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A Comprehensive Review on AISI 4340 Hardened Steel: Emphasis on Industry Implemented Machining Settings, Implications, and Statistical Analysis

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Abstract: Turning of hardened AISI 4340 steel is regarded as one of the demanding challenges in machining sectors where precision tolerances are essential for automobile parts. The AISI 4340 steel is broadly utilized in forged steel automotive crankshafts systems, hydraulic forged and additional machine tool purposes because of their improved characteristics. Moreover, one of the keys confronts in the machining of hard 4340 steel is the comparatively deprived machining behavior that reduces the functionality of the material and further leads to component rejection at the final inspection stage. In addition, accelerated tool wear necessitates for repeated changing of cutting tool that results in higher machining and tooling costs. This comprehensive review aimed to present in-depth features on the development of machining performances using various cutting tools. This review focus is to provide a broad perceptive of the role of controllable variables during machining of hardened steel. This review analysis examines the response variables and their advantages of chip morphology and heat generation. The comprehensive overview of machining settings, key machinability indicators and statistical analysis for AISI 4340 steel. This overview will provide academic, industrial and scientific communities with benefits and shortcomings through improved conceptual understanding towards further research and development.

Keywords: AISI 4340 hardened steel, machining performance, optimization techniques, cooling conditions

1. Introduction

In the year 1980s, the concept of hard part turning has been introduced in the machining sector. In this process, more than 45 HRC materials are generally used. In recent years, the manufacturing industry faces the need for higher production, adaptability, and part quality because of the advancement of the global machining scenario. From the past few decades and new production strategies, for instance, quick and superior cutting, dry hard machining, complete integration of all the process, developed insert material and total machining, have been implemented. Hard steel machining (45–65) HRC to be dependent on many variables, for example, machining scheme, cutting tool, process parameters and measurable characteristics of materials and tools. Advanced hard part steel material has more requirements for the assembling of cars, aircraft, tooling of machine components and engineering applications owing to their high strength, thermal stability and durability Contrasted with the traditional grinding process, hard part turning is considered as technological cost-effective approach due to less setup time, more material removal rate and rapid cycle time [1].

With the improvement of new hard work materials, the introduction of new performance cutting tools is developing very fastly for machining with better material removal rates. Further, in hard part turning, the assessment of machining performance, for example, tooling wear, formation of the chip, cutting force and measurement of surface integrity is of prime importance [2]. In a modern production scenario, the manufacturing of better quality parts is very

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momentous. The better surface machined quality of the product indicates the quality of work. The operating parameters had a momentous influence on the quality of machined parts [3]. The most usually utilized tools are carbide coated PVD and CVD, PCBN, CBN, and ceramics. The coated tool gives more extended tool life, superior surface texture, and lesser machining temperature when contrasted with uncoated one [4].

Using lower depth of cut and axial feed rate on turning of AISI 4340 grade hardened steel (50 HRC), lesser cutting forces were noted with comparison to less hard material, because of increasing the temperature at cutting region, and it softens the cutting area of the work-piece [5]. To prolong the life span of the inserts, multilayer coatings are needed to provide a combination of better properties. The coating AlCrN offers high corrosion resistance and resists the oxidization temperature up to 1100ºC, it’s a new generation coating [6]. Hard part machining is beneficial in industries due to its dry machining, high productivity, and better surface quality and enriched mechanical properties of finished parts, over grinding processes [7].

It has been observed that the effects of axial feed are more important than machining speed for obtaining better surface roughness [8]. In hardly part machining, the higher hardness of material part, more machining force and excess heat generation at workpiece and tool leads to wear at the tool. This leads to a reduction in the finished product’s quality. Therefore, insert materials act an important phenomenon influencing the insert wear and maintain the superior quality of the machined part [9].

The advantages of the technological development and requirement of better quality components for generating the need for manufacturing parts with superior dimensional and geometrical precision. Moreover, the knowledge of basic machining processes implies fundamental aspects and control of the cutting tools wear and its further influence on the output responses. When the demand for a quality product in the manufacturing sector increases, the ‘Hard Turning’ finds a suitable place concerning this. Various factors affecting this process include machining behavior involving characteristics of the material, cutting tool geometry [10].

More effectiveness of machining and improved surface finish of hardly turned part parts major influence on better functionality at the end concerning tribological behavior, wear, and corrosion resistance. Also, the finish hard turn part can be only achieved by a suitable selection of input variables, the material of tool and it’s the design and machining environmental circumstance. Appropriate choice of the main governing cutting parameters will prolong the tooling life. [11-12]. Improved surface quality and precision accuracy requirements are growing nowadays for the machining sector. Concurrently, the rigidity of machine components and material consumption is minimizing. Since the cutting temperature increases exponentially in the cutting area, effective manufacturing outcome is adversely affected by frequent tool failure/wear in the hard part turning [13].

In hard turning heat generation is a common phenomenon. Basically, it generates in contact zones like tool-workpiece and tool-chip. It influences the machinability characteristics, so heat reduction is essential with the application of cutting fluid. The cutting fluid has three primary functions like it can lubricating the cutting zone, cooling for the tool and workpiece and removal of heat, and also assist for removing the chips from the cutting zone [69]. Kumar et al. noticed that the catastrophic failure of the CBN tool occurs with increasing the hardness of the workpiece and it can be improved by providing the coating on the cutting inserts [71].

The output variables for the quality of the machined part and the tool span life may be disturbed by increasing the cutting temperature through the machining of hardened AISI 4340 alloy steel. For this, worldwide researches have introduced a novel nanofluid lubricating technique which to minimize the friction and heat on the cutting region. The prospective features of Nanofluids have enhanced the thermal conductivity, greater lubricating capability; lessen of pumping power required, and ability of quick heat transfer [106].

In general, the cutting tools are lead to higher cutting temperatures and machining forces, induced by immense abrasion and distortion in hard turning. Coatings are introduced for enhancement of the cutting inserts and are usually layered by PVD and CVD on cutting inserts. The execution of PVD and CVD coated inserts have more wear resistance proficiency. Moreover, nitride-based coatings like TiN, TiCN, TiAlN AlCrN are also used for better performance [107]. The AISI 4340 hardened steel has the capability to develop higher strength when it is heat-treated. It remained investigated that the surface attribute escalates by enhancing the feed rate. But when using the multilayer coated carbide inserts with the CVD layer in dry machining on AISI 4340 steel, it improves the surface roughness value [108]. From the comprehensive reviews conducted by researchers, various output efficiencies are assessed using various input variables like the geometry of the inserts, hardness of work surface, process variables. More importantly, surface roughness, the tool was as output responses as analyzed.

1.1 Significance of 4340 Hardened Steel

AISI 4340 hardenable steel is medium carbon content, high toughness, and strength (after heat treatment) alloy steel. This material is used in oil and gas industries, automotive and aircraft industry and also used in over-all engineering applications like shafts, spindles, pins, gears, chucks, couplings, connecting rods, etc. Because it's hard for machine material, therefore many investigators are interested in studying the impacts of various machining conditions and perspectives for AISI 4340 steel [4].

