on flank wear, surface roughness, chip morphology and cutting forces in finish hard turning of AISI 4340 steel using uncoated and multilayer TiN and ZrCN coated carbide inserts at higher cutting speed range. The process has also been justified economically for its effective application in hard turning. Experimental results revealed that multilayer TiN/TiCN/Al₂O₃/TiN coated insert performed better than uncoated and TiN/TiCN/Al₂O₃/ZrCN coated carbide insert being steady growth of flank wear and surface roughness. The tool life for TiN and ZrCN coated carbide inserts was found to be approximately 19 min and 8 min at the extreme cutting conditions tested. Uncoated carbide insert used to cut hardened steel fractured prematurely. Abrasion, chipping and catastrophic failure are the principal wear mechanisms observed during machining. The
turning forces (cutting force thrust force and feed force) are observed to be lower using multilayer coated carbide insert in hard turning compared to uncoated carbide insert.

Khaider Bouacha et. al. (48) focused on delimiting the hard turning domain and investigating tool wear and forces behavior evolution versus variations of work piece hardness and cutting speed and the relationship between cutting parameters (cutting speed, feed rate and depth of cut) and machining output variables (surface roughness, cutting forces) through the response surface methodology (RSM) while hard turning with CBN tool of AISI 52100 bearing steel, hardened at 64 HRC. The combined effects of the cutting parameters on machining output variables are investigated while employing the analysis of variance (ANOVA). The quadratic model of RSM associated with response optimization technique and composite desirability was used to find optimum values of machining parameters with respect to objectives (surface roughness and cutting force values). Results show that surface roughness is mainly influenced by feed rate and cutting speed. Also, it is underlined that the thrust force is the highest of cutting force components, and it is highly sensitive to work piece hardness, negative rake angle and tool wear evolution. Finally, the depth of cut exhibits maximum influence on cutting forces as compared to the feed rate and cutting speed.

J. Rech , A. Moisan b(49) studied the influence of feed rate, cutting speed, and tool wear on the effects induced by hard turning on case-hardened 27MnCr5 gear cone brakes by using TNGA 160408 S inserts. Finishing cutting processes, such as grinding or hard turning, have a great influence on the surface integrity, because of the thermo mechanical material removal mechanisms. The hard turning process is interesting with regard to its capacities to produce a low surface roughness during a long cutting time and also to induce compressive residual stresses when machining at low feed rate and low cutting speed. Feed rate is the major parameter that influences the surface roughness, whereas cutting speed is the major parameter that influences the residual stress level. TiN coating substantially improves the surface integrity of hard turned surfaces. The hard turning process has some restrictions, especially because of the generated helical surface topography (not existing in cylindrical grinding processes) and the occurrence of material side flow at very low feed rates or with worn tools. Another restriction of hard turning is
the influence of the flank wear which shifts the residual stresses towards tension and also tends to induce white layers. In hard turning operations, residual stress levels and white layers are the main criteria for a change of insert, far before roughness or accuracies-to-size, although these parameters are very difficult to follow in a production plant. The restrictions of hard turning could be solved by the association with a subsequent abrasive process (such as lapping or belt grinding), which is supposed to delete the helical topography and the presence of material side flow, and, at the same time, should shift the residual stress level towards compression.

Gaurav Bartarya, S.K. Choudhury (50) reviewed that the type of tool material, cutting edge geometry and cutting parameters affect the process efficiencies in terms of tool forces, surface integrity and white layer. Adequate machine rigidity is essential to minimize the process inaccuracies. Also moreover, for finish hard turning, where the depth of cut is less than the nose radius of the tool, the forces deviate from the conventional trends as the radial force component is the maximum and axial force component becomes minimum.

