**MECHANICAL ENGINEERING**

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Author : **A. PRASAD REDDY**

Title of the thesis : **Mechanical and Tribological Properties of Aa6061-**

 **2sicp-Xgr Hybrid Nanocomposites Fabricated**

 **Through Ultrasonically Assisted Stir Casting Method**

Guide : **Dr. P. VAMSI KRISHNA**

Degree: **Ph. D.**

Student ID No.: **714014**

**ABSTRACT**

Worldwide the global requriment is increasing for new generation of materials to staisfy advanced engineering applications. The usage of metal matrix nanocomposites (MMNCs) has been substantially increased in many sectors due to its stiffness, strength to weigth ratio, mechanical and tribological properties. Ceramic nano-reinforcement particles are added to improve the mechanical and tribological properties of the aluminium and its alloys. The aluminium metal matrix nanocomposites (AA-MMNCs) have been used in various applications. The nano-sized ceramic particles reinforced AA-MMNCs are observed to be better mechanical and tribological properties due to the strengthening effect of nanoparticles. The strength of these AA-MMNCs is proportional to the weight percentage of nano-reinforcement and particle size. The recent reports reveal that the wear properties of AA-MMNCs containing more than one nano-reinforcement (i.e. hybrid nanocomposites) are observed to be beneficial compared to single nanoparticle reinforced composites.

The present study investigate the mechanical and tribological behaviour of AA6061 aluminium alloy, AA6061-x wt. % SiCp (x = 0.5, 1, 1.5, and 2) (denoted as 0.5NC, 1NC, 1.5NC, and 2NC) nanocomposites and AA6061-2wt. % SiCp-y wt. % graphite (y = 0.5, 1, 1.5, 2 and 3) (denoted as 0.5HNC, 1HNC, 1.5HNC, 2HNC, and 3HNC) hybrid nanocomposites. The nanocomposites are fabricated through ultrasonic assisted stir casting process. The results have proven that microstructures are greatly refined with the addition of SiCp and graphite nano-reinforcement particles. The density, yield strength, tensile strength and microhardness of the nanocomposites increased with increase of wt. % of SiCp nano-reinforcements in the matrix. In case of hybrid nanocomposites the density, tensile strength, and microhardness decreased with increase of graphite nano-reinforcements in the matrix. Strength of nanocomposites is affected due to the strengthening effect of SiCp and graphite nano-reinforcement particles. Enhancement of yield strength of nanocomposites and hybrid nanocomposites is predicted using various strengthening mechanisms such as Orowan strengthening effect, thermal dislocation mismatch effect, load bearing effect, Hall-Petch effect, and porosity effect. The Orowan strengthening effect and thermal dislocation mismatch effect is found to play a significant role in the nanocomposites. The predicted yield strength values using Ramakrishnan’s model, Zhang and Chen model, modified Clyne model, Mirza and Chen model are compared with the experimental results.

The dry sliding wear behaviour of AA6061 aluminium alloy, nanocomposites, and hybrid nanocomposites on EN31 steel counter face at an applied load of 5-20 N, sliding distance of 1000-3000 m, and sliding velocity of 0.5-2 m/s is studied. The wear response in terms of volumetric wear rate, wear coefficients, and coefficient of friction is analyzed and compared with each other. The wear rate is low with increasing the wt. % of SiCp nano-reinforcements in the AA6061 aluminium alloy matrix. It is noticed that the wear coefficients of nanocomposites decreased with increase of SiCp nano-reinforcements in the matrix at all conditions. The microhardness of the SiCp reinforced AA6061 aluminium alloy based nanocomposite materials dominated the wear coefficients. Experimental results also confirm the increase of coefficient of friction for nanocomposites with rise of SiCp nano-reinforcement particles.

The effect on tribological properties is found to be better with the addition of graphite as a secondary reinforcement in the nanocomposites. The wear rate is decreased with increasing the graphite nano-reinforcements up to 2 wt. % and then increased. It can be seen that the wear coefficients of hybrid nanocomposites decreased with the increase of graphite nano-reinforcements in the matrix. The experimental results also confirm the increase of coefficient of friction for 3HNC hybrid nanocomposite with more than 2 wt. % of graphite addition in the matrix.

The two body abrasive wear experiments of AA6061 aluminium alloy, 2NC nanocomposite, and 2HNC hybrid nanocomposite are conducted with pin-on-disc equipment at an applied load of 5-20 N, sliding distance of 60-180 m, sliding velocity of 0.5-2 m/s, and grit size of 50-150 μm. The wear response in terms of volumetric wear rate, wear coefficients, and coefficient of friction is analyzed and compared with each other. The volumetric abrasive wear rate reduced for 2NC nanocomposite and 2HNC hybrid nanocomposite. The wear coefficients decreased with increase of applied normal loads, sliding distances and sliding velocities. The wear coefficients increased with increase of abrasive grit particle size. The volumetric wear rate is lower for least size abrasive grit paper and higher for coarse sized grit paper.

Overall results showing the improvement in tribological properties of hybrid nanocomposites by reducing the wear and friction.

**MECHANICAL ENGINEERING**

Author : **BHANU PAVAN RAVURI**

Title of the thesis : **DEVELOPMENT AND PERFORMANCE EVALUATION**

 **OF SELF-LUBRICATING GRINDING WHEELS IN**

 **GRINDING INCONEL 718**

Guide : **Dr. M. AMRITA**

Degree: **Ph. D.**

Student ID No.: **701138**

**ABSTRACT**

Surface grinding is an abrasive technique, in which each abrasive grain acts as a cutting tool. Due to rubbing and ploughing of the workpiece surface by the abrasive grits, intense heat and high cutting forces develop at the wheel–workpiece interface. These, in turn, cause poor surface finish, higher specific power requirements, higher wheel wear, microcracks, thermal burns, residual stresses and phase transformations. This phenomenon is more prominent in difficult-to-machine materials like Inconel 718 due to its high hot strength, poor thermal conductivity, high thermal expansion coefficient, etc., which in turn affects the surface and subsurface quality of the ground components. The surface quality of the ground components is of prime concern especially in aerospace applications as they influence failures produced by fatigue, wear, creep and stress corrosion. Hence, in order to extend the life of the ground parts, surface quality has to be improved by reducing the excessive heat and cutting forces generated during grinding of Inconel 718.

The most commonly used technique for controlling the temperatures and cutting forces is flooding the contact zone with cutting fluids to aid lubrication and cooling. In spite of having numerous advantages, flood cooling has some serious disadvantages concerned with economic and ecological aspects. Minimum Quantity Lubrication of the grinding zone with cutting fluids seems to be a potential alternative to economic and ecological concerns of the flood grinding. However, performance wise MQL grinding stood between dry and flood grinding due to insufficient cooling and improper lubrication at grinding site. Hence, the development of new strategies and lubricants which can provide better cooling and lubrication at the grinding zone is very much essential for energy efficient and sustainable grinding.

Solid lubricants (graphite, molybdenum disulphide, calcium fluoride, boric acid, etc.) which can provide lubricity over a wide range of temperatures seem to be an effective alternative to the conventional cutting fluids. However, efficient delivery of the solid lubricants at the wheelworkpiece interface is a major hindrance in achieving the desired results. In addition, type and quantity of solid lubricant will also have profound influences on the process results. Among various solid lubricants, very limitedly explored graphene nanoplatelets(GNP) were selected in this work due to their remarkable properties such as high thermal conductivity and selflubricating behaviour. In view of these drawbacks, the present work focuses on exploring the effectiveness of GNP in reducing the friction and associated heat generation in the grinding process by developing efficient methods for proper application of GNP at the wheel–workpiece interface with an ultimate objective to improve the wheel life and surface quality of Inconel 718. For this purpose GNP based self-lubricating grinding wheel and GNP based nano-cutting fluids were developed and their performance in terms of surface finish, wheel wear, grinding temperatures, specific energy requirements, etc. are evaluated and presented in this work.

Self-lubricating resin bonded grinding wheels with varying GNP concentrations (0.25, 0.5, 1, 2 and 4 wt %), and surface areas (300, 500 and 750 m2/g) are manufactured, in order to have a proper application of solid lubricants at the wheel-workpiece interface. For this purpose, GNP is impregnated into the wheel structure during the moulding stage itself. In order to ensure the uniform dispersion of GNP without any entanglements, GNP is treated with a cationic surfactant. Different aspects of grinding performance (i.e. cutting forces, grinding temperatures, surface roughness, grinding coefficient, specific grinding energy and grinding wheel wear) are evaluated by grinding Inconel 718 in dry condition with these newly developed self-lubricating grinding wheels and compared the results with that of the standard grinding wheel. The experimental results show a considerable improvement in grinding process results with GNP as compared to standard grinding wheels. Grinding wheels having 2 wt% GNP has produced lower grinding forces and grinding temperatures, and better surface finish. Among various GNP surface areas considered, GNP with the larger surface area is found to be more effective in improving the quality of the ground surface.

Another approach adopted in this work for effective application of GNP at wheel workpiece interface is to deliver GNP into grinding zone in the form of aerosols by using conventional cutting fluid and air as a medium. For this purpose, nano-cutting fluids with varying concentrations (0.1, 0.2, 0.3, 0.4 and 0.5 wt%) and surface areas (300, 500 and 750 m2/g) of GNP are prepared. The basic properties like thermal conductivity and viscosity are evaluated at different temperatures. Since the effectiveness of the cutting fluid in providing effective cooling and proper lubrication at the grinding wheel–workpiece interface depends on the thermal conductivity and viscosity, these properties are evaluated at different temperatures. It is observed that viscosity increased with increase in GNP concentration and surface area but decreased with increase in temperature. Thermal conductivity observed to be enhanced significantly with an increase in GNP weight fractions, surface area and temperature. Furthermore, to assess the performance of the developed nano-cutting fluids, Inconel 718 is ground using conventional grinding wheel while delivering minimum quantity nano-cutting fluid into grinding zone in the form of aerosols. The experimental results show that GNP significantly lowers the grinding force, grinding temperature, surface roughness, grinding coefficient and specific grinding energy. Nanocutting fluid with 0.3 wt% and 750 m2/g GNP is found to be effective in improving the surface quality of the Inconel 718.

