CHAPTER 2
LITERATURE SURVEY
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2.1 Introduction:
Drilling operation is well familiar to the manufacturing industries since the early period of industrial revolution and constitutes major part of the machining processes. The different forms of drilling tools and different types of tool geometries to produce the optimum results are widely available commercially. The drilling operation demands the good dimensional and geometrical tolerances at economic cost which motivated researcher community to study and analyze the drilling process. The drilling operation is well established area in the field of research and many authors contributed to its development and progress. Large number of literature relating to drilling processes is available which shows the importance of the process.

Friction drilling which is considered as the revolutionary breakthrough for sheet metal drilling is recently developed technology which caters with joining of the sheet material by forming the hole with bush. Friction drilling has been existence for over 20 years, yet in manufacturing, it is in its nascent stage due to lack of research and awareness about the process. The revival of friction drilling process with handful publications has been credited to S.F. Miller et. al. (2005-08). Very few researchers have reported their work so far in the friction drilling process. Also the work which is reported so far is limited to certain aspects of the friction drilling process and research related to commercial applications of friction drilling with standard geometry tools is rare to see. Therefore attempt has been made in this work to study the friction drilling process keeping in view the parametric analysis and robust process design much needed for economic utilization of the process.

This work related to study and analysis of the standard geometry friction drilling tool on the commonly available material viz. AISI 1015. The literature review has been carried out considering the technological aspects of the process, process control methodologies, robust process design, optimal machining conditions, and process improvements strategies. The technological aspects of the process are studied first by finding out the literature on the process or on the similar type of the processes. The theoretical and mathematical concepts of the friction drilling process like heat generation, force, tool wear etc. have been studied in depth. The detail literature reviews in regard process control and robust design have been well researched with
plenty of research papers. The optimization techniques which are prominently used by the manufacturers and researchers have been studied well. The intelligent manufacturing control system to monitor the process has gained more importance in today’s manufacturing scenario due to production economy and high competition. Therefore keeping in mind this situation the intelligent monitoring tool ANN have been studied and implemented for the friction drilling process. Literature review for the work has been categorized as below:

2.2 Friction Drilling Process:

The mechanics of friction drilling process in which the force model based on pressure and contact area to predict the thrust force and torque reported. The theoretically developed model has been applied to predict the yield stress and contact pressure between the tool and workpiece and to calculate the thrust force and torque [1]. The research is carried out to quantify the wear and surface degradation of tungsten carbide tools used in friction drilling of steel using changes in tool shape and mass, to characterize worn tool surface features, and to analyze the surface chemistry of the worn tool tip [2]. Work material is subjected to the large deformation and high temperature during the friction drilling process which causes alteration in macrostructure and material properties. Authors in this work described that the quality of hole is affected by magnitude of friction forces and heat produced during friction drilling process which in turn depending on thermal conductivities of materials involved [3]. The bushings generated in the friction drilling of brittle cast materials, exhibit cracks or petals. This problem illustrated that methods like high spindle speed and workpiece preheating have been suggested to obtain better results [4].

Thermo mechanical finite element modeling of the friction drilling process to understand the material flow, temperature, stresses and strains which are difficult to measure experimentally has been studied. The 3D finite element modeling has been employed to model the large plastic strain and high temperature work-material deformation inherent in friction drilling process [5]. The model with improvement in material plastic flow in terms of the yield in shear rather than the yield in compression, using a single, variable friction coefficient instead of assuming two unrelated friction coefficients in fixed values has been suggested [6]. The basic features of the friction drilling process and its technological aspects have been nicely
presented. The detailed attempts have been made to measure thrust force, torque and characterization of the process [7].

The performance of coated (TiAlN and AlCrN) and uncoated tungsten carbide drills for the friction drilling of austenitic stainless steel AISI 304 have been investigated. This work explored the changes in relationship between drill surface temperature, tool wear and axial thrust force [8]. The process characterization of friction drilling process for Austenitic stainless steel (AISI 304) with sintered carbide tool has been reported by Han-Ming et. al. This work demonstrated the effect of input parameters such as drill shape and friction angle, friction contact area ratio, feed rate, and drilling speed [9]. The mechanical aspects of friction drilling are investigated by P. V. Gopal Krishna et. al. Aluminum (AA6351) is taken as work material and friction drilling is carried out by high speed steel conical tool. Mathematical models are developed in this work for axial thrust and torque [10].