Lower cutting forces were required for machining the AISI 4340 grade steel with a low depth of cutting and axial feed rates when the hardness of the work part decreases 50 to 42 HRC [5]. For obtaining the required level of mechanical properties like strength, ductility, and hardness of AISI 4340 alloys that should be subjected to a heat- treated process like quenching and tempering, to satisfy the needed [8]. The thermomechanical hardening process generates a better-hardened layer and it will be a cost-effective method than other conventional hardening processes with special benefits like less production cost, waste reduction and minimize the cycle time [14]. It has been depicted that when the machined surface of AISI 4340 steel material's hardness value was more than 50 HRC, the segmentation type chips were formed [15]. The surface hardness of AISI 4340 steel enhanced by the ion nitriding treatment process increases the time and temperature. The most extreme work hardness was acquired at 500 °C for 8 hrs, and also the maximum thickness of the workpiece was formed at 540 ° C for 16 hrs [16].

1.2 Factors Affecting HSLA Steel

Various effects significantly affect the machining of the hard part turning of high strength low alloy steel. The factors affecting the hard turning of HSLA are demonstrated in Fig.1. In addition to the above factors, 4340 the details chemical composition of hardened 4340 alloy steel is depicted in table- 1.

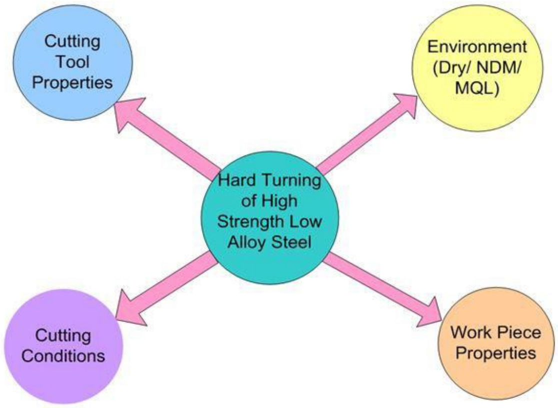

Fig. 1 - Factors affecting the hard turning of HSLA Steel

Table 1 - Details composition (Chemical) of hardened AISI 4340 alloy steel [3]

Constituents	Fe	Cr	Ni	Mn	C	Mo	Cu	Si
%	95.6	1.270	1.41	0.456	0.412	0.203	0.294	0.211

1.3 Features of Reliability

Evaluation of reliability of tools and future envisage of the tooling wear evolution will be enormously important as the cutting with a worn tool influences the surface finish, precision dimensional accuracy.

The reliability of a cutting tool concerning with the tool flank wear is of principal significance during cutting because of its straight influence on the part accuracy and supportive surface finish. The reliability of the tool is evaluated to comprehend the tool wear mechanism and growth at various stages of tool life studied by Chinchanikar and Gaddafee [17]. Premature failure of the tool can bring about the wasting of the machining component and yet getting downward the manufacturing system to a halt [18].

2. Machining Settings

There are various important factors associated the cutting condition. Different types of machine tools, cutting inserts and environment are the attributes that significantly influence the marching practice.

2.1 Machine Tool

There are important CNC factors for machining like maximum feed rate, acceleration, S-curve time constant, acceleration following interpolation time that affect the surface roughness, accuracy, and cycle time [19].

Commercially available machine tool used in experimentation with 4340 steel. The ideal characteristics [20] of the high precision lathe is presented below:

- Precision compable to conventional grinding machine
- Low power needed
- High thermal stiffness
- The hydrostatic bearing of slides and spindle

Moreover, the different machine tools used by various researchers as presented in table 2. Maximum investigators have used CNC lathe machines during the experimentation. This is because the use of CNC machine tool provides more precision products as compared to the conventional one.

Table 2 - Machine tools used by various researchers

Investigator (s)	Machine Tool
Selvam and Sivaram [3]	Geared Conventional Lathe (Pinacho SC200)
Coelho et al. [6]	Nakamura Tome SC-450 (CNC) lathe.
Natasha et al. [8]	TORNADO CNC lathe machine
Chou [14]	YAM CNC lathe
Mondal and Das [21]	Kiloskar lathe
Dhar et al. [22]	Lathe Machine (Lehman Machine Company,USA)
Khan and Bhivsane [23]	CNC machine ace Marcomatic company
Das et al. [24]	CNC lathe (SPRINT 16TC, Batliboi Ltd.)
Kumar et al. [25]	CNC LATHE (Galaxy Midas 6)
Gnanadurai [26]	Kirloskar Turn master-35 lathe
Varadarajan et al. [27]	VDF S500 heavy-duty lathe
Cydas [28]	CNC lathe (John Ford T 35)
Jena et al. [29]	CNC lathe (model,CJK6132, make, Bhavya Machine Tools)
Das et al. [30]	CNC lathe machine (Jobber XL, AMS India)
Das et al. [31]	CNC lathe (SPRINT 16TC, make: Batliboi Ltd
Naigade et al. [32]	Machine tool (Jobber XL Make)

2.2 Summary of Inserts using AISI 4340 Steel

Cermet cutting inserts are used extensively for cast iron and steel cutting due to their thermal crack resistance and hot hardness. These tools produce improved geometrical accuracy, longer tooling life, and superlative surface finish than tungsten carbide tools in terms of assessing responses. The cryogenically treated cermet tool exhibited lower tool flank wear than that of cermet cutting tool (untreated) during machining of AISI 4340 steel hardened (43-45 HRC) [33]. Hard part turning with minimum application of fluid in the occurrence of pure form grease and 10% graphite gives improved cutting output behavior as compared with dry turning with minimum quantity fluid application [34]. Tool wear measurements revealed the ability of CNMA-120408-KR grade K-20 (TiCN-Al_2O_3-TiN) multilayer coated tools in turning of heat-treated 4340 steel with supportive tool life [35]. The performance of various cutting inserts for the machining of 4340 hardened steel under multifarious environments is presented in table- 3.

Table 3 - Summary of various machining details of AISI 4340 grade hardened steel materials with its variable parameters

Ref & year	Tool details	Tool holder details	The hardness of work materials(HRC)	Response variables	Findings
[5] 2007	Carbide coated insert with ISO gradeH15 and P15 GC4015, SNMG120408-PF (Sandvik)	PSDN 25 25 M12	23, 35, 42, and 50 HRC	cutting force, feed and thrust forces	When spindle speed increases, the cutting force was reduced with thrust forces and axial feed remains constant.
[6] 2006	PCBN coated and uncoated edges. (TiAlN, TiAlN-nanocoating, and AlCrN.) CNGA432	MCLNL-164D		roughness, tool wearing, and cutting forces	TiAlN-nanocoating inserts Performing well regarding surface roughness value and tooling wear.
[7] 2006	CBN–TiN coated (BN250), PCBN (CNMA432)	DCRNL854D,	HRC = 53	tooling wear, supportive surface roughness, machining forces, tool lifespan	The PCBN inserts provided a constant machined surface value than cBN+TiN coated inserts but it requires more cutting forces than PCBN inserts because of the large tool nose radius.
[8] 2018	Flat face P10 CVD coated carbide insert coated with TiC + Al2O3.	N.A	N.A	Tool wear, surface roughness	Tool wear influences the values of the machined surface Roughness.
[9] 2018	Multilayer ($TiN/Al_2O_3/TiCN$) CVDcoated carbide-TT8125 and Single-layer (TiCN) PVD-coated carbide-TT8020 [SNMG 120408 for both]	MSDNN 2020 K12	48 ± 1 HRC	Tool life(flank wear) VB	At high-speed machining multilayer, CVD coated carbide (8.1–27.5 mins) performs better than Single-layer PVD one (4.8–40.3) mins at flank wear 0.2 mm.
[10] 2018	MT PVD multilayer carbide coated (Al2O3 outer layer) [CNMG120408]	PCLNR2525M12	50±1 HRC	Tool flank wear, surface (work) roughness	Feed influence the roughness values in both dry and MQL. More flank wear occurs