Further, Inconel 718 is ground in different grinding environments i.e. standard grinding wheel in dry, self-lubricating grinding wheels in the dry, standard grinding wheel in nanoMQL and self-lubricating grinding wheels in nanoMQL environments. Overall, the combination of selflubricating grinding wheels and nanoMQL has led to decrease of various aspects of grinding performances (i.e. cutting forces, grinding temperatures, surface roughness, grinding coefficient and specific grinding energy)and yielded improved surface quality of Inconel 718 components.

**Keywords:** Inconel 718, Graphene nanoplatelets, Grinding, Self-lubricating grinding wheels, nano-cutting fluids, nanoMQL

**MECHANICAL ENGINEERING**

Author : **Mr. GANESH SEGOJI WARKHADE**

Title of the thesis : **EXPERIMENTAL INVESTIGATION AND**

 **OPTIMIZATION OF SUPERCHARGING AND**

 **COMPRESSION RATIO IN A BIOFUELED DI**

 **VARIABLE COMPRESSION RATIO ENGINE**

Guide : **Dr. A.VEERESH BABU**

Degree: **Ph. D.**

Student ID No.: **715042**

**ABSTRACT**

The present work deals with three issues related to direct injection compression ignition engine. The first concern, the heavy utilization of fossil fuel in industrial and transportation sector leads to higher environmental pollution and depletion of its natural sources. Hence, there is need to search for new and sustainable resources of fuel. The second concern, the conventional CI engine work on fixed compression ratio and optimized for petro-diesel as fuel. The conventional engine at full load has a higher combustion pressure problem. The reduction of the compression ratio can minimize this problem. Moreover; it ought to be sufficiently high pressure at starting and at part load operation for better combustion, excellent reliability, longer engine life, and low emission. For utilization of the alternative source of fuel to replace the conventional petro-diesel fuel; the engine must be modified and optimized to suit the physical and chemical properties of the alternative fuel. The third concern is the stringent emission regulation norms imposed periodically and effective conversion of fuel’s chemical energy into useful mechanical work to get more and more power from the same size of engine and quantity of fuel.

The present work addressed these concerns by performing experimental investigations of biodiesel-fueled single cylinder DICI engine with varying the percentage engine load, compression ratio, and inlet boost pressure. After reviewing the available literature, the non-edible linseed vegetable oil selected for the biodiesel production. This oil highly unsaturated and has more percentage of linolenic acid. Hence two-stage transesterification is used to convert the raw oil into biodiesel. In the first stage of the investigation, the biodiesel prepared from non-edible linseed oil (LB100) blended with petro-diesel (PD) on the volume basis and tested in compression ignition engine at different CR and load to replace the petro-diesel. The obtained result compared with baseline fuel PD operated at rated compression ratio 17.5:1. The result shows the higher value of cylinder combustion pressure; cumulative heat release, combustion duration, and combustion mean gas temperature and lower ignition delay for biodiesel and its blends compared to PD. On an average the ignition delay increases by 30% and 3.3% at CR 14:1 and 16:1 respectively, and declining by 28.3% at CR 18:1 for LB blends. At CR 16, the maximum BTE improvement observed was 26.73% for LB30. The maximum gain in BSFC for LB10 was 3 -12% higher. The EGT increases with load, biodiesel contents and decreases with CRs. The emission of CO, HC, and CO2 reduced with an increase in CRs except penalty in the discharge of NOx by a maximum of 30.8% for LB30 at CR18. Thus higher blends, i.e., LB20 and LB30 can also be used as an alternative fuel in a partially modified diesel engine, i.e., at CR 18.

The second stage considered the optimization of working parameters of unmodified compression ignition engine powered with the linseed methyl ester biodiesel and its blends as an alternative fuel. The objective accomplished by choosing three levels for each input parameters. Taguchi's L9 orthogonal array with Taguchi based grey relational analysis (TGRA) was utilized to get the optimum combination of input parameters. The optimum combination of input parameters by TGRA observed to be fuel mix B10, CR 18, and load 100%. The S/N ratio analysis of grey relational grade (GRG) shows the fuel B10, CR 16, and load 100% optimal input factor level. This optimal level further confirmed by analytical hierarchy analysis (AHP) and TOPSIS method. The analysis of variance for contribution for GRG demonstrates the most influential affecting variable is the load of 52.82% contribution followed by CR 28.38%, and fuel 10.52%. The confirmatory results demonstrate the improvement by 56.1%. Overall, the present study provides a necessary framework to enhance further research in this area.

Based on the results of stage-I. The biodiesel blends LB10, LB20, and LB30 shows performance in agreement with standard petro-diesel. Therefore, in the third stage, the experimental setup is modified for supercharged condition (forced induction) for further investigations. The present work carried out with above said three biodiesel blends and petro-diesel (PD). The operating input parameters were 4 different CRs (14, 16, 17.5, 18) and 3 boosting pressure (g) (0.5, 1, 1.5 kPa) including the natural aspiration (NA) of the engine. The output characteristics measured for all tested fuels and compared with baseline fuel (PD) at standard operating condition (CR 17.5 at NA). The output parameters considered for projected downsizing are performance and combustion characteristics. From the investigations, found that the supercharger improves the engine performance by 10-15%. The boosting improves both phases of combustions namely premixed and diffusion. The exhaust gas temperature decreases with increase in boost pressure and CR for all tested fuels. The exact engine downsizing in terms of increase in specific power and decrease in specific weight are discussed in detail.

**MECHANICAL ENGINEERING**

Author : **GOPALA RAO THELLAPUTTA**

Title of the thesis : **SOME EXPERIMENTAL STUDIES AND MODELING OF**

**ROTARY TOOL MILLING WHILE MACHINING INCONEL – 625 ALLOY**

Guide : **Dr. P. SUBHASH CHANDRA BOSE**

Degree: **Ph. D.**

Student ID No.: **701420**

**ABSTRACT**

Nickel based superalloys are generally known as difficult to machine materials because of their toughness, high heat resistance, high operating temperatures, hardness and chemical property to react with tool materials, low thermal conductivity and creep resistance. Although these awesome properties are necessary design requirements, they cause a greater challenge to the manufacturing engineers due to the high temperatures and stresses generated during machining. The tool materials with better hardness like carbides, ceramics and CBN are regularly used for machining of Nickel based Super alloys. Betterments in machining productivity can be attaining with the advanced machining techniques such as rotary machining. The Nickel based superalloys mainly used in aerospace applications due to their excellent properties at high temperature. In the recent past, there is a rapid development in advanced aerospace materials resulting in the developments of Nickel, Titanium and structural composite materials with improved properties such as strength to weight ratio, corrosion resistance, etc. The difficulties in machining of these materials economically and effectively are limiting their applications. As the development of new cutting tool materials are reaching an optimum level, the attention of manufacturers all over the world is focused on novel tool designs. One such development is the rotary tool machining operations i.e. self-propelled rotary tool turning and self-propelled rotary tool milling operations in which the tool life increases enormously and aerospace materials can be machined at a faster rate at lesser tool cost than that of conventional machining operations.

Inconel 625 is nickel based superalloys with high temperature mechanical properties and outstanding oxidation resistance whose applications include gas turbine engines and Aerospace engines. Along with these properties they also exhibit very high hardness at high temperature which causes problems during machining. Defense organizations have been working with Inconel 625 for their scramjet engines. It is found that the machinability data of Inconel 625 is not available with rotary tools. Knowledge of interaction of machining process variables on surface finish, cutting force, and temperature and models for prediction of output variables are scarcely available. Generation of such rotary machining data, response and models are very much required for the user industries such as aerospace and defense.

In this work, an attempt is made to design and fabricate a rotary face milling cutter with a provision for insert inclination angles 20°, 30°, 40° and 50° and testing of this cutter under varied machining conditions. The performance of the developed cutter has been evaluated while machining some of the difficult-to-cut aerospace materials like Nickel based super alloy namely Inconel 625 and SUS 304. Cutting forces in three directions (FX, FY & FZ), surface roughness (Ra) and tool chip interfacial cutting temperature have been considered for evaluation. Detailed investigations have been carried out based on Full-Factorial Experimentation for evaluating the performance of rotary face-milling cutter with the selected process parameters.

For cutting force, surface roughness and cutting temperature investigations, experiments have been conducted according to the Full-Factorial and Response Surface Methodology (RSM) techniques. Design Expert 7.0.0 software has been used for implementing the RSM .Analysis of experimental results using Analysis of Variance (ANOVA) has been employed to study the performance characteristics of the cutters. In addition to this work, experiments are conducted using MQL and MQL with nano coolants for three higher, medium and minimum values of output variables. Also, in this work, models for predicting the cutting forces, surface roughness and cutting temperature generated during the rotary face milling operation have been developed using RSM and same were validated. Also, soft computing model using Multi Gene Genetic Programming (MGGP) technique has been developed and validated for predicting the cutting forces, surface roughness and cutting temperature. A multi objective problem is formulated using Non-dominated Sorting Genetic Algorithm-II (NSGA-II) for an optimal combination of settings to minimize the cutting force, surface roughness and cutting temperature to obtain multiple sets of optimal solutions to choose a specific optimal set of input variables based on the particular requirements.

It can be noticed that the machining with lower inclination angles exhibits lower thrust forces and it is almost 30% of the total thrust force generated in the case of conventional face milling cutters. Hence, rotary milling cutters are recommended for mass production in machining of difficult to machine materials such as Nickel based super alloys and Titanium Alloys for aerospace applications. According to the surface roughness variation graphs, cutting speed and feed rate show a greater influence on surface finish having less surface roughness at low feed rates and high surface roughness at high feed rates. In the case of insert inclination angle, there exists an optimum angle between 300 and 400 at which the surface roughness is found low. According to the cutting temperature variation graphs, cutting speed and feed rate show a greater influence on cutting temperature. The optimum inclination angles are in between 300 and 400 to get minimum cutting temperature.