2.3 Fundamentals of Cold and Hot Working, Friction Stir Welding and Heat Transfer:

The in depth analysis of hot and cold metal working process is explained with the view to carry out detailed investigations of the forging process where material is plastically deformed in one or more operations into a product of relatively complex configuration[11]. The tribological behavior of the material having frictional contacts is explained and frictional heat generation, tool wear, contact deformations etc. have been analyzed in detail [12]. The extrusion process which exhibits the generation of frictional heat has been studied and discussed [13]. The most advanced study for predicting metal flow and temperatures has been presented [14]. The conduction of heat in solid that involve the heat generation and transfer have been investigated [15]. The wear mechanism and their genesis have been discussed with view to analyze the behavior of metal in contact [16]. The wear coefficient which is the critical component in the theory of solid mechanics and Tribology has been thoroughly studied and analyzed [17].

The study focusing on nitriding of low carbon steel after warm rolling and the valuation of the final mechanical properties and microstructure has been conducted [18]. The report prepared as an account of work sponsored by ASME and the ASME Standards Technology, LLC (ASME ST-LLC) for Comparison of ASME specifications and European standards for Mechanical testing of steels for Pressure
equipment [19]. The review, to describe the historical development and properties of cemented tungsten carbides has been carried out. Also synthesis and consolidation efforts for nano-grained WC/Co have been carried out [20]. The survey of the engineering materials, compositions and their applications have presented in very systematic way [21].

The literatures corresponding to the friction stir welding process which has similar characteristics as friction drilling process have been studied. Friction stir welding is a refreshing approach to the joining of metals. Although originally intended for aluminium alloys, reach of FSW has now extended to a variety of materials including steels and polymers. This review deals with the fundamental understanding of the process and its metallurgical consequences. The focus is on heat generation, heat transfer and plastic flow during welding, elements of tool design, understanding defect formation and the structure and properties of the welded materials [22, 23]. The study relating to temperature distribution and heat transfer of the FSW process for both workpiece and the tool is conducted [24, 25].

Encountered welding difficulties in FSW process are solved after being guided by the theory of inventive problem solving (TRIZ) design method [26]. The factors determining the temperature, heating rate, microstructure, and strain rate in Al 7075-T6 friction stir spot welds are investigated [27]. The FSSW parameters such as tool rotational speed, plunge rate, plunge depth, and dwell time play a major role in determining the strength of the joints [28]. Effect of welding parameters on the strain rate and microstructure of friction stir spot welded 2024 aluminum alloy has been investigated [29]. The Thermo-Mechanical and Microstructural Modeling of Friction Stir Welding of 6111-T4 Aluminum Alloys has been studied [30]. The detailed investigation in regard the current developments, three dimensional modeling and refined energy based modeling have been presented [31-33].

Considerable changes have occurred in metal forming in the last decade. A record of these changes can be found in keynote papers presented by the members of the Scientific Technical Committee—forming, at the CIRP Annual General Meeting each year. The keynote papers are excellent references on important developments in metal forming and are used as a reference, globally. The authors of each section are shown in order of presentation [34]. The present work deals with the influence of the oxide-forming alloying elements aluminum and silicon on the oxidation and wear of three selected hot work steels [35]. The theory of kinetics of static recrystallization of
steel during hot forming links the phenomenon to certain critical strain, grain size, strain rate, activation energy and temperature. The basic description is provided by the Avrami equation. An overview of equations used was compiled and comments on selected parameters prepared [36]. An elastic-viscoplastic constitutive model for the Hot-forming of aluminum alloys is presented [37].

2.4 Drilling Process Analysis and Sheet Metal Working:

Delamination in drilling has been correlated to the thrust force during exit of the drill. Higher thrust force introduces more extensive delamination to the workpiece. This paper presents a parametric study to achieve low thrust force in use of core drill by using the Taguchi method [38]. The prediction and evaluation of thrust force and surface roughness in drilling of composite material using candle stick drill based on Taguchi method and the artificial neural network has been carried out [39]. A methodology to combine experimental, simulation, and statistical tools to reduce the time and cost of parameter studies has been shown. The statistical analysis is based on an experimentally verified simulation that predicts burr height, force, heat flux, and temperature at breakthrough [40]. The estimated values of tool wear were obtained by statistical analysis and by various neural network structures. Comparative analysis has been done between statistical analysis, neural network structures and the actual values of tool wear obtained by experimentation [41]. The non linear optimization routine has been used to calibrate the drilling model [42]. Modeling of twist drills wear and determination of twist drill temperature in dry drilling have been attempted [43, 44]. The effect of thermal property degradation on wear of WC-CO inserts in dry cutting has been studied [45].

For sheet metals, the endurance to fracture under different strain paths may be different. Based on plastic deformation energy, the sheet metal forming limit is calculated, and the relationship model between maximum allowable integral value of the general plastic work criterion and the strain path is built. In addition, the strain-hardening exponent, anisotropy coefficient and the initial thickness of the material are also taken into account to consider their effects on forming limit [46]. Optimization has been used to evaluate alternative sheet metal forming processes. Six process setups were first defined in a hierarchy of designs and optimization was then used to evaluate each forming process of these designs [47]. To evaluate the use of linear and quadratic approximating response surfaces as metamodels in a reliability assessment
of a sheet metal forming process using the Monte Carlo simulation technique is studied. [48].