Wit Grzesik, Krzysztof Z (51) studied the surface finish produced by hard turning of 41Cr4 low-alloy steel quenched to about 60 HRC hardness, using mixed Al2O3–TiC ceramic inserts. The surface finish was subsequently modified by super finishing and multi pass burnishing operations. In the case of hard turning surfaces were produced by conventional and Wiper cutting tool inserts. The main goal of this study was to examine how additional abrasive and non-removal technological operations change 2D and 3D roughness parameters and enhance service properties of the machined surfaces. It was documented that both super finishing and burnishing operations allow to obtain smoother surfaces with lower surface roughness and better bearing characteristics.

Ronan Autret et.al. (52) performed an experimental study to examine the effect of minimum quantity lubrication over completely dry condition in the turning of hardened high carbon steel materials with low content CBN cutters. A range of feeds, speeds, and depths of cut were tested with a water soluble propylene glycol ester solution as cutting fluid at a constant flow rate and a nozzle pressure. It can thus be concluded that
the use of cutting fluid at minute amounts can potentially protect the tool while holding
the cutting forces relatively unchanged in comparison to completely dry cutting.

Khan M.M.A., Dhar N.R. (53) studied the experimental investigation on the role
of MQL by vegetable oil on cutting temperature, tool wear, surface roughness and
dimensional deviation in turning AISI-1060 steel at industrial speed-feed combinations
by uncoated carbide insert. The encouraging results include significant reduction in tool
wear rate, dimensional inaccuracy and surface roughness by MQL mainly through
reduction in the cutting zone temperature and favorable change in the chip-tool and work-
tool interaction.

Y.S. Liao, H.M. Lin (54) presented a mechanism of MQL in high speed
machining of hardened steel. Comparing with dry cutting, the tool performance can be
enhanced by MQL under all cutting speeds in this study. It is found that MQL can
provide extra oxygen to promote the formation of a protective oxide layer in between the
chip–tool interface. This layer is basically quaternary compound oxides of Fe, Mn, Si,
and Al, and is proved to act as diffusion barriers effectively. Hence, the strength and wear
resistance of a cutting tool can be retained which leads to a significant improvement of
tool life. It is found that there exists an optimal cutting speed at which a stable protective
oxide layer can be formed. When cutting speed is lower than this speed, there is less
oxide layer and the improvement of tool life is less apparent. As the cutting speed is far
beyond the optimal value, the protective layer is absent and the thermal cracks are apt to
occur at the cutting edge due to large fluctuation of temperature. Resultantly, application
of MQL is inappropriate in the extreme high-speed cutting condition irrespective of its
little increase in tool life. Based on this study, it is concluded that the tool life can be
effectively improved by MQL in high speed machining of NAK80 hardened steels when
cutting parameters are chosen properly.

M. Rahman et.al. (55) made an attempt to evaluate the performance of MQL with
a view to investigating it as an alternative to the traditional flood cooling method.
Considering the drastic reduction of 1/300 000 times in lubricant consumption it can be
easily deduced that the MQL (8.5 ml /hr) technique can be adopted as a replacement for
dry machining and it may also be regarded as an alternative economic approach for flood cooling (42 l/min), especially when the ecology and the operator’s physiology is of major concern. The results show that tool wear obtained in MQL is comparable to that for flood cooling at low feed rates and low speeds and depths of cut. No chipping was observed for MQL or for flood cooling in spite of higher flank width for MQL. In almost all cases, the surface roughness generated by MQL is almost equivalent to that obtained by flood cooling. However, the applicability of dry machining must be rejected owing to rough finish at higher feed rates. No significant difference in cutting force was observed between that of flood cooling and MQL. However, at higher depths of cut, the cutting force increased for MQL owing to inadequate lubrication. Fewer burrs formed during machining with MQL which is a distinct advantage compared to dry cutting and the flood cooling method resulting in a lower deburring cost in MQL. As for flood cooling, sticking of chips with the burrs was not found in MQL-aided machining. From EDX analysis performed on the rake face of the insert, it may be concluded that the temperature at the chip–tool interface was lower in flood cooling as compared to that of MQL, while it was highest for dry cutting. The direction of the MQL nozzles was found to be a significant aspect of MQL-aided machining with respect to tool wear and surface finish.