The developed rotary face milling cutter can be used for machining of components made of high strength and difficult-to-cut alloys for aerospace and Defence applications. The validated models developed in this work can be ready to use by any industry to predict the cutting forces, surface roughness and cutting temperature for rotary milling operations.

**MECHANICAL ENGINEERING**

Author : **J. AMALA RANGA BABU**

Title of the thesis : **PERFORMANCE EVALUATION OF NANOFLUID**

 **BASED SOLAR THERMAL COLLECTORS**

Guide : **Dr. K. KIRAN KUMAR**

Degree: **Ph. D.**

Student ID No.: **701412**

**ABSTRACT**

Mankind is living in the arena of evolution of technology in which energy is an integral part. However, this enrichment of science and technology has opened new pathways for energy consumption and generation as well. Raise of population density is another root cause for energy demands. Fossil fuels are depleting at faster rate and leaving carbon footprints on environment. In this scenario, it is inevitable to depends on renewable energy sources which are inexhaustible, eco-friendly and abundantly available in nature. Amid all renewable sources, effective utilization of solar energy is a viable alternative to meet the growing energy demands, particularly for low temperature applications. While consumption of solar energy for various domestic applications is not new, but it is suffering from lower effective energy conversion problem.

Solar collectors are the device that absorbs the incident solar radiation and converts into useful form. Among different types of collectors, solar flat plate collectors (SFPC) are the noteworthy devices to convert the incident radiation into heat energy of working fluid. In view of enhancing the thermal efficiency of collectors, there are two major approaches as either changing the geometry and operating parameters or enhancing the properties of working fluid. Since, various geometrical and operating parameters and modifications are more or less saturated, present work is focused on enhancing the thermophysical and optical properties of working fluid by suspending nanoparticle as an approach for effective conversion of solar radiation into useful heat energy.

Thermophysical properties and their influence on thermal performance of SFPC are estimated using the empirical correlations available in open literature and comparisons are made with the experimental outcomes. It is noticed that a substantial variation exists between the analytical and experimental outcomes. Thus, the influence of each parameter on collector efficiency is critically examined. Both thermal conductivity and viscosity of all working fluids are experimentally measured and compared with the existing correlations. It is noticed that, existing correlations are under-estimating the nanofluid properties, particularly this deviation is considerable for the viscosity of nanofluid. For example, 18.58 % deviation is noticed at 1.0 % particle concentration of CuO/water nanofluid. Therefore, a new correlation is developed for precise calculation of viscosity for both mono and hybrid nanofluid and further analysis is carried out using the developed correlation.

In the current research, thermodynamic analysis is carried out using laws of thermodynamics to evaluate the energy, exergy efficiencies, and to study the various parameters that causes entropy generation. Experimental and analytical approaches are conducted based on mode of fluid circulation i.e. forced circulation and natural circulation as well as on type of incident radiation absorption i.e. direct absorption and indirect absorption.

All the experiments are performed as per ASHRAE standards 93-86 to calculate the instantaneous efficiency of SFPC. Experiments are conducted with different nanofluids like Al2O3/water, Cu/water, CuO/water, SiO2/water and TiO2/water nanofluids. It is observed that among all nanofluids Cu/water and CuO/water nanofluids exhibits higher thermal performance and lower entropy generation than other working fluids.

Along with the enhanced thermophysical properties, optical properties of Cu/water and CuO/water nanofluids are found to be enhanced. Therefore, by amalgamating Cu with CuO nanoparticles, a new hybrid nanofluid is developed. It is found that Cu-CuO/water hybrid nanofluid exhibits enhanced optical properties than the individual constituents and exhibits higher collector efficiency than its constituents in the direct absorption mode of operation.

It is noticed from the experimental outcomes that, instantaneous efficiency of SFPC is increasing with particle concentration and mass flow rate. In case of forced circulation indirect absorption, SFPC with Cu/water nanofluid is 16.86 % more efficient, while that with Cu-CuO/water and CuO/water are 10.55 % and 9.81 % more efficient for respectively compared to water.

While in case of direct absorption, SFPC with Cu-CuO/water hybrid nanofluid exhibits higher instantaneous efficiency of 18.45 % compared to that of water. While, SFPC with Cu/water and CuO/water nanofluids are exhibiting 13.64 % and 11.34 % enhancement compared to water.

By comparing indirect and direct absorption collectors, direct absorption collector is exhibiting 7.9 % higher instantaneous efficiency with Cu-CuO/water hybrid nanofluid under similar operating conditions.

Similar to forced circulation, in natural circulation also SFPC with Cu/water nanofluid exhibits 11.51% higher instantaneous efficiency. While SFPC with Cu-CuO/water and CuO/water nanofluids exhibits 8.12% and 6.84% more instantaneous efficiency respectively compared to water.

In natural circulation direct absorption, SFPC with Cu-CuO/water nanofluid show 13.25 % higher instantaneous efficiency than water and that is 9.53 % and 8.71 % in case of Cu/water and CuO/water nanofluids.

From the above experimental analysis, it is noted that no single working fluid is suitable for all modes of operation.

It is noticed that in case of indirect absorption system thermophysical properties play an important role, while in case direct absorption along with thermal properties, optical properties also have a major contribution to absorb the incident solar radiation. It is also noticed that in case of forced circulation, more amount of incident radiation is collected due to lower heat loss because of reduced temperature difference between absorber plate and bulk working fluid, whereas, in natural circulation mode, higher convection and radiation losses lead to reduce the thermal efficiency of the collector.

**MECHANICAL ENGINEERING**

Author : **J.V.SATYANARAYANA MOORTHY**

Title of the thesis : **STUDIES ON SUSTAINED SUPERSONIC**

 **COMBUSTION WITH RAMPS AND CAVITIES**

Guide : **Dr. G. AMBA PRASAD RAO**

Degree: **Ph. D.**

Student ID No.: **701212**

**ABSTRACT**

There has been a wide spread activity among combustion community with renewed interest in high-speed propulsion and realization of supersonic combustion ramjet engine for hypersonic flight applications. Therefore, supersonic combustion ramjet (SCRAMJET) is expected to be suitable for serving as an economical and effective propulsive system for hypersonic flight and gaining access to the space. A main source of energy release in scramjet is the combustor and for a given combustor configuration, its performance is determined primarily by fuel injection distribution and flame holding. Many theoretical, numerical and experimental research efforts have been made to investigate various aspects of the fuel injection inclusive of fuel mixing, reliable ignition, combustion stability and propulsion performance. Achievement of ignition and sustained combustion in high speed flows is a perennial challenge in supersonic combustion, and should be done within a short length of the combustor. The successful achievement of sustained supersonic combustion lies with good fuel injection scheme and flame holding.

Concepts for fuel injection in supersonic combustors that have been widely researched and adopted are wall injectors and strut injectors. Cavity based flame-holders have been tried out in scramjet combustors. Cavities provide re-circulation zones in the combustor which create conditions for increased residence time of air in the combustor and thus act as flame holders.

Thus, research necessitates study of coupling mechanism between the mixing of supersonic air/fuel streams and flame holding. Very few researchers have tried out ramps for imparting fuel injection. Generally, ramps are used to add axial velocity to the flow near the fuel injection with fuel injectors on the trailing edge of the ramp injecting fuel parallel to the flow. The flow over ramps creates counter-rotating vortices that increase mixing. Due to the supersonic flow in the scramjet, the ramps also create shocks and expansion waves which cause pressure gradients and enhance mixing. The main objective of the present study is to examine the coupling between the ramp assisted fuel injection and cavity flame holding as well as the potential for improving combustion in a scramjet combustor.

To understand the flow physics of supersonic combustion and other pertinent parameters, detailed computational studies, adopting the widely used commercial software ANSYS Fluent v15.0, have been conducted with hydrogen, aviation kerosene and ethylene as fuels. Flow field, along the length of combustor, is studied in terms of Mach number, static pressure, static temperature and mass fraction of species. A parameter, turbulence intensity has been chosen to observe the completeness of mixing. To overcome the issues with liquid fuels, gaseous ethylene is tried out as a candidate fuel for mixing and supersonic combustion.

Extensive numerical studies have been done for understanding parametric variation on a full-scale combustor, with and without cavities, with and without ramps and with rampcavity with ethylene as fuel. Fuel equivalence ratios of 0.3, 0.4, 0.6 and 0.8 are studied. Better flow-field effects are observed with fuel equivalence ratio of 0.8. However, it is noticed from mass fraction contours of species that considerable amount of fuel goes without combustion out of combustor. As a trade-off, fuel equivalence ratio of 0.6 is considered for studies on the full-scale, ramp-cavity configuration. In numerical studies, combustor entry Mach number is varied from 2, 2.5 and 3. Better performance is observed for the full-scale, ramp-cavity combustor with entry Mach number of 3. Detailed analysis has been carried out on the full-scale, ramp-cavity configuration with combustor entry Mach number of 3 and fuel equivalence ratio of 0.6.

Fuel is injected from four sets of ramps located in the combustor. Fuel injection pattern

is studied by injecting the same amount of fuel with injection of fuel from three sets of ramps each time. In the first stage, fuel is not injected from the first set of 4 ramps, 2 each on top and bottom walls of the combustor. In the second stage, fuel is not injected from 2nd set of 4 ramps. In the third stage, fuel is not injected from 3rd set of 4 ramps. In the final stage, fuel is not injected from the 4th set of two ramps, one each on top and bottom wall. In each case, the length of the combustor for mixing and subsequent combustion is different. The calculated values of thrust for 2nd stage and 3rd are observed to be 61.3 kgf and 58.71 kgf respectively. It may be inferred that the fuel injected from 1st set of ramps would mix with supersonic air-stream in the 2nd stage and combustion takes place resulting in higher thrust. The pattern in third stage may also have been similar to the 2nd stage of injection of fuel in the combustor.