					in dry conditions than MQL.
[13] 2019	Multilayer PVD coated ceramic tool (Al_2O_3–TiCN) [CNGA120408 AB2010]	PCLNL2525M12	49HRC	Machined surface value (Ra)	When the axial feed rate increases, the value of Ra also increases but opposite in cutting speed.
[25] 2018	Cemented carbide with TiCN and Al2O3 coatings [CNMG 120408]	PCLNR 2525M12	49±1HRC	surface roughness and tooling wear	Feed rate influences surface roughness and depth of cutting impacts on tool wear followed by machined cutting velocity.
[36] 2016	Single-layer TiN-coated CBN inserts and uncoated CBN one,(K5625)[SNGA 431S0425MT]	MSSNR2525M12	45 HRC	surface roughness (Ra)	The lowermost machined surface value was attained at a spindle speed of 150 m/mins with a low axial feed rate by using TiN-coated CBN inserts.
[37] 2013	Multilayer (TiN+TiCN+Al2O3+ZrCN) carbide coated- CVD [CNMG 120408]	PCLNR 2525M12	47±1HRC	surface roughness	Machined surface attribute value escalates by incrementing the axial feed rate and it minimizes by enhancing the rotational speed.
[38] 2007	SNMM 120408 (Carbide coated)	PSBNR 2525M12	N.A	Tooling wear, surface roughness	By reducing the tool flank wear and notch wear, supportive surface roughness value can be better enhanced under MQL conditions.

Tool lifespan was generally influenced by work material's hardness characteristics. The tool with CVD coated performed better than PVD coated one. Tool lifespan has been controlled by spindle speed. The best parametric value used for machining was spindle speed (150 m/min), axial feed (0.15 mm/rev) and depth of cut (0.4mm) [4]. It is difficult to machining the AISI 4340 steel with the hardness exceeds 50 HRC by carbide coated inserts, even with low MRR [5]. Coated materials generally provide more hardness value at high-grade temperature; better lubricant properties, and well chemical bonding stability and also better thermal behavior and many more. Both physical vapor deposition and chemical vapor deposition coatings are commonly applied for this. The coating materials like Al_2O_3 have been successfully implemented as an intermediate layer of a cutting insert [6]. In hard turning, PCBN is also the best tool material because of its high degree of thermal stability, high level of wear resistance and great hardness characteristics [7]. Nose radius plays a vital role in obtaining a better surface roughness than other parameters, for example, cutting pace, axial feed rate and depth of cutting [23]. The superior quality of the workpiece surface was identified by the use of CBN (TiN-coated) tools, compared with CBN uncoated tools, in dry conditions of hard turning. It has been found that improvements in surface quality are between 10 and 15% [36].

2.3 Cutting Tool Surface Texturing

In general, coatings advance the life span by minimizing the thermal energy entering into the cutting tool material. Surface texturing is a promising technique that is assisted with the tribological characteristics of the textured inserts. Furthermore, these innovative tools have various geometrical shapes and sizes. The textures are formed either on the flank or rake surface. Enhancement of the basic tribological properties leads to enhancement in lubrication capability, which assists in minimizing the cutting tool wear, augment surface roughness, and the components of metal removing forces [39]. An efficient technique to improve machining behavior is to eradicate the heat from the deformation areas. This helps considerably to enhance tooling life by restraining the temperature-reliant factors and machining at an elevated value of cutting pace and feed rate, so improving the manufacturing productivity. The 4340 grade-steel is usually used low-alloy high-strength steel [40]. Since the chemical reactions, diffusion is temperature dependant therefore; temperature measurement is related directly to manufacture parts quality, tool wear pattern. Thus, the manufacturing production rate and efficiency of production are adversely affected by temperature increment [28].

Using the lower magnitudes of cutting pace, feed rate, and depth of cutting, tooling wear can be reduced. Normally, at lower range of machining conditions undersized broken shaped non-regular chips were produced. The plausible cause may be at lower turning situations abrasive actions and rubbing are the main factors than the tangible cutting and consequently uneven shaped chips are generated [41].

The microstructural features and mechanical characteristics are significantly affected by tempering process temperature and the holding time. The hardness and strength of tempered martensite decrease as the tempering holding time and temperature are effectively improved [42]. The factors e.g. depth of cutting, feed, and rotational speed are considered as main variables with an effort to examine supportive roughness as only output performance factor [29]. By far, an inherent observation was found through the turning of hard 4340 AISI grade steel using ceramic cutting tools at dry conditions. When rotational speeds vary from 150 and 250 m/min, the ceramic alumina tools (ZrO_2) have ameliorative wear resistance than the alumina mixed cutting tools [43].

The cryogenic turning process fundamentally involves the modeling and optimization of the input cutting parameters affecting the machining output performance and value-oriented towards sustainable manufacturing [44]. The distribution of residual stress during tuning of bearing hardened components has been explored experimentally [45]. CNC cutting process 4340 bar in MQL method with the addition of nanofluid for distinctive roughness and machining forces as output measure has been studied. Further, to attain the best parameter, the smaller the better criteria for surface roughness have been considered [46]. The appropriate utilization of coated (multilayer) carbide tool in hard part turning has various benefits over the conventional grinding practice such as; lessening of manufacturing costs, better manufacturing production rate, shorter cycle time, supportive surface roughness and fewer environment glitch devoid of the cutting fluid utilization [30].

It was approximated that the overall cutting cost per turned component is Rs.8.21 for 4340 hardened grade steel with CVD based carbide tool [31]. The thickness of the white layer on the freshly turned surface was lesser with the coated tool than with the cermet uncoated one [47]. The cutting tool material should have more temperature resistant characteristics with a better ability to survive higher levels of stress in machining. Besides, they should have, shock resistance, superior corrosion resistance, and chemically inert towards workpiece material [48]. 4340 plates of steel used for manufacturing critical parts for automotive transmissions bearings production, gears, cams, duty shafts, axles, spindles, pins, and, couplings, aerospace engineering that require geometric accuracy, prolong service lifespan and high-value surface finish where rigorous dynamic loading compels stringent conditions on the turned surface. The fast- growing requirement for the superior quality of surface and precision geometrical accuracy has effected the immense amount of production research [49]. Modern industries require imperative surface roughness with prolonged tool lifespan and decreased temperature at machining zone and force while cutting [50]. The proportional assessment of CBN inserts in cutting of AISI4340 steel in traditional wet and dry turning with MQL has been experimented by changing the depth of cut, speed, and feed [51].