Thamizhmanii (56) investigated the machining of Inconel 718 nickel based material by milling process applying vegetable oil by minimum quantity lubrication (MQL). The results predict that MQL does not contribute any significant results when milling with low cutting speeds. Super alloy tools show good performance on surface roughness at 30 m/min by MQL than dry milling. There was improvement in surface roughness at 37.5 ml/ hour MQL supply than 12.5 and 25 ml per hour. The flank wear by 37.5 ml / hour by MQL was low. The tool life was increased by 43.75 % by MQL than dry cutting. It is no doubt that dry milling has increased surface roughness and flank wear with all cutting speeds. Beyond the cutting speed of 30 m/min. there would be increase in flank wear and surface roughness.

D. G. Thakur et.al. (57) made an attempt to show the effect of minimum quantity lubrication and optimization of its parameters as an alternative to the use of abundant
cutting fluid for machining super alloy Inconel 718. Minimum quantity lubrication (MQL) under pulsed jet mode proved to be an effective approach for low thermal conductivity and specific heat difficult-to-cut material super alloy Inconel 718 material. Also MQL under pulsed jet mode protects the operator’s health and reduces the detrimental effects on the environment.

N.R. Dhar (58) presented an experimental investigation on the role of MQL on cutting temperature, tool wear, surface roughness and dimensional deviation in turning of AISI-4340 steel at industrial speed-feed combinations by uncoated carbide insert. The results show that the cutting performance of MQL machining is better than that of dry and conventional machining with flood cutting fluid supply because MQL provides the benefits mainly by reducing the cutting temperature, which improves the chip-tool interaction and maintains sharpness of the cutting edges. MQL jet provided reduced tool wear, improved tool life and better surface finish as compared to dry and wet machining of steel. Surface finish and dimensional accuracy improved mainly due to reduction of wear and damage at the tool tip by the application of MQL. Such reduction in tool wear would either lead to improvement in tool life or enhancement of productivity allowing higher cutting velocity and feed.

Y.S. Liao (59) has undertaken the feasibility study of the minimum quantity lubrication (MQL) in high-speed end milling of NAK80 hardened steel by coated carbide tool. Flood cooling and dry cutting experiments were conducted also for comparison. It is found that cutting under flood cooling condition results in the shortest tool life due to severe thermal cracks while the use of MQL leads to the best performance. MQL is beneficial to tool life both in the lower speed cutting and the higher speed cutting conditions. A less viscous oil of MQL is essential in high cutting speed so that cooling effect can be effective. SEM micrograph of the insert shows that the use of MQL in high-speed cutting can delay welding of chips on the tool and hence prolongs tool life as compared with dry cutting condition. The application of MQL also improves machined surface finish in high-speed milling of die steels.
L. R. Silva (60) analyzed the behavior of the MQL technique under different lubrication and cooling conditions, developing an optimized fluid application methodology based on the creation of a special nozzle through which a minimum amount of oil is pulverized in a compressed air stream. The comparative analysis of the residual stress values showed that residual compressive stresses were obtained under all the lubrication/cooling conditions and types of abrasive tools employed. The highest residual compressive stress obtained with the aluminum oxide grinding wheel with MQL under the condition of \( V_{\text{air}} = 30\text{m/s} \) and \( V_{\text{lubri.}} = 40\text{ml/h} \) was \(-376\text{MPa}\) against the \(-160\text{MPa}\) attained with conventional cooling, representing a 135\% increase in residual compressive stress. An increase in residual compressive stress was also found when applying the MQL technique compared with the conventional cooling system with the CBN grinding wheel. The flow rates selected for application with MQL did not result in dispersion of the mist, contributing toward environmentally correct manufacturing and allowing for easy viewing of the grinding operation.