A full-fledged test facility has been designed and developed simulating the high altitude conditions in terms of total pressure and temperature. The instrumentation has been calibrated at regular intervals. Initially, a sub-scale combustor has been designed and studied experimentally, with physical ramps followed by cavities across the combustor on both top and bottom walls. The combustor performance is experimentally evaluated in terms of wall static pressures and temperatures, along the combustor. Hydrogen as a pilot fuel is employed for effective utilization of aviation kerosene. With the experience of sub-scale combustor studies, a full-scale combustor has been designed with cantilevered ramps along the combustor in four stages. In each of the first three stages, two ramps on the top wall and two ramps on the bottom wall are located. In the final stage, one ramp each on top and bottom walls are provided. Two cavities are configured on the top wall of the combustor. The top wall of combustor is designed with staged divergence to avoid thermal choking in the combustor. Tests have been conducted with aviation kerosene as fuel. In the full-scale combustor, the wall pressures are 1 to 1.2 bar. Temperatures are about 1500- 1800 K in the experiments. Variety of fuels such as hydrogen, aviation kerosene and ethylene fuels are employed in the studies.

It is noticed that fuel injection and flame holder together would be vital components for

effective working of supersonic combustor. The advantage of providing ramps is that blockage to the flow is significantly less compared to other mixing devices. Numerical studies has established that ANSYS FLUENT has well-predicted the flow field characteristics. The studies on both sub-scale and full-scale combustors has established an achievement of sustained supersonic combustion with combined arrangement of ramps and cavities. It is observed the computed values of static pressure match closely with the experimental results.

**MECHANICAL ENGINEERING**

Author : **KAREDDULA VIJAYA KUMAR**

Title of the thesis : **INVESTIGATIONS ON SI ENGINE TO STUDY THE**

 **INFLUENCE OF WASTE PLASTIC PYROLYSIS OIL**

 **BLENDS WITH AND WITHOUT DISTILLATION AND**

 **ADDITIVES**

Guide : **Dr. RAVI KUMAR PULI**

Degree: **Ph. D.**

Student ID No.: **701414**

**ABSTRACT**

Technological development makes the world as global village and energy are becoming an integral part of it. However, the existing sources to generate the energy are non-replenishable in nature and also finite in availability. The replenishing period of the fossil sources is not balancing with the energy demands of the world and causes for the energy crunch. Among all fossil energy consuming sectors, the transportation sector occupies the second place. However, the transportation sector causes for releasing massive pollutants. On the other hand, modernizing life styles and rising of human comforts leads to raising another kind of pollution called plastic waste. Even though, the scientific community warns the mankind regarding the problems associated with the plastic utility, use of plastic and its accumulation become inevitable. Usage of the plastic at the domestic level becomes the major culprit of this plastic waste.

 A common solution to the above two problems is converting the plastic waste into usable fuel form. The process of converting this waste plastic into the fuel is called pyrolysis. Though the experimental works on the suitability of plastic oil in IC engines has been carrying out from a decade, no considerable outcomes exist. Most of the research work is run around the diesel grade fuel but very minimal on petrol grade fuel. Therefore, the main objective of this research is studying and analyzing the feasibility of Plastic Pyrolysis Oil (PPO) in SI engine. This research work aims to analyses the SI engine performance and emission characteristics fueled with waste plastic oil blends with and without distillation and additives.

The experiments are conducted using at 10%, 20%, and 25% of crude plastic pyrolysis oil blends to run the engine by varying the load at a constant speed of 1500 rpm. From the experimental studies, it is noticed that when SI engine operated beyond 25 percent crude plastic pyrolysis oil causes for misfiring and abnormal engine vibrations. Therefore, experiments are carried out up to 25PPO blend percentage. Thereby, strong sparks are initiated to ignite the fuel iridium spark plugs are replaced instead of normal spark plugs. Performance of the engine is marginally improved and emissions are controlled to the extent but the blend proportion cannot be raised beyond the 25 % of PPO.

The performance and emissions of the engine are not at the considerable level, and also blend percentage is limited. Therefore, in order to control the emission rates and to improve the performance of the engine 5% alcohol additives are added to the same PPO blends. Methanol and ethanol are chosen as additives to control the emissions and also to enhance the performance of engine. It is observed from the results, the BTE of 25PPO5E blend is 10.68% increases compared to PF and 20% increases than 25PPO. The BTE of methanol additive blend is 8.01% increases compared to PF and 21.74% increases than without additive blend. The HC emissions of 25PPO5M blend are 34% decrease compared to PF and 25% decreased than 25PPO. Whereas HC emissions of 25PPO5E blend is 41% increase compared to PF and 79% increase than 25PPO. The NOx emissions of 25PPO5M blend are 31.89% decrease compared to 25PPO and 2% decreased than PF. Whereas NOx emissions of 25PPO5E blend is 52.63% decrease compared to 25PPO and 6% decrease than PF. It is note to worthy from the experimental results that, by adding the alcohol additive in plastic oil blend the performance improved and control the NOx emissions. However, addition of ethanol is unable to control the HC emissions, while methanol additive augments the thermal performance and also able to control the CO, HC and NOx emissions. Therefore, methanol additive is best-suited additive for the plastic oil blended with petrol. Though, the performance and emissions are refined but unable to increase the blend proportion beyond the 25 % of PPO.

A noteworthy alternative to increase the blend proportions and to control the rate of emissions is altering the properties like viscosity, density and calorific value and octane number of crude PPO is distillation. Experiments are conducted with blends at 10%, 20%, and 25% of distilled plastic pyrolysis oil and compared with crude PPO blends. The BTE increases with DPPO-PF fuel blends compared to PPO-PF blends but less than PF. Nearly 9.4% increment in the BTE is observed for 25DPPO operation when compared to 25PPO but 2.9% decrement compared to PF. The NOx emissions of 25DPPO blend are 10.75% decreased compared to 25PPO and 23.8% increase compared to PF. From the results, it is clear that the engine can run beyond 25% of distilled plastic oil blends without any modifications.

Further, tests are conducted even up to 50% DPPO and pure DPPO. From the results, the BTE increases with increase in DPPO blend up to 30% DPPO, proportions but less than PF. Nearly 4.3% decrement in the BTE is observed at full load for 50DPPO operation when compared to PF. The NOx emissions increases with increase in DPPO blend, proportions compared to PF. The NOx emissions of 50DPPO blend are 44.3% increase at full load condition compared to PF. Engine fuelled with pure DPPO, nearly 5.7% decrement in the brake thermal efficiency and 73% of NOx emissions is observed. From the experimental studies, it is noticed that the engine can run even beyond the 50 % blend i.e. pure DPPO, but further increasing the blend percentage beyond 50% causes for higher NOx emissions and lower thermal performance. Therefore, the experiment is restricted to 50 % DPPO alone.

**MECHANICAL ENGINEERING**

Author : **Mr. KATAM GANESH BABU**

Title of the thesis : **EXPERIMENTAL INVESTIGATIONS ON DI CI ENGINE**

 **USING MIXED CULTURE MICROALGAE BIOMASS AS**

 **AN ADDITIVE IN COCONUT AND KARANJA**

 **BIODIESEL FUELS**

Guide : **Dr. KATAM GANESH BABU**

Degree: **Ph. D.**

Student ID No.: **701413**

**ABSTRACT**

The global depleting fossil fuels reserves, increasing population insisted on looking into new energy sources. In India, increasing Urban ization by cause of development in the Industrial and Transportation sectors is leading to a search for new alternative sources. As observed from the literature the biofuels are the best alternative energy sources to fulfill Diesel fuel demand by reducing environmental issues.

Among all biofuels, the biodiesel was the best alternative fuel to meet Diesel fuel demand. Because of the lower maintenance cost, the Compression Ignition (CI) engines are playing a vital role in Industrial and transportation sectors. The researchers, scientists, have produced biodiesel from first, second and third generation biodiesel sources. Among all lipid sources, the Microalgae were the most quickly growing, higher oil yielding one.

The by-products while algae to biodiesel conversion process are most valuable than others. The practice of Biodiesel or Diesel in CI engines is leading to increasing NOx emissions. Among all emissions, the Oxides of Nitrogen (NOx) and Particulate Matter (PM) are the most harmful emissions to human and environment. To reduce emissions from the diesel engine, the use of additives in Diesel, biodiesel and their blends is very well practicing fuel modification technique. The higher cost of phenol, amine-based antioxidants is causing to increase CI engine operating cost.

The study involves improving the performance of Coconut oil (of high saturated fatty acids) and Karanja oil (of high unsaturated fatty acids) with the influence of additives. These oils have different physicochemical properties, eg. Coconut had higher Oxygen, Cetane number, and lower Calorific value, density than Karanja biodiesel fuel. To investigate an unmodified diesel engine characteristics, the very finely grounded mixed culture Microalgae (MCM) biomass particles emulsified in neat Coconut, Karanja biodiesel fuels. The Triton X-100 surfactant used to prepare stable blends preparation for avoiding MCM particles sedimentation. Initially, the test runs on the engine carried out by using base fuels (Diesel, neat Coconut, Karanja biodiesels), all MCM particles based blends and Lauric acid contained blends at standard operating parameters (SOPs).

The blending of MCM particles in different proportions (CB+1gAP, CB+2gAP, and CB+3gAP) in Coconut biodiesel has experimentally proved the reduction of NOx emissions. However, about this reduction, there are two different opinions by Doctoral scrutiny committee (DSC) members. Firstly, this could be because of the presence of Lauric acid in CB, and secondly, this could be because of MCM particles blending in the same biodiesel. Therefore, the author has selected KB, which is free from Lauric acid composition. The author experimented with different proportions of Lauric acid, and MCM particles separately in KB fuel.

The Kinematic viscosity of biodiesel blends increases with either the increase in MCM particles addition or with Lauric acid volume. The author has observed an increase in Brake thermal efficiency by cause of the multilevel micro-explosion of MCM particles. The reduction in NOx emissions is due to the absorption of heat by MCM particles from the combustion chamber. The properties described above are influenced to increase CO, HC, and Smoke emissions though there was an increase in BTE and decrease in NOx emissions than CB, KB fuels.