2.5 Design of Experiments and Taguchi Methods:

Design and analysis of experiments provides the way to carry out the systematic study of engineering, business processes to gain the useful knowledge about the process. The study aims at improving the quality, efficiency and performance of the working system [49]. Meet Minitab introduces the most commonly used features in Minitab. Throughout the book, functions, graphs, and statistics are explained [50]. Taguchi method has been widely used in manufacturing for decades to conveniently design a product or process with a single quality characteristic. Many successful applications of Taguchi methods have been reported to optimize several process and product reliability and quality [51-54]. Significant process parameters and their effect on the response in the die casting process is determined using the taguchi methods [55]. Taguchi method is used to find the optimal cutting parameters for turning operations [56, 57]; optimization of cutting parameters for turning operations based on the Taguchi method has been studied [58, 59].

The use of Taguchi method in the design of plastic injection mould for reducing Warpage is attempted. [60]. Comparison of tool life of Tungsten carbide Coated by multi Layer TiCN and TiAlCN for end mills using the Taguchi method has been studied [61]. A study of the Taguchi design applications to optimize surface quality in a CNC face milling operation has been conducted [62]. A procedure utilizing the statistic regression analysis and desirability function to optimize the multi-response problem with Taguchi’s dynamic system consideration has been discussed [63]. The parametric analysis of the flow forming process has been conducted [64]. Taguchi optimization in drilling of AISI 316L stainless steel to minimize burr size using multi-performance objective based on membership function has been presented [65].

The methodology of Taguchi optimization method for simultaneous minimization of delamination factor at entry and exit of the holes in drilling of SUPERPAN D’ECOR (melamine coating layer) MDF panel has been discussed [66]. The study to combine quality function deployment (QFD) and the Taguchi method to analyze the produced quality characteristics and to optimize the process parameters
have been elaborated [67]. The Taguchi method, a robust experimental design, is used to optimize manufacturing parameters of a brake lining [68]. Genichi Taguchi's contribution to the field of quality and manufacturing engineering from both a statistical and an engineering viewpoint has been reviewed. His major contributions are first listed and then described in a systematic and analytical manner [69].

2.6 AHP and TOPSIS methods:

The selection of best alternative in the multiple criteria environment is very cumbersome task and needs due considerations since all the processes have more than one objectives. In such situation right decisions by scientific method results in lot of savings in terms of resource utilization and direct expenditure. The use of the heuristics method in multiple decision making situation is quite popular in manufacturing. The use of Analytic Hierarchy Process instantly take the control of situation and decides the weightage to be given to individual parameter based on simple relative comparison [70-73]. A logical procedure for material selection for a given engineering design based on a combined TOPSIS and AHP method has been presented [74]. A ‘flexible manufacturing system suitability index’ is proposed that evaluates and ranks flexible manufacturing systems for the given industrial application using TOPSIS and AHP methods together [75]. An effective procedure called PCR-TOPSIS that is based on process capability ratio (PCR) theory and on the theory of order preference by similarity to the ideal solution (TOPSIS) to optimize multi-response problems has been presented [76]. An extension of TOPSIS (technique for order performance by similarity to ideal solution), a multi-attribute decision making (MADM) technique, to a group decision environment is investigated [77]. A state-of-the-art literature survey to taxonomize the research on TOPSIS applications and methodologies has been conducted [78]. A new approach for determining weights of Decision Makings in group decision environment based on an extended TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) method [79]. A framework that integrates the analytical hierarchy process (AHP) and the technique for order preference by similarity to ideal solution (TOPSIS) to assist designers in identifying customer requirements and design characteristics, and help achieve an effective evaluation of the final design solution has been demonstrated [80]. Ranking Efficient Units in Data Envelopment Analysis by Using TOPSIS Method has been shown [81].
2.7 **Neural Networks:**