In general, AISI 4340 alloy steel is used steel having used in automobiles and other applications due to its excellent hardenability attribute [52]. Dry cutting is regarded as sustainable manufacturing; although, machining of hardened steel with high hardness, a higher temperature and difference in machined surface entail thermal pacification [53]. The axial depth of cutting reveals the utmost sway on cutting components of forces compared with the feed and rotational speed to attain the required quality with more attention on the appropriate choice of the operating parameters [54].

3. Machining Environment

In machining of each workpiece, the high-temperature zone is formed due to the interface of the chip-tool or work piece-tool and this heat is hazardous to both the work and cutting insert. Additional heat produced on the cutting area will result in the higher tool wearing and lessen the features of the surface that will have an impact on the economy of production. This extreme heat will be well controlled by the application of cutting liquid solutions during the process of turning which performances as lubricants in between work as well as tool and diminishing the generated friction. The surface roughness value rises with escalating depth of cut and feed rates for all conditions of machining [3]. Because of the increasing cost-effective demand and an environmentally friendly machining process, the green machining strategy moves towards a great scope. Environmental friendly (Green) machining strategy generally includes MQL, spray, dry, cryogenic and air cooling machining conditions. Many investigators examine the characteristics of MQL, dry machining and cryogenic cooling systems throughout the hard turning in 4340 steel [4]. Machining with small axial feed and depth of cutting, it remained observed, lesser cutting force, with turning on AISI 4340 hardened steel material of HRC 50 in comparison with 42 HRC [5].

3.1 Dry Machining Conditions

In hard turning operation, hardened steel is usually machined with dry conditions, so it generates more heat on the cutting zone and can make easily shearing by dropping the shearing strength of the workpiece, and finally produces better surface finish. But it may change the metallurgical properties of the work surface, also formed the white layer and tensile residual stress distribution on the workpiece and also affect the tooling life due to high heat generation. It reduces the machining cost, and environmental as well as labor-friendly with the absence of lubricants. On the other hand, deprived tool life may increase production costs [1]. The dry hard machining appeared due to its improved performances although it is challenging to turning the hardened materials with commonly coated insert without the use of coolants [4, 82]. For large scale manufacturing industries with a high production rate, the dry condition machining is desirable [10].

3.2 Lubrication Conditions

Hard turning with cutting fluids by different lubricating and cooling techniques may improve the cutting performance but it harmful to the environment. It can be replaced with liquid nitrogen (cryogenic cooling), solid lubricants like molybdenum di-sulfite (MoS2) and minimum quantity lubrication in hard machining. Solid lubricants can reduce the surface roughness and cutting force as associated with dry hard turning, but it does not really affect tooling life [1]. In coolant flood machining, fluid is permitted to be reused inside the machine, because of the development of micro- bacteria (which leads to bad odor). This is unsafe for the surroundings when it is disposed of [3]. Generally, the cost of cutting fluids is higher than the cutting inserts which impacts the total machining costs [22]. With the mixing ratio of 1:20, an oil-based lubricant can be used at the flank and rake surface of the tool by the nozzle [82].

3.3 Near Dry Machining (NDM)

NDM uses a small amount of liquid that is mixing with highly compressed air and produces a good mist coolant that cannot be seen by the human eye and almost is considered dry machining. This mist dramatically reduces the amount of heat by the compressed air and very little amount of coolant. NDM takes out the reusing of coolants, which avoids the presence of microorganisms inside the work environment and thus can eliminate all health problems [3].

A larger extent of heat is produced on the machining zone for the period of dry hard turning because of friction between the surface of the machined work and cutting inserts. To accomplish better surface quality and to reduce heat generation, the use of coolant is needed, as a result, the procedure of MQL (minimum quantity lubrication) meets the desired. The carrying out of machining performance with MQL was best when contrasted with flooded and dry environments at the stage of AISI 4340 hardened steel machining, i.e. (improved tool life and surface roughness). This strategy gave both financial and environmental advantages as the coolants are eco-accommodating and its utilization throughout the process was just 900 millilitre per hour which is insignificant when contrasted with regular cooling techniques [4]. The importance of MQL with oil and air brings down the contact length contrasted with dry machining at both longer and smaller engagement machining time [55]. The application of supplementary water jet with MQL on the topmost surface of the machined chip and tool tip-work surface contact area that improves the chip curling and diminishes the contact length of a tool- chip. It provides improved rake face cooling at the tool- chip contact area. By the application of nominal fluid with an auxiliary pulsing jet of water, that produces tightly coiled chips. Its impact is better on the shop floor environments [26]. The introduction of MQL on machining can give better surface roughness and chip formation [105].

3.4 **Cryogenic Environment**

Cryogenic conditions reduce the heat, produced in the area that is treated as a working zone and the microstructure of work specimens is not influenced during the machining activity, even when using high-performance parameters. It has been observed that the use of cryogenic conditions is very workable when the flow of coolant is taken away from the edge of the cutting tool [4]. Cryogen cutting fluids like helium, oxygen, methane, liquid nitrogen, ethane, and argon, etc. are used as a cutting fluid for reducing the cutting temperature during hard turning and it affects the outputs of machining like machining temperature, tool wearing, surface roughness and cutting forces [8]. MQL reduces the tool wear, improves the tooling life span and machined surface finish as associated with dry and show conditions while machining the AISI 4340 hardened steel, because of minimizing the cutting temperature. That improves the tool life/efficiency with advanced cutting speed and axial feed rate [22]. Machined surface finish and tool wear are greater under machining in dry conditions than wet conditions [25]. The jet flow of nitrogen liquid to the work zone from the nozzle pipe (internal diameter 1.5mm) with the rate of flow pressure 0.36 lit/min. gives better performance than dry and wet lubricating conditions on the turning of AISI 4340 hardened steel [82]. Machining with cryogenic conditions that are like liquid nitrogen and frozen carbon dioxide as the main cutting fluid, can reduce the cutting force and increases productivity [105].