Nihat Tosun (61) presented the optimization of the face milling process of 7075 aluminum alloy by using the gray relational analysis for both cooling techniques of conventional cooling and minimum quantity lubrication (MQL), considering the performance characteristics such as surface roughness and material removal rate. The feed rate was the strongest factor among the other milling parameters used on the multi performance characteristics. The importance of the controllable factors on the multi performance characteristics was in order of feed rate, cutting speed, tool material and cooling technique. The study indicated clearly that the gray relational analysis accomplished effectively the optimization of surface roughness and MRR in the milling operation at multiple quality requests.

Ahmed Hassan (62) investigated the process for face milling of titanium alloy while using minimum quantity lubrication (MQL) as the cooling technique was optimized by the use of Taguchi method to improve characteristics. The multiple performance characteristics such as tool life, volume removed, and surface roughness can be improved simultaneously by using this approach instead of using engineering
experience. The most important influence on the cutting parameters with multiple performance characteristics in face milling titanium is the feed rate.

M.M.A. Khan (63) presented the effects of minimum quantity lubrication (MQL) by vegetable oil based cutting fluid on the turning performance of low alloy steel AISI 9310 as compared to completely dry and wet machining in terms of chip–tool interface temperature, chip formation mode, tool wear and surface roughness. It was seen from the results that the substantial reduction in tool wears resulted in enhanced the tool life and surface finish. Furthermore, MQL provides environment friendliness (maintaining neat, clean and dry working area, avoiding inconvenience and health hazards due to heat, smoke, fumes, gases, etc. and preventing pollution of the surroundings) and improves the machinability characteristics.

N. R. Dhar (64) developed an artificial neural network (ANN) model as a function of cutting parameters in turning steel under minimum quantity lubrication (MQL). A feed-forward back propagation network with twenty five hidden neurons has been selected as the optimum network. The results imply that the model can be used easily to forecast tool wear and surface roughness in response to cutting parameters.

L. B. Abhang (65) used minimum quantity of lubrication of boric acid mixed with base oil SAE 40 has proved to be a feasible alternative to the conventional cutting fluid. In the present work 10% boric acid by weight mixed with base oil SAE 40 is used as a MQL in turning process. Variations in cutting (lubricant) force, cutting temp, chip thickness and surface roughness are studied under different machining conditions. The results show that minimum quantity lubricant can be reduced the chip-tool interface temperature by 20 to 30% depending upon the level of process parameters and work material. The reduction in cutting temperature using minimum quantity lubricant was high at lower level of machining parameters and low at high level machining parameters. Minimum quantity lubricant reduced the cutting forces by about 5 % to 12% favorable change in the chip-tool interaction and retention of cutting edge sharpness due to reduction of cutting zone temperature seemed to be the main reason behind reduction of cutting forces by the minimum quantity of lubrication. Minimum quantity lubricant
machining reduces chip thickness up to 12 to 17% over dry turning that is also favorable for chip formation in compare to dry machining. Surface finish also significantly improved mainly due to significant reduction wear and damage at the tool tip by the application of minimum quantity lubricant.

Dinesh G. Thakur (66) made an attempt to enhance the machinability characteristics in high speed turning of superalloy Inconel 718 using quantity of lubricant, delivery pressure at the nozzle, frequency of pulses, direction of application of cutting fluid, cutting speed, and feed rate as the process parameters. Results indicated that the use of optimized minimum quantity lubrication parameters under pulsed jet mode leads to lower cutting force, cutting temperature, and flank wear. The improvement of cutting force, cutting temperature, and flank wear from initial cutting parameters to the optimal cutting parameters was about 145%, 180%, and 155%, respectively.