The popularity of soft computing in manufacturing and services has been evident in the recent years. Owing to good generalization capability of neural networks, it has been used extensively in the past decade to monitor the progress of tool wear in machining [82-84]. The book presents the theory of neural networks, discusses their design and application, and makes considerable use of the MATLAB environment and Neural Network Toolbox software [85]. A new approach for solving multiple criteria decision-making (MCDM) problems is proposed based on Decision Neural Network (DNN) system presented [86]. Modeling of tool wear in drilling by statistical analysis and artificial neural network has been attempted. Also the comparative analysis has been done between statistical analysis, neural network structures and the actual values of tool wear obtained by experimentation [87]. The prediction and evaluation of thrust force and surface roughness in drilling of composite material using candle stick drill based on Taguchi method and the artificial neural network has been presented [88]. Evolutionary algorithms (EAs) are deployed for multi-objective Pareto optimal design of group method of data handling (GMDH)-type neural networks which have been used for modelling an explosive cutting process using some input–output experimental data [89]. A numerical study of the crushing of thin-walled circular aluminum tubes has been carried out to investigate their behaviors under axial impact loading using genetic algorithm and neural network [90]. A neural network-based approach to complex optimization of cutting parameters is proposed. It describes the multi-objective technique of optimization of cutting conditions by means of the neural networks taking into consideration the technological, economic and organizational limitations [91]. Modelling and multi-objective optimization of a variable valve-timing spark-ignition engine using polynomial neural networks and evolutionary algorithms has been shown [92]. The neural network has been successfully utilized for modeling and optimization applications [93-104].

2.8 **Grey Analysis, Thread Forming and R^3I methods:**

The effectiveness of optimizing multiple quality characteristics of Nd:YAG laser welded titanium alloy plates via Taguchi method-based Grey analysis has been demonstrated. The modified algorithm was successfully used for both determining the optimum settings of machine parameters and for combining multiple quality
characteristics into one integrated numerical value called Grey relational grade or rank [105]. A hybrid optimization approach for the determination of the optimum laser cutting process parameters which minimize the kerf width, kerf taper, and kerf deviation together during pulsed Nd:YAG laser cutting of a thin sheet of nickel-based super alloy SUPERNI 718 (an equivalent grade to Inconel 718) was discussed [106]. The optimum conditions for direct CO2 laser cutting of 6-mm-thick polymethylmethacrylate (PMMA) for backlit module applications [107]. An approach to improve the yield of Chrome (Cr) thin-film sputtering process of the black matrix (BM) in color filter manufacturing and to find the robust parameters of the process with multiple quality characteristics by using the Taguchi method combined with the grey relational analysis has been proposed [108]. The optimization of the process parameters using Grey Analysis has been proposed and implemented for multiple applications [109-114].

Largely applied to internal threading of extruded tubes, cold form tapping is now becoming a promising process for internal threading of holes in non ferrous and ferrous solid components, more particularly for mass production in the automotive industry. The surface properties of the threads resulting from form tapping process are presented here [115]. Analyzing the tribochemical mechanisms of lubrication during the process of form tapping and consequently optimizing the formulation of the lubricant has been attempted [116]. The effect of the factors like hole diameter, the forming speed and types of tool on the responses: torque, hardness, fill rate, and thrust force of the form tapping process have been investigated [117]. General cutting mechanics approach, successfully used for different machining operations using cutting tool with complex geometry, applied for prediction of cutting forces in tapping with machine tap [118]. The calculation and modeling of pull out force for self tapping fasteners in aluminium screw slot connection is presented [119]. A mechanistic model for the prediction of tapping torque and axial force is developed. The model is capable of predicting tapping torque and axial force resulting from chip formation and tool flank/workpiece friction under various machining conditions, including dry tapping and tapping with different cutting fluids [120].

The concept of relative reliability risk assessment for original designs, where information availability is less, to calculate reliability is presented. The function structures of the product under consideration and application of the analytic hierarchy process using verbal assessments for relative measurements has been done. The
weight assigning technique used is the entropy method. A final value of R3I (Relative Reliability Risk Index) is calculated and the idea of concept functionality graphs is presented [121]. The degree of assistance offered Relative Reliability Risk Index, the ease of application of the methodology by the novice designer and the potential consistency of the evaluation process has been evaluated. Modular design of machine tools using relative reliability index for competitive manufacturing has been analyzed [122]. The Intelligent Control System for Roundness-error in En-8 Steel which is turned is assessed [123].

2.9 Concluding Remarks:

The literature review corresponding to mechanics, process, intelligent control etc. have been carried out for the friction drilling process. Firstly the theoretical inputs were available about the process from the published literature on this process. These inputs were of great help while deciding the experimentation strategies for the friction drilling process. Also the work material selection and tool selection was possible after the detailed investigation of the literature. Keeping in mind the basic concept of the friction drilling process other literatures on the similar type of work like Forming process, friction stir welding process, sheet metal working process were useful to gain in depth understanding of the process. The concept of frictional heat generation and their effect on coefficient of friction and resultant forces have been well understood by the literatures on Forming process and friction stir welding process. The experimental investigations of the process and its analysis have been possible after studying Taguchi method and DOE books. The literature available on multi attribute decision making was helpful to carry out the process optimization. The neural network modeling which is one of the highly result oriented analysis and controlling tools has been well understood with the literatures available on it. Finally the thread tapping and forming literature was utilized for the process study and analysis.