4. Analysis of Machining Studies and Their Functional Relationships

The parameters, which influence the different stresses produced during machining of AISI 4340 grade hardenable steel are mainly main operating parameters, tools, and work characteristics. The formation of residual stress has been found to depend on the feed and speed of the process, while the depth of cut had an insignificant impact on hoop residual stress [4]. When hardness was raised from HRC 23 to 35 the cutting force slightly falls, but thrust forces and feed rate increases concerning hardness [5]. The significance of surface roughness diminished when the spindle speed increases concerning feed rate of (0.3 & 0.4) mm/rev, in both dry and cryogenic states. This may be because of greater temperatures, which are made a higher cutting rate, which makes softer the workpiece. Thus, lesser forces required for machining and give improved machined surface value than cutting with lower speed [8]. Machined surface quality in harden material turning can be improved by choosing a combination of proper parameters, such as tool geometry and materials, details of work materials and cutting environs [36].The depth of the cut isn't too high impact the surface roughness value, however a slight increase by increasing the depth of cutting for harder material due to chatter [13]. Nose radius of cutting insert influences surface roughness value [56]. Due to the escalation of feed rate, the MRR value also increases that produces more heat and swaying the surface roughness value than spindle speed and depth of cut [57]. The distribution of residual stress and micro-hardness difference on the machined surface was biased by the axial feeding rate. However, the measured surface roughness value was increased due to a swift tool wearing at higher cutting speed when machining the AISI 4340 harden-able steel [58]. At higher axial feed rate, residual stresses also are more tensile because of only increasing the cutting temperature that also increases measured surface roughness value [59]. Chip segmentation occurrences increase when the cutting velocity (Vc) rises and it may be decreased by increasing the axial feed rates (f). The saw-tooth chip instigation is caused by adiabatic shear at the tool edge and machined surface. Narrower band type chips are generally formed owing to the softening phenomenon of workpiece material [60]. Feed force increases at a higher depth of cut but at higher cutting speed and feed rate, the feed force decreases [61]. By using coated and PCBN tools on AISI 4340 hardenable steel it was found that when the cutting speed increases, machining forces were reduced and the surface finish of the machined part also improved but feed rate may be deteriorated [62]. The machined surface roughness value (Ra) for dry environmental turning was 1.2 µm and for wet environment turning was 1.1 µm respectively but in the case of MQL conditions, it was 0.9 µm [63].

4.1 Turning process parameters

The high-quality turning of HSLA steels depends on the proper selection of process parameters includes operating parameters and tool characteristics. The main operating parameters include the tool feed rate, the rotational speed and depth of cut. Moreover, the cutting tool distinctiveness includes the cutting tool types, tool geometry, tool materials, and hard coatings. Moreover, main governing parameters are interrelated to the tool characteristics and both have a greater impact on output characteristics are surface roughness and tooling wear. Consequently, the selection of appropriate turning parameters is necessary for operation because optimum process parameters help in the best performance of turning operation and maintaining the acceptable surface finish [64].

4.2 Overview of Chip Formation

The analyses of chips are significant since the surface integrity of the freshly turned part is extremely reliant on the chip formation in the hard part turning. For that reason, the analysis of chip formation and its microphotography is extremely imperative for any cutting practice to a better understanding of the work-cutting tool performance in cutting circumstances. [65-66]. Turning hard part steel is a general process in modern industrial practice that is basically employed for a wider variety of industrially manufactured goods, such as bearings, cams, axes, cast pieces, matrices. However, one of the most vital performance issues in hard turning is the surface integrity [67]. In an overview summarized by Dogra et al. [18] on the major techniques to attain surface finish issues and on the modeling methods to effectively, signify surface integrity. Chip formation analysis is the key research area during the hardened steel machining. The exhaustive shear process mainly depends on machining approaches and rotational speed. The accomplishment of superlative surface quality and various forms of the chip are assessed by hard turning technology [68].

4.3 Overview of Heat Generation

In precision finish hard turning process, the output characteristics are influenced highly by the frictional heat increased through the cutting practice. The higher frictional heat generation grounds the cutting tool wear that tends to diminish the machining behavior. The generation of heat is a natural occurrence for any cutting maneuver. It produces at different zones essentially in tool-workpiece and cutting tool – chip contact region. Reduction of heat is vastly necessary because it sways various output characteristics aspects. Therefore, the reduction of heat and augmentation of output performance is the prime motive for the cutting process [69].

4.4 Overview of Surface Roughness

Surface roughness has been investigated as a sign of quality characteristics for the machining process. Product quality plays an indispensable role in competitive industries. From a customer's point of view, quality significantly throws into elongated revenue because of the extent of customer satisfaction [11]. The cutting process reliant nature of the surface roughness generation approach with the various uncontrollable parameters that impinge important phenomena, make impractical for a direct solution [70]. The work surface quality is the main function variable machining variables. Production parameters are the important factors that significantly affect the product quality, tooling lifespan and finally the production rate. Generally, the input factors are selected based on working material and tools. Enhanced output characteristics are observed during turning of AISI 4340 hardened cylindrical bars with the narrow, TiC coated, and without groove tools when the operating cutting speed is larger than 100 m/min [21].

4.5 Significance of Turning Responses

The hard materials coating on inserts is useful to augment output performance. The output characteristics can be improved by offering the coating of the hard material of on inserts. The responses of CBN tools (TiN-coated) are assessed of hard AISI 4340 steel during dry turning that offers significant benefits [71].

Table 4 - Literature review based on AISI 4340 steel

Workpiece specification	Cutting Tool	Tool Holder	DOE	Author (s)	Turning Responses
Diameter 65-mm and length 350-mm	K5625 (grade), SNGA 431S0425 MT	right-hand tool holder, MSSNR2525M12	(CCD) of RSM	S.Kumar [36]	chip–tool flash temperature, cutting force
Diameter 150 mm and length 400 mm	Authors prepared (Y-ZTA) zirconia toughened alumina ceramic cutting tool		(CCD) of (RSM).	Mandal et al. [61]	The surface quality of machined surface
Diameter 32 mm and length 100 mm	TNMA160408-THM-WIDIA uncoated carbide cutting insert	PTGNR-2020-16		Singh et al. [72]	Temperature, cutting forces, Microphotography of chips
Diameter 90 mm and length 400 mm	PVD-coated TiAlN carbide insert	N.A.	N.A.	Chinchanikar and Gaddafe [17]	Tool wear
Diameter 90 mm and length 220 mm	PVD–TiN coated Al_2O_3–TiCN mixed ceramic tool CNGA120408 AB2010	PCLNL2525M12.	desirability function approach of RSM	Panda et al. [102]	Surface Roughness

A review of the main cutting parameters and the cutting tool characteristics that affect the effectiveness of hard turning concerning texture, machining forces, and surface machined integrity machined has been presented. [73]. Shalaby and Veldhuis [43] observed that the tribo-films outlined at the machining area significantly swayed the wear resistance of the cutting tools.

4.6 Effects of Measured Residual Stress during Hard Turning

The magnitude of principal residual stresses and its orientation is of enormous importance. Residual stress is an essential direction as if it corresponds with the direction of stresses acting on the component, therefore. the nominal load and component service life will be affected significantly, leads to probable untimely failure of the part [74]. Residual stresses influence the mechanical performance of the parts. It observed that maximum stress is focused approximately 30° from the direction of cutting. The trial was performed on AISI tempered martensite 4340 steel bars [75]. During the trials, depth of cut was constant (0.6 mm) and cutting speed, feed rate, and approach angle, and are varied to four levels and to examine the consequence on the three components of the cutting forces and the on the tool- edge temperature variations. The PVD based inserts generate improved results contrasted to coated inserts (CVD) regarding machining forces components and tool-cutting edge temperature [76].