To overcome the above issues as per the literature is concerned the increase in injection pressure was the predominantly influencing factor. In the final stage of the experimental investigation, the author applied 190, 210, 230 and 250 bar injection pressures on each fuel. In this approach, the increase in brake thermal efficiency, NOx emissions, and the decrease in CO, HC, and smoke emissions have observed. Finally, the reduction in NOx emissions has observed with blends of Lauric acid in KB than MCM particles contained blends, but there was a reduction in Brake thermal efficiency.

At engine, SOPs 3.28% higher ICP (In-cylinder pressure) observed with CB+3Gap blend than KB+3gAP blend. The 28.02, 26.32% highest BTE observed with CB+1gAP blend (@ 250 bar IP) and KB+1gAP blend (@ 210 bar IP) respectively. The highest 14.2% NOx emissions reduction observed with KB+30gLA blend at 210 bar IP. The present investigation revealed that the lower level (1g) addition of MCM particles is improved the engine performance with a slight penalty in NOx emissions. The higher level addition (3g) of MCM particles has reduced NOx emissions with a slight compromise in performance. Overall the MCM particles blends have attained more performance than Lauric acid blends.

**Keywords:** Biodiesel, blend, compression ratio, combustion, diesel, engine, emissions,

injection pressure, microalgae, performance.

**MECHANICAL ENGINEERING**

Author : **KISHORE KUMAR KATIKANI**

Title of the thesis : **DESIGN AND ANALYSIS OF SPECIAL PURPOSE**

 **CUTTER FOR MACHINING SOLID PROPELLANT**

 **GRAIN**

Guide : **Dr. V VENKATESWARA RAO**

Degree: **Ph. D.**

Student ID No.: **701211**

**ABSTRACT**

The main workhorse of satellite launch vehicles and long-range missiles are powered by large Solid propellant Rocket Motors (SRM) because of their simplicity, minimum manufacturing time and they are credited with reliability and consistent performance. These SRM are produced with case bonded Composite Solid Propellant (CSP) grains with suitable binder and oxidizer formulation as main propulsion system. In comparison to liquid engine rockets, solid rockets are relatively simple, easy to apply, require little servicing and have minimum or no moving parts. Thrust characteristics of the solid rocket motor are largely determined by the initial ignition surface of the propellant grain to meet specific requirements. Due to economic and technical reasons, surface area of the propellant exposed to initial ignition, called grain configuration, is to be accurately achieved by machining.

Machining is required to trim off the uneven and porous top surface of the propellant grain and also to generate the desired configuration for the grain. However, the CSP is sensitive to friction, heat, static charge and impact load which are generally associated with machining. In view of this, the chips and powder produced during machining of grain are to be disposed immediately from cutting zone because they become further sensitive to ignition in tiny form. Since these composite propellants are also hygroscopic in nature, the application of cutting fluid leads to disqualification of grain.

Hence, the motivation for the present work is to design and analyse custom-built cutting tool for safe machining of composite solid propellant grain of SRM as regular cutters are not able to meet the above requirements. A special purpose cutter has been designed in the present work to cater versatile machining operations required for different contours of grain configuration with a provision made for an instant and safe disposal of chips.

The experimental studies on microstructure of CSP are carried out for the assessment of ‘Hazard to machine’ material on safety aspects due to non-availability of data in machining aspects. Experimental investigation of microstructure of CSP by SEM analysis and their mechanical properties by INSTRON UTM are performed to decide the tool material and its geometry such as nose radius, rake and relief angles. This study enabled proper design of cutting element and to conceive safe experimental set up for an effective conduct of machining trials.

A prototype cutter is developed for the evaluation of tool signature for low cutting force. This work resulted in the development of a disk shaped cutter with HSS as the tool material. Based on the existing designs, 4 conical inserts were employed on the periphery of the cutter. The micrographical studies revealed that large rake and relief angles are required for the tool in order to minimize the cutting forces. Exat values of tool signature is experimentally evaluated for minimum cutting force and these values are considered for the final cutter assembly.

To meet the machining requirement of propellant grain, a final cutter assembly called ‘Turbine cutter’ was developed and its performance is evaluated through machining trials under stringent safety machining conditions as prescribed in the Department of Defence safety manual for ammunition and explosives, US Government. A new concept of chip slicer is introduced for safe disposal of propellant chips. Staggered chip slicer is incorporated in order to yield good surface finish and for instant disposal of chips. The cutter developed is simple in construction with minimum components and no moving or sliding parts to avoid source of friction in the cutting zone and yet versatile in application to meet the different profiles of given grain configuration.

The cutter is also economical as a provision for indexing the insert is incorporated in the present design. Cutter is also provided with self and instant chip evacuation provision when integrated with Chip and Dust Collection System (CDCS) to meet the safety requirement of machining.

The effect of process parameters on cutting power and material removal rate was evaluated based on full factorial (27) experiments on live propellant material using the developed turbine cutter. Two factor interaction (2FI) models for low cutting power and maximum material removal rate were developed to investigate the influence of process parameters in machining CSP materials. ANOVA is performed to evaluate the significant process parameters for safe and effective machining. Response surface methodology (RSM) is used to find the optimum machining parameters for safe and effective machining of CSP materials and mathematical modelling. Adopted approach and models for optimising the cutting parameters are also validated. This analysis establishes the safe and effective machining parameters for ‘hazard to machine’ CSP material using Turbine cutter.

Tool wear studies are also carried out to understand the predominant tool wear mechanism in machining of CSP material with the developed HSS Turbine cutter. The micrographs of cutting insert obtained from Scanning Electron Microscope and Vision Inspection System after machining are analysed. It was observed from the analysis that the predominant tool wear in machining the CSP grain is the progressive chemical wear. It is also found that the developed turbine cutter at uncontrolled ambient condition has a tool life of 60 hrs. Thorough cleaning of cutting element with Dioctyl adipate (DOA), subsequent cleaning with water and drying of the insert at the end of every cutting day ensures to extend the tool life significantly.

The present research focuses on the development of a special purpose cutter for machining hazard to machine materials by meeting the safety requirements. This cutter further helps in machining of required grain configuration with a single tool and set-up. It also provides a methodology for machining composite propellants that contain energetic ingerdients.

**Keywords:** Propellant grain machining, composite solid propellant, Turbine cutter, chip slicer, Design of experiments, chip evacuation and chemical tool wear.

**MECHANICAL ENGINEERING**

Author : **KRISHNA KISHORE MUGADA**

Title of the thesis : **INFLUENCE OF TOOL GEOMETRY ON MATERIAL**

 **FLOW AND CHARACTERIZATION OF FRICTION STIR**

 **WELDED AL 6082 ALLOY**

Guide : **Dr. ADEPU KUMAR**

Degree: **Ph. D.**

Student ID No.: **701346**

**ABSTRACT**

Joining of aluminum alloys, was more promising with the latest friction based process named friction stir welding which comes under the category of solid-state joining processes. The formation of bond in friction stir welding depends on tool shoulders frictional contact and pins friction contact plus shear deformation.

In this present investigation, the influence of welding processes parameters, tool geometry such as shoulder end features, pin features and the combined effect of shoulder end features and pin features was studied with the use of marker insert technique to understand the material flow during friction stir butt welding of Al 6082 alloy. In the initial phases, pilot experiments were conducted and optimized the process parameters with a simple tool geometry (shoulder: flat, pin: taper cylindrical) and resulted in defect-free welds at 800 rpm, 40 mm/min and tilt angle of 10. The shoulder diameter was varied from 18 mm to 24 mm with an interval of 2mm and noticed that the welds resulted in 21 mm shoulder diameter possessed higher joint strength.

With the goal to reduce the weld size and improving the weld joint efficiency, in the third phase of work, the influence of various proposed/designed shoulder end features tools on

material flow and temperature distribution was studied. The 18mm shoulder diameter in combination with shoulder end features has resulted in improved joint strength and better flow of material as compared with the welds with 21 mm shoulder diameter with simple flat shoulder

geometry along with the reduction of the weld bead. Further, the shoulder end features were

attached with the various polygonal pins to study the individual material flow effects of shoulder and pin. The study clearly revealed that the pin drives the sheared material to the top layers of the weld and the shoulder plasticizes it generating heat which leads to the bond formation. However, it was observed that each shoulder is having a best possible combination of the pin to aid better material flow such as concentric circles tool with a triangular pin, ridges shoulder tool with square pin etc. so that the balance of heat was achieved and resulted with four best combinations of shoulders and pins.

In the final phase of the work, the welds obtained with four best combination of shoulder and pins were studied using electron backscattered diffraction (EBSD) at three locations on advancing side, weld zone and retreating side. This analysis clearly distinguished the favorable orientation of grains leading to final strength and identified that ridges shoulder end featured tool with square pin profile has higher joint strength with the better material flow.

**MECHANICAL ENGINEERING**

Author : **M. VIJAY KUMAR**

Title of the thesis : **STUDIES ON THE IMPROVEMENT OF CI ENGINE**

 **PERFORMANCE, COMBUSTION AND EMISSIONS**

 **WITH THE USE OF BIODIESEL BLENDS, ADDITIVE**

 **AND ENGINE MODIFICATIONS**

Guide : **Dr. A. VEERESH BABU**

Degree: **Ph. D.**

Student ID No.: **701415**

**ABSTRACT**

The diesel engines have high efficiency, reliability and durability together with their low

operating cost. These essential features make them be widely used in the transportation, automotive, agricultural application and industrial sector. These vast fields of usage lead to the increasing requirements of diesel fuel and going for depletion of petroleum fuel shortly. The emissions from engine exhaust can cause health problems to human beings and will have an impact on the environment such as climate change, global warming, acid rain, ozone depletion and photochemical smog. Hence, it is essential to go for an alternate fuel to diesel and effective controlling methods such as additives, fuel nozzle hole diameters, exhaust gas recirculation and diesel particulate filter can diminish the pollutions.