N. R. Dhar (67) presented an experimental investigation on the role of MQL on cutting temperature, tool wear, surface finish and dimensional deviation in turning of AISI-1040 steel at industrial speed-feed combinations by uncoated carbide insert. The results indicated that the most significant contribution of application of MQL in machining the steel by the carbide insert undertaken has been the high reduction in flank wear, which would enable remarkable improvement in tool life. Such reduction in tool wear might have been possible for retardation of abrasion and notching, decrease or prevention of adhesion and diffusion type thermal sensitive wear at the flanks and reduction of built-up edge (BUE) formation which accelerates wear at the cutting edges by chipping and flaking. Deep notching and grooving, which are very detrimental and may cause premature and catastrophic failure of the cutting tools, are remarkably reduced by MQL. Dimensional accuracy also substantially improved mainly due to significant reduction of wear and damage at the tool tip by the application of MQL. MQL also provided better surface finish.

Kyung-Hee Park (68) to extend the applicability of MQL to more aggressive machining conditions, we have developed a potential additive to MQL lubricant. After the preliminary wetting angle measurement of the various lubricants, one commercially

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available MQL vegetable oil was chosen, which is then mixed in a high-speed mixer with exfoliated nanographene particles. The resulting nanoenhanced MQL lubricant was evaluated for its tribological and machining behaviors together with the suspension stability of the mixture. Friction coefficients of new nanoenhanced MQL oil were also measured in terms of loads, speeds and lubricants. Finally, MQL-ball milling tests with nanographene enhanced lubricant were performed to show a remarkable performance improvement in reducing central wear and flank wear as well as edge chipping at cutting edge. The results from the wetting angle test and the friction coefficient measurement show that Nano-Graphene Enhanced Lubricant (xGnP) vegetable oil improved the wettablility on the cutting surface and reduced the surface friction.

A. Attanasio (69) aimed to determine if the minimal quantity lubrication (MQL) technique in turning gives some advantages in terms of tool wear reduction. These results obtained from turning tests and SEM analysis of tools, at two feed rates and two cutting lengths, using MQL on the rake and flank of the tool. The results obtained show that when MQL is applied to the tool rake, tool life is generally no different from dry conditions, but MQL applied to the tool flank can increase tool life.

2.2.3 Flooded Turning:

N. H. Rafai (70) presents experimental and analytical results of a comparison of dry and flood turning in terms of quality of turned parts. Subsequently, the influence of independent input parameters on quality characteristics is investigated in order to optimize their effects. Three techniques; traditional analysis, Pareto ANOVA analysis, and the Taguchi method are employed. Hardened alloy steel AISI 4340 has been selected as work material. The results show that for certain combinations of cutting parameters, dry turning produced better dimensional accuracy compared to that produced by flood turning. Therefore, in the future, it will be possible to develop a system through modeling the cooling process that will be capable of predicting the situations where dry turning will be beneficial. This will reduce the application frequency of cutting fluids by avoiding their unnecessary applications and, consequently, their negative impact on the
environment. The performance of the manufactured products is often evaluated by several quality characteristics and responses and experimental techniques.

S.S. Chaudhari (71) developed a Taguchi Technique for single characteristic response optimization model to optimize process parameters, such as speed, feed, depth of cut, and nose radius of single point cutting tool. Taguchi’s L9 orthogonal array is selected for experimental planning. The experimental result analysis showed that the combination of higher levels of cutting speed, depth of cut and lower level of feed is essential to achieve simultaneous maximization of material removal rate and minimization of surface roughness. The study also aimed to determine parametric relationship and its effect on surface finish.

M. Venkata Ramana (72) presented experimental investigations and optimization of process parameters for surface roughness in turning of Ti-6Al-4V alloy under dry, flooded and minimum quantity lubrication (MQL) conditions using Taguchi’s robust design methodology and development of prediction models for surface roughness using multiple regression analysis. The results have been compared among dry, flooded and MQL conditions and it reveals that MQL shows better performance and improvement in reduction of surface roughness compared to dry and flooded lubricant conditions. From Analysis of Mean (ANOM), it is observed that MQL is suitable at higher depth of cut compared to dry and flooded lubricant conditions. It is observed from ANOM that, under MQL condition uncoated tool shows better performance compared to the CVD and PVD coated tools, whereas CVD coated tool shows better performance for dry and flooded lubricant conditions compared to uncoated and PVD coated tools. It was also observed from the ANOVA that, feed rate has major contribution in optimizing the surface roughness.