4.7 Formation of While Layer and its Effects during Hard Machining

White layer formation is because of the transformation of phase to martensite. The coolant is favored to be utilized in the hard part turning to reduce the thickness of the white layer**.** Three general contributing mechanisms like plastic flow, fast heating and quenching, surface reaction (carburizing, nitriding, and oxide plowing), cooling rate and pressure strain rate and are identified responsible for white layer formation [73].

4.8 Microphotography of Chips

The size and shape of the chip generated are a prominent aspect for assessing any performance trial. Microphotography of chips eventually signifies the decrease in the chip–tool flash contacts gamut and decrease in metal removing forces. The chip surface morphology study with surface integrity is crucial for unidentified work piece- tool amalgamation in machining. Moreover, the formation of chip influences the dynamics of machining, tooling span and product quality [77]. With the enhancement in rotational speed, more frictional heat is produced at the machining zone. The major area of the heat developed is removed by the chips (intermediate) because of high frictional force along with plastic deformation [3, 4]. Formation of saw tooth-kind of a chip is observed while CBN tools machining indicating easy eradication of the chip because of exhaustive plastic deformation. Moreover, the continuous types of chips are shaped with CBN tools (TiN-coated) due to more frictional heat production and the TiN performs as a lubricant, has a tendency to curtail the heat [36]. Furthermore, while machining AISI 4340 graded steel, a high-quality surface finish with discontinuous has been obtained that confirms the stability of the insert generated [77].

4.9 Tool Wear Phenomenon

During the cutting practice, the interaction amid the tools, workpieces, and chips causes tooling wear. Usually, tool wear influences directly the quality of the finished part and manufacturing costs; however, wear is an inevitable phenomenon. The influence of various lubricating surroundings by pure canola oil and graphene mixed in canola oil, on the output characteristics of textured carbide uncoated tools in MQL based AISI 4340 turning has been studied effectively [72].

4.10 Influence of Cutting Forces

The manufacturing efficiency of any machining practice generally depends on metal removal forces as this response is reliant directly on the insert material, geometrical parameters, work material like hardness and depthness of cut, cutting pace, feed rate) [39]. Impingement of cutting fluid presents competent heat transfer leading to lesser cutting temperatures compared to traditional wet turning [27].

4.11 Analysis of Tool Life

Inserts wearing are the most significant perspectives on hard turning. When the hardness of material increases up to 50 HRC, the wearing is reduced on ceramic and PCBN tools, after that it increases constantly. When the uncoated inserts are used for machining, the Cutting force has been increasing, due to the accelerated flank wear of tool [56]. The crater wearing PCBN inserts is more than cBN–TiN coated one due to its better friction resistance [7]. Ginting et al. investigated that using CVD-(TiN/Al_2O_3/TiCN) coated inserts demonstrates the results of tooling life (T) ranges from (8.1–27.5) minutes and for PVD monolayer coated carbide (TiCN) shows the results of tool life (4.8–40.3) minutes. The more tool life is obtained from the CVD multilayer than the carbide coated PVD monolayer layer tool. However, the carbide coated PVD monolayer layer cutting tool performs better on light cutting or finishing conditions. In hard turning, the frictional force generates in between work surface and tool, which resulting in the initial wear of the tool that decreases the quality of the surface and also dimensions of the finished part. The coating makes an important role in increasing the tool wearing resistance [36]. In hard turning, nanocrystalline and nanocomposite coating improves the performance of machining and tool life, and also improve the better-machined surface integrity [78] Coated carbide tool (Al_2O_3) have better abrasive wear resistance (approximate 4.6 times) than uncoated one [79]. The PVD coated multi-layered carbide inserts perform better on hardened AISI 4340 steel under different environments without any tooling failure or catastrophic failure [10]. The discontinuous chip is because of the internal crack formation and propagation in the cutting tool front [80]. It is very important to reduce the axial feed rate and escalation of the cutting velocity to accomplish the less surface residual stresses (tensile) on machining the AISI 4340 hardenable steel, so it improves the life span and surface integrity of machined part [59]. The life span of multilayer TiN coated carbide inserts and ZrCN is approx.19 min and 8 min respectively but for carbide inserts(uncoated)lower than 1 min for hardenable AISI 4340 (47 ± 1 HRC) steel under extremely dry conditions [81]. The various cutting fluid used by various researchers is presented in table- 5.

Table 5 - Cutting fluid used by various investigators

Investigator	Cutting parameters (process variables)	Cutting insert details	Cutting fluid details	Cutting environments	Conclusions
Selvam and Sivaram[3]	Cutting Speed, depth of cutting, feed rate	TiN-coated carbide cutting tool CNMG 431-PF 4325 80º	Water with 'S' grade Servocut oil	Dry, near-dry and flooded	The hard machining in near dry conditions delivers superior surface roughness value than the flooded environment.
Lima et al.[5]	cutting speed, feed rate and depth of cut	Coated carbide, ISO grade P15, H15 (Sandvik GC4015, SNMG 120408-PF	N.A	Dry turning	More cutting force is required for high hardness material and it increases relating to raise the axial feed and depth of cutting.
Coelho et al. [6]	Rotational speed (150 m/min), feed (0.07 mm/rev) and depth of cutting (0.2mm)	PCBN coated (TiAlN-nanocoating) and uncoated edgesCNGA432			PCBN TiAlN-nano coated inserts have more tooling life and better surface finish than uncoated ones. Uncoated insert required higher cutting force.
More et al. [7]	cutting speed (100–125 m/min), feed rate (0.15–0.20 mm/rev), depth of cut (0.25 mm).	carbide coated composite (Cbn–TiN), PCBN, CNMA 432	N.A	dry	The carbides coated (CBN–TiN) inserts have less crater wear, better surface finish and tooling life than PCBN inserts.

Natasha et al. [8]	cutting speeds (160, 200 , 240 m/min), feed (0.3 , 0.4 mm/rev) and depth of cut 1mm.	Carbide coated multilayer (TiC + Al_2O_3) inserts, P10	liquid nitrogen (LN)	dry and cryogenic	At the higher cutting pace the Ra value diminished for both cryogenic and dry conditions but cryogenic environments have better effects at minimum cutting pace and higher feed rate.
Ginting et al. [9]	cutting speed, feed, depth of cut	Multilayer (TiN/Al_2O_3/TiCN) CVD, coated carbide (TiCN) PVD	N.A	dry	The multilayer CVD coated carbide tool performs improved than a single layer PVD coated carbide one.
Kumar et al. [36]	tool nose radius 1.2mm, feed rate 0.125 mm/rev, cutting speed 150 m/min, workpiece hardness	CBN tools both coated(TiN) and uncoated	N.A	dry conditions	Superior surface quality was obtained under dry situations when using CBN TiN-coated as compared with uncoated one.
Panda et al. [13]	cutting pace 240 m/min, depth of cutting 0.1 mm, axial feed rate 0.0556 mm/rev.	TiN-coated mixed (Al_2O_3–TiCN) PVD ceramic Tool (CNGA120408 AB2010)	N.A	dry	By investigating, the sixteen numbers of experimental data through ANOVA, the results revealed that feeding and speed were the pre-eminent controllable input parameters for obtaining better surface roughness.
Gupta and Sood [82]	Speed, feed, and cooling conditions	Uncoated tungsten carbide	Liquid nitrogen	Dry, wet and cryogenic	Cryogenic cooling gives the best result for optimizing the machining performance.
Mondal and Das [21]	Cutting velocity, feed, and depth of	Carbide insert with titanium carbide (TiC) coated[SNMA 120408, SNMG 120408]	N.A	dry	Better machining was perceived when the pace speed was 272 m/min and feed rate 0.1 mm/rev with the