The objectives of the research were to study and perform experimental investigations to attain improved performance with a reduction in emissions of NOx and particulate matter using

Mahua biodiesel blends. To achieve these goals we have considered locally available Mahua non-edible oil after detailed survey.

The Mahua methyl ester was obtained with less than 1% FFA and attained a maximum yield of 85% by the esterification and transesterification process. The Mahua biodiesel preparation was considered with the concentrations of sulphuric acid, potassium hydroxide, methanol, calcium chloride and distilled water are used for the best yield. The fuel properties of diesel, raw Mahua oil and Mahua methyl ester were tested for its physical properties and compared with the requirement of American Standard for Testing Materials (ASTM-D6751). The different blends of Mahua methyl ester were investigated on a diesel engine with standard parameters and established that B20 fuel is the optimal biodiesel blend for improved performance and reducing emissions, but with an increase of NOx emissions with B20 to reconfirm the reported works as per the literature reviewed.

Based on the observed NOx values with a simultaneous observation on other emissions, it has proposed with different techniques to reduce NOx levels. Firstly, with a change in fuel composition with the introduction of metal-based additive (Cerium Oxide). The performance of BTE and combustion of pressure data are observed to be enhanced by the addition of metal-based additive. The CO, HC, and smoke are decreased for B20 fuel with nanoparticles. The NOx is reduced by dosing the CeO2 due to the oxidation of unburned CeO2 in the exhaust.

Secondly, using different multi-hole injector orifice diameters (Ø 0.28 mm (base), Ø 0.31

mm, Ø 0.20 mm) with improved B20 fuel. The authentic results were observed by using B20 and smaller orifice NHD. It is observed that smaller orifice NHD improves the air-fuel mixing, atomization, and vaporization which leads to shorter combustion duration. The B20 fuel also showed better results than the baseline diesel. The combination of B20 with smaller orifice NHD are very much appreciable results were seen, but the only drawback was NOx is found to be increased.

Thirdly, with the introducing of partly cooled exhaust gas recirculation system of 10%, 20%, 30% rates for the best fuel injector orifice diameter (Ø 0.20 mm) with B20 fuel. The results observed by the partly cooled EGR of 10% rate for diesel and B20 fuel with smaller orifice NHD, the performance of BTE and BSFC are improved at partial load conditions. As increasing the EGR rates, the NOx is decreasing due to the in-cylinder temperature decreasing. The increasing EGR rate mainly leads to reduce the performance and raise the HC, CO, soot emissions levels.

Finally, investigating the performance with the use of diesel particulate filter along with the partly cooled exhaust gas recirculation system to after noticing the increased levels of soot with partly cooled exhaust gas recirculation investigation. From these, it has resulted that the partly cooled EGR with 10% rate with a combination of DPF is very effective without too many disturbing the performance and exhaust emissions, because of trapping the soot particles in the DPF. For EGR 20% and 30% rate with the combination of DPF, the combustion and emissions are disturbing very badly. Moreover, there is a fluctuation of speed for 30% EGR rate with DPF at higher load condition due to the adverse pressure which is caused by the accumulated soot particles in the DPF.

It has compiled explicit experimental results and made notable conclusions in the domain of alternate fuels focusing majorly on the reduction of NOx from 839 ppm to 645 ppm (With 20% EGR & DPF) and soot emissions from 42.90% to 34.90% (With 10% EGR & DPF).

**MECHANICAL ENGINEERING**

Author : **MARUTI BHAGWAN MANDALE**

Title of the thesis : **ESTIMATION OF STATISTICAL ENERGY ANALYSIS**

 **PARAMETERS FOR STRUCTURAL ELEMENTS**

Guide : **Dr. P. BANGARU BABU**

Degree: **Ph. D.**

Student ID No.: **701137**

**ABSTRACT**

The statistical energy analysis (SEA) method has been developed for middle and high audio-frequencies. It is a useful tool for designers to predict power transmission paths and radiation of complex mechanical systems, such as airplanes, ships, buildings, transport vehicles and electromechanical equipments. In statistical energy analysis, damping loss factor, coupling loss factor and modal density are the essential parameters for vibro-acoustic analysis of complicated structures.

Damping is usually characterized by the amount of energy dissipated and the most common measure of this dissipation is damping loss factor. The effects of materials used for plate on damping loss factors are described. Half-power bandwidth method had used for determining damping loss factors of aluminium, mild steel and stainless steel rectangular plates with free-free, simply supported and clamped free condition. Also this method had used for determining damping loss factors of composite plates with different fiber orientations. Damping loss factor values of composite plates are higher than aluminium, stainless steel and mild steel plates for free-free boundary condition.

In statistical energy analysis the resonant modes are grouped into different frequency bands. Modal density gives the relation between number of resonant modes in selected frequency band and frequency range. Modal densities had determined and compared by theoretical and experimental methods for rectangular plates of different materials like mild steel, aluminium, stainless steel and composites. Also modal densities of unidirectional, quasi isotropic and cross ply fiber orientations of composite plates had compared. The effect of graphene addition in composite plate on modal density had verified.

In industries, the use of appropriate junctions between components is of paramount interest. The values of coupling loss factor had calculated and compared for different junctions. The screwed and bolted junctions had examined for thin rectangular aluminium plates of same size. The energy level difference method had used to find coupling loss factors because of its simplicity. These experimentally found coupling loss factors had later compared with analytical solutions. It is noticed that the analytical results are in qualitative agreement with experimental results. It is also observed that coupling loss factors for bolted junction are relatively higher than that of screwed junction. Also the values of coupling loss factor had estimated by using energy level difference method by varying tightening torque applied at junction. Higher values of coupling loss factor have been observed for higher tightening torque on bolted junction.

The values of coupling loss factor had determined for different structural junctions of composite plates. The riveted and bolted junctions had examined for rectangular composite plates of same size and in same plane. It is observed that coupling loss factors for bolted junction are relatively higher than that for riveted junction of composite plates. The values of coupling loss factors are found to increase with increasing tightening torque applied at structural junctions of composite plates. It is also noticed that the experimental results of coupling loss factors for point junctions vary with changes in fiber orientations of composite plates.

It is firmly believed that the various findings of the statistical energy analysis parameters in the current thesis help for vibro-acoustic analysis of complicated structures.

Keywords: Statistical energy analysis, Modal density, Damping loss factor, Coupling loss factor, Structural junctions, Power flow equation.

**MECHANICAL ENGINEERING**

Author : **NARASIMHA SURI TINNALURI**

Title of the thesis : **HEATLINE VISUALIZATION OF THERMAL**

 **TRANSPORT IN ANISOTROPIC POROUS MEDIA**

 **USING A GENERALIZED NON DARCY FORMULATION**

Guide : **Dr. D. JAYA KRISHNA**

Degree: **Ph. D.**

Student ID No.: **714130**

**ABSTRACT**

The understanding of hydrodynamics and thermal transport in enclosures filled with fluid saturated porous media is of great importance due to its extensive applications. Some of the applications such as heat exchangers, nuclear fuel rod bundle, food processing, solar thermal systems etc. involve intricate geometries which are isotropic and anisotropic in nature. For the efficient design of these systems a thorough understanding of thermal transport is required. Visualization of thermal transport in terms of heatlines was observed to provide a better insight.

In the present study, initially a numerical code has been developed for the visualization of isotherms and heatlines in two-dimensional domains viz. square, trapezoidal, skewed, S-curve and H-curve. The developed code is used to read the mesh of various shapes from commercial meshing software (GAMBIT). Here, the data pertaining to mesh has been given as input to the numerical code developed for the visualization of thermal transport in these domains. The integral form of the governing equations are discretized using collocated grid based Finite Volume Method (FVM). The resulting governing equations are solved using the Gauss-Seidel iterative method. The present numerical scheme is rigorously validated for temperature distribution with commercial CFD code ANSYS – Fluent. Later, it is extended to

the Bejan’s heatline visualization for the considered geometries provided with and without discrete heat sources. The developed generalized code is validated with earlier numerical works pertaining to heatline visualization. Numerical results are presented in terms of temperature distribution and heatlines for analyzing the thermal transport in 2D solid geometries.

Further, the study is extended to investigate the hydrodynamics for a lid-driven flow saturated with non-Darcy anisotropic porous media. The applications include float glass production, food processing, soil liquefaction etc. The Reynolds numbers (Re) considered for

the study are 10, 100 and 1000. The effect of Darcy number (10-5 ≤ Da ≤ 10-2) and porosity (ε = 0.3 and 0.6) have been varied to analyze the permeability ratio (K\* = 0.1, 1 and 10), Forchheimer constants ratio (F\*=1, 10 and 100) and principal axes inclination (θ = 0o, 45o and 90o) on flow behavior. A SIMPLE algorithm based finite volume method has been employed to solve the governing equations. The quadrilateral cells in a collocated grid arrangement have been considered. Initially, the consistency check for the numerical scheme has been carried out by setting porosity equal to unity and Darcy number to a very high value. This is the limiting case for porous media, where the porous media tends to behave as a single-phase fluid. Further, the validation of pertinent problem is carried with available literature. The flow physics has been interpreted by plotting the results in terms of streamlines and maximum stream function values. The study could reveal that with the increase in Reynolds number the influence of non-linear drag forces become significant. Also, it is observed that the anisotropic parameters of the non-Darcy porous media profoundly modulate the flow.

Finally, thermal hydraulics for anisotropic porous media is analyzed to study the influence of anisotropic parameters by varying Rayleigh number (Ra = 103 - 106), Darcy number (Da = 10-6 - 10-2), porosity (ε = 0.3, 0.6) and Prandtl number (Pr = 0.1,1 and 10). The anisotropic parameters investigated are permeability ratio: K\* (0.1, 1 and 10), principal axes inclination: θ (0o – 90o), Forchheimer constant ratio: F\* (1, 10 and 100) and thermal conductivity ratio: k\* (0.1, 1 and 10). The results are presented in terms of streamlines, isotherms, heatlines and average Nusselt number. The heatlines are plotted to visualize the path of thermal transport. The anisotropic behavior of the porous matrix is observed to significantly influence the thermal hydraulics. Heatlines along with isotherms are observed to help in great detail for the understanding of thermal hydraulics in these geometries.