Venkata Ramana (73) studied performance evaluation and optimization of process parameter in turning of Ti6Al4V alloy with different coolant conditions using Taguchi’s design of experiments methodology on surface roughness by uncoated carbide tool. The results have been compared among dry, flooded with Servo cut oil and water and flooded with Synthetic oil coolant conditions. From the experimental investigations, the cutting
performance on Ti6Al4V alloy with synthetic oil is found to be better when compared to dry and servo cut oil and water in reducing surface roughness. The results from ANOVA shows that while machining Ti6Al4V alloy, the Synthetic oil is more effective under high cutting speed, high depth of cut and low feed rate compared to dry and servo cut oil and water conditions. The ANOVA also reveals that feed rate is dominant parameter under dry, servo cut oil and water and synthetic oil conditions in optimizing the surface roughness.

P. C. Siow (74) investigated the machinability of JIS FCD 700 cast iron by using chemical vapor deposition (CVD) coated titanium nitride (TiN) carbide cutting insert. The turning tests were carried out with two set of cutting parameters and performed under flood lubrication condition with two types of lubricants. This study revealed that, within the cutting parameter under investigation, abrasion is the predominant wear mechanism, and was followed by attrition, built up edge (BUE) and plastic deformation. The cutting insert was subjected to three stages of tool wear, i.e. (i) rapid wear, (ii) uniform wear and (iii) drastic wear that led to tool failure. Cutting insert had longest tool life when performed at 120 m/min of cutting speed, 0.3 mm/rev of feed rate and 0.6 mm of depth of cut under commercialized emulsified water-based coolant, and had shortest tool life when carried out at 220 m/min of cutting speed, 0.2 mm/rev of feed rate and 2.0 mm of depth of cut under palm oil based MWF 67 coolant.

S. S. Bhambale (75) dealt with experimental investigation on the role of wet lubrication system on cutting temperature, tool wear in turning of mild steel at industrial speed-feed combinations by H.S.S cutting tool. The encouraging results include significant reduction in cutting temperature, tool wears by wet lubrication system mainly through favorable chip-tool and work-tool interaction.

2.2.4 Genetic Algorithm:

Darrell Whitley (76) state that the thing that is striking about genetic algorithms and the various parallel models is the richness of this form of computation What may seem like simple changes in the algorithm often result in surprising kinds of emergent
behavior. Recent theoretical advances have also improved our understanding of genetic algorithms and have opened the door to using more advanced analytical methods.

T. Srikant (77) proposed a real coded genetic algorithm (RCGA) to find optimum cutting parameters. The study explains various issues of RCGA and its advantages over the existing approach of binary coded genetic algorithm. The results obtained, conclude that RCGA is reliable and accurate for solving the cutting parameter optimization. This study proposes a real coded genetic algorithm (RCGA) to find optimum cutting parameters. The study explains various issues of RCGA and its advantages over the existing approach of binary coded genetic algorithm.

Roman Gäatzi (78) presented a tool, which applies GA to solve typical problems in structural optimization, integrating ANSYS on a UPF (User Programmable Features) level to evaluate the objective function (fitness values of GA individuals). To overcome efficiency limits, the method is implemented for parallel evaluations on a workstation cluster. The performance of the software tool is shown by two real world applications, the frequency optimization of a complex machine tool frame and the weight minimization of a fuel cell plate.