	cut				inclusion of a wider groove tool inserts SNMG 12 04 08/1025 K15.
Das et al. [80]	Seed, feed and depth of cut	MT PVD multilayer carbide coated (Al2O3 outer layer) [CNMG120408]	LRT 30	Dry, MQL	Improved surface finish in MQL than dry condition.
Das et al. [57]		multilayer carbide coated [CNMG120408]	LRT 30 [DROPSA Italy]	MQL, Dry	Carbide coated multilayer tool gives better performance and surface finish at superior cutting speed in MQL than dry conditions.
Das et al.[37]	cutting speed, feed rate, and depth of cut	multilayer(TiN+TiCN+Al2O3+ ZrCN) carbide coated- CVD [CNMG 120408]	N.A	Dry	The feed rate is the vital parameter than the cutting pace for surface roughness.
Dhar et al.[38]	Speed, feed	SNMM 120408(Carbide coated)	Air, Lubricant	dry, wet, MQL	MQL is superior to dry and wet machining by minimizing the cutting temperature which improves the tool wear.

Very little scientific analysis has been started on, tool wear mechanism, chip, and machined surface morphology that to be explored for the improvement of manufacturing production. Generally, precited cutting factors have very few capabilities for achieving lucrative surface finish and further introduction of new generation tools is associated with the production enterprises, consequently, it is complicated for an operator to choose the best machining factors. In the machining purpose, for some tool-workpiece amalgamation, it is essential to identify the quality characteristics and accuracy (dimensional) in progress. Quality is considered as one of the instructive attributes in modern's cutting enterprise influencing customer satisfaction. [83].When the rotational speed increases the chip variations its form from continuous to saw tooth. Conversely, as the depth of cutting raises, the chip becomes discontinuous type [32]. The performance of hard coatings multilayer on carbide substrate using CVD for cutting of 4340-grade steel was assessed [84]. The 4340 hardened grade steel with the use of synthetic oil provides an improved output at the elevated speed [85]. The experimental research work emphasizes that the proper choice of the work hardness, cutting tool geometrical pattern and operating factors is necessary for achieving process efficiencies in the 4340 hard part turning practice [71]. Various analyses have been carried out by the researchers for the sway of various input variables e.g. main parameters, tool geometry, hardness workpiece, and environmental conditions on various responses.

- For better practical manufacturing enhancement by hard turning of HSLA steel thoroughly influence of the main operating parameter is important.
- The turning of hard part materials is typically experienced to have poor machinability.
- Especially fewer consideration has been presented where different cutting tool material-work piece amalgamation of AISI 4340 grade steel.

5. Statistical Analysis

Investigators have concentrated on modeling and optimization to predict and regulating the results to reduce the roughness value of harden-able steel. The measured output performances are developed by different input process factors and the main goal is to get the link between inputs to measured parameters [13]. For modeling, the software regression analysis can be used. It may find out the good relationship among various parameters like cutting pace, feed, depth of cut and tool nose radius, etc. with surface trait values [23]. From the analyses of ANOVA, it has been concluded that feed is the most significant factor for machined surface roughness (70.22%) followed by cutting speed

(21.93%) and depth of cutting (6.21%) [24]. The optimal operating parameters for getting minimum-machined surface roughness, flank wearing, cutting forces, tangential forces and vibration of the workpiece are as follows: spindle speed 360 rpm, axial feed rate 0.12 mm/rev and depth of cut is 0.2 mm [86].

5.1 Model of Finite Element Methodology

The FEM approach is appropriate for large non-linear distortions at high straining rates and temperature generated through the process. The FEM simulations have been indicated that tool–chip temperature can be stable at even 800ºc when using coated insert like TiAlN and uncoated one like PCBN. The coating layer resists the thermal activities during the process but the uncoated tool like PCBN a lower the temperature [6].

5.2 Analysis of Variance Technique (ANOVA)

The lifespan of the tool, measured metal removal forces, and surface roughness is significantly impacted in regards to varying the cutting speed and axial feed rate has been analyzed using ANOVA methodology [7]. ANOVA indicates that axial feed (60.85%) is the most vital parameter than the cutting speed (24.6%), i.e. with increasing the axial feed rate there also continuously escalations the machined surface value and it minimizes by enhancing the cutting speed [37]. From ANOVA, it was depicted that, both cutting speed and cutting environment have a major influence on material machining forces. During machining with MQL conditions, it was found less cutting forces than dry and wet environments [63]. ANOVA revealed that the feeding rate had a major influence on the machined surface roughness value pursued by the depth of cutting and speed of spindle in NDM, dry and flood machining conditions. By utilizing the software MINITAB, for surface roughness value, a non-linear regression model has been developed and concluded that NDM presented an improved machining performance as far as weight loss of tool, surface quality and consumption of lubricants, in comparison with dry machined and flooded [3].

5.3 Response Surface Methodology (RSM)

The main objective of RSM is to enhance the process variables and to catch out on the finest values of the process parameter. According to RSM the best value of process variables is cutting speed 150 m/min, axial feeding rate 0.125 mm/rev, nose radius (1.2mm) and hardness in the Rockwell scale was 45 HRC [36]. The optimization component looks for the combination of different parameter levels that simultaneously meet the requirements on all the responses and parameters that attempting to adjust the model accordingly. The implementation of the approved optimization procedure is given by the composite index of aspirations by the gradient algorithm. This is a geometric mean with a weighted average of the individual desire indicators designed for all responses in the 0-1 range. Whereas the objective outcome is close to zero, the answer will be rejected completely. Then again, if its value methodologies unity, the answer will be recognized. Optimal cutting speed (240 m/min), axial feed rate(0.0556 mm/rev), and depth of cut (0.10 mm)are found during cutting of 4340 steel by utilizing RSM method, for attaining least surface roughness, that's equal to 0.5451 μm [13].In RSM more than two levels of factors on quality can be observed and find the optimal value [56]. Using RSM it can be developed a reduced quadratic model, which is realistically precise and further can be utilized for forecast within the limit factors analyzed [61].

6. Cost Analyses

To validate the cost-effective feasibility of the machine and tool the cost analysis discussion has to be made. Material cost, machine cost, labor cost, and tool cost are the main factors to be considered for cost analysis. According to More [7] the total machining cost of coated CBN–TiN tools are generally lesser than PCBN inserts. The desired level of achievement was 99.8% for the CBN inserts with TiN coating and 97.9% for the CBN with uncoated one [36]. The working fluid minimization tends to economic profits by saving the cost of lubricants and cleaning cycle time of workpiece/ machine tool and shop floors [22]. From the literature appraisals, the CBN and ceramic tool materials cost is more as compared to carbides due to longer tool life. However, some researchers have been directed for the use of coated carbide inserts for their better cutting performance and economical feasibility when cutting of AISI 4340 hardenable steel [24]. Multilayer TiN coated carbide inserts are able of minimizing the machining costs (93.4%) contrasted to uncoated carbide and 40% to coated carbide (ZrCN) respectively in hard part cutting process with the cap of 0.3 mm flank wear [81]. The prominent results obtained by various investigators are presented in table- 6.