**Keywords:** Non- orthogonal; Collocated grid; Isotherms; Heatlines, Visualization; Finite Volume Method; Various geometries; Thermal transport; Discrete heat source; Anisotropy; natural convection; Porous Media; Generalized Non-Darcy Formulation.

**MECHANICAL ENGINEERING**

Author : **P. ANIL KUMAR**

Title of the thesis : **DESIGN AND DEVELOPMENT OF METALLIC**

 **VIBRATION ISOLATORS FOR AIR BORNE VEHICLES**

Guide : **Dr. P. BANGARU BABU**

Degree: **Ph. D.**

Student ID No.: **701244**

**ABSTRACT**

Electronic packages meant for executing key roles like control, guidance, navigation, etc. in air borne vehicles will experience random vibration during flight. This vibration gets further transmitted to internal subsystems like Printed Circuit Boards (PCBs) with amplification. If the amplified vibration response on PCB exceeds the qualification limit, then the electronic components mounted on PCB will either malfunction or lead to catastrophic mission failure.

Mounting configuration of PCBs in chassis greatly influence the amplification factor. Stacked mounting and wedge guide mounting are two basic configurations of electronic packages. During qualification testing of packages in both the configurations, very high vibration responses are observed. Thorough analysis of this problem conveyed a message that the rigid mounting condition of PCBs with respect to chassis is the chief contributing factor to the high vibration response.

It is understood that the solution for reducing this high vibration response is to relax the rigidity between PCBs and chassis using vibration isolators. Commercially available vibration isolators which are made of rubber are not fit for electronic packages as shelf life of rubber is not on par with anticipated storage time of air borne vehicles and also due to the environmental sensitivity of rubber material.

Keeping these issues into consideration, an attempt is made in this research work to design, develop and experimentally evaluate metalic spring isolators for electronic packages in stacked mounting configuration and metalic C-isolators for electronic packages in wedge guide mounting configuration.

To begin with design criteria for effective isolation is evolved considering methodology identified from literature as a reference. Design constraints are identified and the associated governing relations are brought out. Subsequently isolators are designed and their dimensions are worked out.

Further Graphical Use Interface (GUI) based software is developed in MATLAB for design of spring isolator. The necessary formulation, which is derived as part of design, is converted in form of code. The intention behind developing the software is to enable the designer to use it as a hand calculator, which just takes the inputs from the user and gives the output quickly.

Design is validated by comparing the stiffness values obtained using calculations with that of Finite Element Analysis (FEA). Subsequently isolators are manufactured with dimensions evolved from the design.

In the later stage these isolators are experimentally evaluated in random vibration environment and isolation effectiveness is quantified. Both the isolators are found to be very effective in reducing vibration levels in their respective electronic packaging configurations. Efficacy of the isolators thus developed is methodically tested in many real life packages and there by consistency in the methodology is established.

Keywords: Mounting configuration, Isolators, Experimental evaluation.

**MECHANICAL ENGINEERING**

Author : **PRABHAKARA RAO GANJI**

Title of the thesis : **PARAMETRIC OPTIMIZATION OF DI CI ENGINE TO**

 **ACHIEVE HCCI COMBUSTION CHARACTERISTICS**

 **FOR DIESEL/BIODIESEL BLENDS**

Guide : **Dr. V. R. K. RAJU**

Degree: **Ph. D.**

Student ID No.: **701343**

**ABSTRACT**

In recent years there has been growing requirement to develop more efficient engines with minimum emissions. This is mainly due to increasing demand for fuel economy and stricter regulations for emissions. Hence it is necessary to develop a technology, which will fulfill both of the above requirements. Diesel and gasoline engines power majority of transportation vehicles today. The operation of gasoline engines is limited by low part load efficiencies, since compression ratio is limited to avoid the phenomenon of knocking. Diesel engines are superior to gasoline engines due to their higher power, efficiency, and fuel economy.

In CI diesel engines the fuel is injected into the cylinder which comprises of hot compressed air. Since the time for the mixture formation is very less, there would definitely be zones of rich and lean mixture inside the cylinder. This makes the overall mixture heterogeneous. HCCI is a mode of combustion in which a homogeneous mixture of air and fuel is prepared and is burnt by developing an auto ignition condition inside the combustion chamber. HCCI works on the principle of both SI and CI engine in the sense that a homogeneous mixture of the air and fuel is prepared as that of SI engine and compression ignited as in CI engine.

Computational Fluid Dynamics (CFD), is an effective and widely used tool to design and optimize of an Internal Combustion (IC) engine. The engine performance and emission characteristics are strongly determined by the complex interacting processes of in-cylinder flow, fuel spray injection and combustion. CONVERGETM CFD code is one of the popular IC engine simulation software which can able to predict the combustion phenomena with reasonably good accuracy.

Two engines were considered for the present study, namely CAT 3401 and VCR engine. The CAT 3401 is a single cylinder version of a CAT 3406 heavy duty, direct injection diesel engine, whereas VCR engine is a genset application laboratory engine. In the present work, three different configurations such as CAT3401 diesel, VCR diesel and VCR PB20 were validated with the experimental results. The study has been extended to evaluate the effect of four design parameters such as Compression Ratio (CR), Start of injection (SOI), Fuel Injection Pressure (FIP) and Exhaust Gas Recirculation (EGR) on the performance and emission characteristics. Regression equations were developed for the responses such as ISFC, NOx and soot. For all the configurations, the parameters are optimized for the minimizing the NOx, soot and ISFC by using the Response Surface Methodology (RSM). It was observed that the interaction effects also play a major role in determining the performance and emission characteristics of the engine.

Increasing CR reduces ISFC and soot whereas it increases NOx emissions and vice versa, but this trend reverses when the SOI and FIP are at their high levels. Increasing FIP reduces soot and also slightly reduces ISFC but increases NOx significantly. But this is also not valid when the low EGR and advanced SOI co-exist. Advancing SOI reduces soot and increases NOx but the ISFC may decrease or increase and will depend on the compression work. Increasing EGR alone increases the soot and ISFC whereas the NOx emissions decrease significantly, whereas this phenomenon turn round when the CR and SOI are at high levels.

Mixture homogeneity is quantified based on TFDI (Target Fuel Distribution Index) for the baseline and optimized models and was compared for all the three cases. Improved TFDI with simultaneous reduction of NOx and soot through optimized configuration ensures combustion characteristics as that of HCCI in all the three cases. The use of PB20 (80% diesel and 20% Pongamia biodiesel) as a fuel in an optimized case is also justified, and recommended as a replacement for conventional diesel based on its favorable ISEC (MJ/kWh).

**MECHANICAL ENGINEERING**

Author : **PUNEET CHANDRAN**

Title of the thesis : **DESIGN AND DEVELOPMENT OF HARD PROTECTIVE**

 **COATINGS ON CUTTING TOOLS FOR DRY**

 **MACHINING APPLICATIONS**

Guide : **Dr. KRISHNA VALLETI**

Degree: **Ph. D.**

Student ID No.: **701349**

**ABSTRACT**

Manufacturing processes are constantly challenged by the perennial advancements in materials technology. To remain on par with the materials progress and overcome the challenges in machining them to near-net shape, the onus must be on developing cutting tools and associated technology. It is well known that high speed dry machining is rapidly gaining interest especially with the employment of difficult-to-machine materials in niche areas. The advantages associated with this technique (high productivity, superior work quality) fall short during the machining of such materials due to the high wear rate and low thermal stability of the conventional tools/coatings. These materials retain their strength at high temperatures, have low thermal conductivity and are chemically reactive which directly affects the tool wear rate. Hence, machinability of these materials poses a paramount challenge when using conventional tools. Several efforts have been made to improve tool life, the first being selection of appropriate cutting tool material. Owing to the inherent shortcomings of these cutting tool materials, surface engineering by means of depositing a hard coating on the existing tool materials has been explored as a plausible option to improve tool life.

Utilization of cutting tool coatings in various manufacturing sectors has proved to be beneficial with a noteworthy extension in tool working hours and facilitating high productivity. It is an established fact that coatings render a highly wear resistant surface on the substrate material by providing oxidation resistance at elevated tool temperatures during machining. The coating industry has been flourishing with the development of CVD and PVD based coatings. Since decades, tool coatings deposited by physical vapor deposition (PVD) have captivated the commercial market owing to their superior properties like high hardness, excellent coating adhesion etc. Among the family of PVD techniques, cathodic arc based PVD (CAPVD) coatings have superior properties, i.e., excellent adhesion (due to high ionization) and high deposition rate over other PVD techniques like magnetron sputter deposition. Therefore, this technique has garnered widespread interest and industrial viability.

The current PhD work is centred on the identification and design of super hard coatings with excellent wear resistance and tribological properties for machining materials at aggressive conditions during dry machining. To achieve this objective, initially wellknown conventional coating TiN was deposited on cutting tool substrates like high speed steel and tungsten carbide. A detailed investigation was carried out on the application of micro-blasting and drag finishing surface pretreatment techniques prior to coating deposition on the tool substrates. Various crucial parameters effecting coated tool life like pre-coating surface morphology, cutting tool microgeometry and cutting tool-coating adhesion were studied. Machining studies carried out on EN 24 material revealed a significant increase in tool life by using optimized pretreatment techniques in comparison to commercial tools.

The next part of the research work dealt with the development of CrAlSiN thin films based on the understanding obtained on the cutting tool-coating necessities from the first part of the study. CrAlSiN thin films were synthesized with varying Cr/(Al+Si) ratio and studied for their physical and mechanical properties. The physico-mechanical properties attained a maximum at the Cr/(Al+Si) ratio of 1.2 which also showcased a nanocomposite microstructure. Machining studies on EN 24 also revealed that the CrAlSiN nanocomposite coating performs better than the well-known TiAlSiN coating owing to its better tribological properties. Notwithstanding the excellent increase in tool life due to the tribological properties of CrAlSiN nanocomposite coating, nanocomposite films are plagued by problems like higher coefficient of friction and residual stresses to name a few.