Z. Car (79) presented a novel approach for optimization of the machining parameters (turning process) by the use of artificial intelligence. The proposed model is combined between GA and implementation of binary linear programming optimization (LP). This methodology has been implemented to optimize the turning simple model process. The main advantage of proposed method is ability to perform multi-object optimization, minimum machining time and minimum production cost, while considering technological and material constrains. The results obtained from the simulation model have presented a fast and suitable solution both to the automatic definition of the machining parameters and to possible implementation in CAPP systems. The simulation results have been confirmed by the experiment.

T. Dereli (80) introduced a ‘system software’ developed to optimize the cutting parameters for prismatic parts. The system is mainly based on a powerful artificial intelligence (AI) tool, called genetic algorithms (GA). It is implemented using C
programming language and on a PC. It can be used as standalone system or as the integrated module of a process planning system called OPPS-PRI (Optimized Process Planning System for prismatic parts) that was also developed for prismatic parts and implemented on a vertical machining centre (VMC). With the use of GAs, the impact and power of AI techniques have been reflected on the performance of the optimization system.

Franci CUS (81) presented a new methodology for continual improvement of cutting conditions with GA (Genetic Algorithms). It performs the modification of recommended cutting conditions obtained from a machining data, learning of obtained cutting conditions using neural networks and the substitution of better cutting conditions for those learned previously by a proposed GA. Operators usually select the machining parameters according to handbooks or their experience, and the selected machining parameters are usually conservative to avoid machining failure. Compared to traditional optimization methods, a GA is robust, global and may be applied generally without recourse to domain-specific heuristics. Experimental results show that the proposed genetic algorithm-based procedure for solving the optimization problem is both effective and efficient, and can be integrated into an intelligent manufacturing system for solving complex machining optimization problems.

Ramón Quiza Sardiñas (82) presented a multi-objective optimization technique, based on genetic algorithms, to optimize the cutting parameters in turning processes: cutting depth, feed and speed. Two conflicting objectives, tool life and operation time, are simultaneously optimized. The proposed model uses a micro genetic algorithm in order to obtain the non-dominated points and build the Pareto front graph. An application sample is developed and its results are analyzed for several different production conditions. The study also remarks the advantages of multi-objective optimization approach over the single objective.

R. V. Rao, V. J. Savsani & J. Balic (83) proposed an efficient optimization algorithm called teaching–learning-based optimization (TLBO) to solve continuous unconstrained and constrained optimization problems. The proposed method is based on the effect of the influence of a teacher on the output of learners in a class. The basic
philosophy of the method is explained in detail. The algorithm is tested on 25 different unconstrained benchmark functions and 35 constrained benchmark functions with different characteristics. For the constrained benchmark functions, TLBO is tested with different constraint handling techniques such as superiority of feasible solutions self-adaptive penalty, $\varepsilon$-constraint, stochastic ranking and ensemble of constraints. The performance of the TLBO algorithm is compared with that of other optimization algorithms and the results show the better performance of the proposed algorithm.

R. Venkata Rao and V. D. Kalyankar (84) presented a new advanced algorithm for the process parameter optimization of machining processes. This algorithm is inspired by the teaching-learning process, and it works on the effect of influence of a teacher on the output of learners in a class. The results obtained by the proposed new algorithm have outperformed the previous results for the considered machining processes.

R. Venkata Rao, Vivek Patel (85) introduced Teaching–Learning-Based Optimization (TLBO) algorithms simulate the teaching–learning phenomenon of a classroom to solve multi-dimensional, linear and nonlinear problems with appreciable efficiency. In this paper, the basic TLBO algorithm is improved to enhance its exploration and exploitation capacities by introducing the concept of number of teachers, adaptive teaching factor, tutorial training and self motivated learning. Performance of the improved TLBO algorithm is assessed by implementing it on a range of standard unconstrained benchmark functions having different characteristics. The results of optimization obtained using the improved TLBO algorithm are validated by comparing them with those obtained using the basic TLBO and other optimization algorithms available in the literature.