Table 6 - Prominent results obtained by investigators using 4340 hardened steel

Authors	Prominent results
Kumar et al.[71]	The responses of CBN tools (TiN-coated) were better in all machining conditions compared with uncoated tools.
Gunjal and Patil [81]	Synthetic oil provides superior output efficiency in tooling life as compared to canola oil.
Suresh et al. [84]	The amalgamation of higher and lower feed rates is essential for curtailing surface roughness.
Naigade et al.[32]	At higher rotational speed the machining chips become continuous and ductile.
Agarwal et al. [61]	Machined material surface roughness value is most notably swayed by the feed trailed by the cutting speed and deepness of cut.
Patole and Kulkarni [54]	The depth of cut shows the maximum cardinal impact on components of metal removal force as compared to the feed rate and cutting speed.
Lohar and Nanavarty [51]	There is an improvement of 30% in the surface finish by using MQL.
Patole and Kulkarni [50]	Surface roughness is influenced highly by nanofluid type with flow rate and pressure.
Rashid et al. [49]	Lower feed rate results in higher tool wear pattern.
Das et al. [47]	The hardness of the machined surface is observed superior for uncoated cermet tools than coated ones.
Das et al. [31]	Enhancing the cutting speed and lowering the feed generated minimal chip thickness.
Shalaby and Veldhuis [43]	The CC650 ceramic tool (mixed alumina) performs well CC620 pure alumina one on 700 and 1000 m/min.
Jena et al. [29]	Quality characteristics of machined HSLA steel with ceramic insert (coated) generated surface roughness within a cap of 1.6 microns.
Abdul Kareem et al. [103]	For affecting the Ra value with respect to cutting speed, the feed rate is the most important parameter. At higher cutting speed with a constant feed rate have better Ra value.
Reddy et al. [104]	Speed 414 rpm, Feed rate 0.1 mm/rev, and Depth of cut 0.5 mm are the optimal value for getting the best MRR, Ra, and tool wear.
Yazid et al. [105]	On dry turning, cutting speed is the significant factor for surface roughness followed by feed rate.

Investigational outputs exhibit that more cutting forces are necessary for machining harder surfaces [88]. While using PVD–coated tools, the advantage of attaining lower surface roughness and cutting forces and with the longest tool life can be achieved by applying the lower parameters of feed and depth of cut and the 176 m/min cutting speed [89]. Superlative surface finish found for hard work material and single-layer PVD TiAlN coated carbide tool [90]. The surface finish of the part enhanced when the rotational speed has been raised, while the surface quality declined with the augmented feed rate [91].

Cutting tool wear was lesser when machining the 35 HRC compared with cutting the 23 HRC 4340 grade steel [92]. Manufacturing cost is the chief remarkable feature to instigate the preamble of new technologies. The work material hardness has important statistical sways on the machined surface roughness, tooling wear and cutting force [93]. The Simulation effects propose that wiper tools can augment cutting force and peak cutting temperature as compared with the trial result; however, it can decrease the distribution temperature in the cutting tip that is valuable to decrease the tooling wear [94].

Cutting speed and tool feed rates were observed to be more influential on tool wear response [95]. The analysis of the morphology of chip together with surface integrity is imperative for any anonymous combination of work-tool in machining situations. Moreover, the formation of machined chip influences machining dynamics, rotational speed, quality of the surface and inset life [77]. The enhance in chip temperature with the cutting speed parameter, the cermet and the MP configuration chip breaker were accountable for the highest chip temperatures while turning 4340 bars steel [96]. Trial observations indicate that the tool work pair contact temperature is more for hard work material and get mostly affected by cutting speed followed by feed [97].

Adhesion and abrasion considered as dominant wear mechanisms for multiple layer MT-TiCN/Al_2O_3 /TiN CVD coated carbide tool. Less wear rate was viewed for PVD applied TiAlN single-layer carbide insert [98]. The application of coatings on the PCBN substrate can bring clear advantages to the life of the insert, extending it up to 38% using TiAlN-nano coating, within the experimented machining circumstances [99]. The tooling flank wear is principally because of abrasive exploits of the martensite element existing in the 4340 hardened steel [100]. The analysis of surface roughness as a function of independent variables in finish cutting has been evaluated using coated (multilayer) carbide tools MT-Ti(C, N)+Al_2O_3+TiN with AISI 4340 grade (31 HRC) with carbon contents lower than 0.3 % [101].

The modeling, as well as optimization techniques, remain developed for the analysis of the output response. The results show that turning in near dry environments almost delivers superior qualities of products than machined under flooded conditions. The machined surface value increases gradually with regard to increasing the axial rate of feed and depth-of-cut, for dissimilar machining environments. This review paper also explored the different grades of cutting insert and its machining performances on hard turning. Wearing the inserts is the most significant phenomenon of metal cutting, particularly on hard turning. In hard part machining, due to tool wear, decreases the machined Ra value and affects the dimensional measurement accuracy of the work part. Therefore, advanced coated tools have an important character for improving wear resistance. The main goal is to improve product quality, reduce the overall cost and minimizing the setup time. Proper selection of the work hardness, cutting tool geometry parameter and turning factors are necessary for improved output characteristics during the turning operation of hardened 4340 graded steel. The selection of main operating parameters for performing turning of HSLA steel must be balanced amid the quality and cost considerations.

7. Conclusions

Based on the review study of different research paper with related to a concise description of the turning practice of AISI 4340-grade steel using various tools in different cutting environments, it can be concluded the following remarkable points that are given below:

- Turning of hardened 4340 steel has been accepted as an alternate for conventional grinding because of its economical benefit, process flexibility, and lower environmental influence.
- The cooling environment MQL gives better tool life and surface finish than dry machining conditions.
- Sizeable tool lifespan and inferior surface finish are initiated by carbide coated PVD tool and it is better for cutting the lighter conditions.
- Appropriate knowledge of cutting tool reliability and its performance, a proper cutting circumstance can be chosen through an outlook to ensure the high performance freshly machined component and its cost analysis.
- Better-quality machined surface with higher dimensional fidelity is the focal process outcomes region in hard part cutting. Nevertheless, in hard part turning, higher heat is produced at the machining region causing premature tooling wear that tends to reduced surface characteristic quality.
- The effect of cutting tool geometry and researchers has explored tools quality (coating). Sufficient rigidity of machine tools is necessary to reduce the inaccuracies of the process.

The future research outlook should be associated with environmentally friendly approaches to advance machining performance with industry Implement cutting conditions. Machining of 4340 hardened steel with Minimum Quantity Cooling Environment resulted in cleaner manufacturing, environmental friendliness and further helped to augment sustainability.

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