Consequently, the final part of this research was focused on enhancing the frictional properties of the CrAlSiN nanocomposite coatings to adapt to dry machining conditions. Initially, the films developed with constant carbon content exhibited a considerable decrease in the coefficient of friction with carbon addition. Subsequently, an increase in the carbon content led to a steep decrease in the hardness values along with a drop in the adhesion values. Therefore, a novel bi-layer coating with hard nanocomposite CrAlSiN as a base layer and Gradient - CrAlSiCN as a top layer was developed to improve the tribological properties without compensating on the mechanical properties. The coatings synthesized with different gradient carbon compositions showed excellent tribological properties and significant increase in tool life compared to the CrAlSiN coatings. These coatings could be an industrially viable solution to machine materials in an aggressive environment without compromising on the work quality.

**Keywords:** Physical Vapor Deposition, Micro-blasting, Drag Finishing, Cutting tool microgeometry, dry machining, nanocomposite coatings, coefficient of friction.

**MECHANICAL ENGINEERING**

Author : **PUNUGUPATI GURABVAIAH**

Title of the thesis : **STUDIES ON LASER ASSISTED MACHINING OF**

 **GELCAST FUSED SILICA CERAMIC COMPOSITES**

Guide : **Dr. P. SUBHASH CHANDRA BOSE**

Degree: **Ph. D.**

Student ID No.: **714123**

**ABSTRACT**

Structural ceramics have interesting mechanical, thermal, chemical and dielectric properties, which suggest great potential for structural applications even at high temperatures. These are also used in electronic applications like insulators, semiconductors, conductors and magnets due to their electrical and magnetic properties. Advanced structural ceramics have been progressively used in aerospace, automobile industries, defence, biomedical, construction, nuclear industries, chemical, petrochemical and oil/gas industries due to their excellent properties. The usage of fused silica in such applications largely depends on the ability to reliably and economically mass produce complex and complicated shaped components. This is a challenge for the ceramic industry using traditional fabrication techniques. Moreover, forming complex shaped parts by machining and grinding of final sintered parts is seldom viable as it is very expensive. Advanced ceramic fabrication techniques such as colloidal direct casting offer a way to produce complex shapes. This study builds upon the gelcasting near net shape casting method by successfully developing a new slutty formulation and processing technique. Among the fabrication techniques for ceramic composites, gelcasting has recently attracted much attention as being a versatile, low cost and environmental friendly process. Defence organizations such as DRDL, ARCI etc. have been working with ceramic radomes used in missiles. During interaction with experts from these prominent R&D Institutions, it is found that radomes are importing from foreign countries like Germany and Russia. Cost of each radome is approximately Rs. 30-40 lakh. Even though manufacturing knowledge transfer is also restricted during these purchases.

Fused Silica ceramics possess low thermal expansion, high chemical resistance, excellent optical qualities, low dielectric constant, low loss tangent and chemical properties. With exceptional physical and chemical properties, fused silica has various applications such as antenna windows, optical devices, heat shields, high power lasers, precision instruments, semiconductor manufacturing, aerospace applications and these applications continuously increasing. For machining efficiently these high precision elements, it is exceptionally difficult using conventional metal cutting methods because of higher cutting force and excessive tool wear which leads to a lower material removal rate and high cost. Laser assisted machining is effective method for improving the machinability of difficult to machine material like ceramics. Fabrication and machining of ceramic composites and development of regression models are very much essential for user industries like aerospace and defence.

Based on the thorough literature survey, gap is identified and formulated the problem on fabrication and characterization of fused silica based composites using gelcasting technique by varying precursor amounts, solid loading, monomers and its contents and to identify the best suitable material for wave transparent materials. Silicon nitride (Si3N4), Boron nitride (BN) and Alumina (Al2O3) added to fused silica (SiO2) to enhance flexural strength keeping porosity and dielectric constant in range. Effect of various parameters of gelcasting on mechanical and dielectric properties are studied on these SiO2 based ceramic composites. New ceramic materials SiO2–Si3N4–BN and SiO2–Si3N4–Al2O3 fabricated for wave transparent applications which have excellent properties. The full factorial approach used for the evaluation of properties of ceramics. RSM and DOE approach is used for the modeling and optimization of the ceramic composites.

The detailed experimental plan involving number of experiments for gelcasting of SiO2–Si3N4–BN and SiO2–Si3N4–Al2O3 ceramic composites was designed using Design Expert 9.0 software. A face centered composite design with 6 center points have been used in the experimental plan. The levels of the input parameters are solid loading (SiO2, Si3N4, BN and Al2O3 content), monomer content and monomer ratio were fixed based on literature. SiO2–Si3N4–BN and SiO2–Si3N4–Al2O3 ceramic composites were fabricated by gelcasting process by varying solid loading, monomer content and monomer ratio. The sintering temperature was kept constant at 1250 oC for fabrication of ceramics. Properties like flexural strength, porosity and dielectric constant are planned to evaluate as per the experimental plan.

The author has fabricated porous SiO2–Si3N4–BN and SiO2–Si3N4–Al2O3 ceramic composites by gelcasting by varying solid loading, monomer content and monomer ratio and evaluated flexural strength, porosity and dielectric constant. The regression models for the analysis of flexural strength, porosity and dielectric constant are developed and the influence of input variables on these responses is studied. The optimum process parameters for maximum flexural strength, maximum porosity and minimum dielectric constant were evaluated with the help of RSM coupled with desirability function to optimize multiple responses. The predicted values for responses such as flexural strength, porosity and dielectricconstant obtained from mathematical models are compared with experimental values for SiO2–Si3N4–BN and SiO2–Si3N4–Al2O3 ceramics.

Erosion test was performed on ceramics which get optimal properties for three types of ceramics pure fused silica, SiO2–Si3N4–BN and SiO2–Si3N4–Al2O3. Different impingement angles (30o, 45o, 60o and 90o) and three impact velocities (86 m/s, 101 m/s and 148 m/s) were chosen to examine the behavior of erosion on gelcasted ceramics using SiO2 particles as

erodent. The maximum rate of erosion is obtained at normal impingement angle (90o), which

shows the brittle nature of ceramics. The impact velocity and angle of impingement have an appreciable effect on erosion rate. Resistance to erosive wear is found to have improved with

the inclusion of reinforcements in the fused silica ceramics. The erosion rates of different ceramics are compared. Ceramic composite with a combination SiO2–Si3N4–Al2O3 shows the

highest resistance to wear. The surface roughness and morphology of the eroded surfaces have also been studied.

Among the ceramics, SiO2–Si3N4–Al2O3 ceramic composite has better properties. Hence, it is considered for the machining with Laser Assisted Machining (LAM). A face centered central composite design of 6 center points has been used in the experimental plan. The levels of input parameters rotational speed, feed, depth of cut and laser power were set based on literature and trail experiments. Machining conducted on SiO2–Si3N4–Al2O3 ceramic with varying rotational speed, feed, depth of cut and laser power as per RSM and DOE basis and evaluated surface roughness and material removal temperature. Regression models for the analysis of responses such as surface roughness and material removal temperature are developed and the influence of input variables on these responses is studied. Optimum process parameters for minimum surface roughness and minimum material removal temperature were studied using RSM coupled with desirability function to optimize multiple responses. The actual experimental values for both responses compared with predicted regression models. Surface roughness of SiO2–Si3N4–Al2O3 ceramic is improved with laser assisted machining.

**MECHANICAL ENGINEERING**

Author : **R SEETHARAM**

Title of the thesis : **METAL FLOW ANALYSIS AND MICROSTRUCTURE**

 **MODELLING OF HOT UPSET Al–B4C COMPOSITE**

Guide : **Dr. S. KANMANI SUBBU**

Degree: **Ph. D.**

Student ID No.: **714017**

**ABSTRACT**

The present work pertains to investigate the deformation behaviour of powder metallurgical (P/M) processed Aluminium-Boron Carbide preforms during hot upsetting. A series of hot upsetting studies are carried out on P/M Al-B4C preforms under various processing conditions to evaluate the plastic flow properties and densification behavior. This study is mainly focused on the formability behavior and developed a model to predict the flow stress and grain size of a porous Al–B4C preforms at elevated temperatures.

The experimental work was performed to study the workability and the densification behavior of a porous Al–B4C preforms in the present investigation. Hot upsetting tests have been carried out on Al–B4C powder metallurgy preforms having an initial relative density of 0.9 and having different B4C compositions of 2wt.%, 4wt.% and 6wt.%. The samples were compressed between two flat dies in a hydraulic press of 50 ton capacity under varying deformation temperatures such as 200 oC, 300 oC, 400 oC and 500 oC under the tri–axial stress state condition. The workability and densification behavior of Al–B4C preforms were analyzed till the initiation of cracks on the outer surface of the preform. The experimental results were analyzed for the various deformation parameters such as axial strain, relative density, formability stress index and different stress ratio parameter under the tri–axial stress state condition. Formability and densification behavior were discussed with the axial strain (εz) during the hot upsetting process. Highest relative density and formability are attained in the Al–2wt.%B4C composite for 500 oC deformation temperatures for any given axial strains. The relationships between the various stress ratio parameters (ζθ/ζeff, ζm/ζeff) and formability stress index (βζ) as a function of the relative density under the tri–axial stress state condition were studied.

A constitutive base analysis has been conducted to develop mathematical equations to predict the hot deformation and densification behavior of P/M Al-B4C preforms. The main aim of this work is to estimate the effect of initial relative density (IRD), deformation temperature, and strain rate on the hot deformation behavior and development of constitutive equations for predicting the hot deformation behavior. For this purpose, upsetting tests have been performed in a hydraulic press for obtaining true stress–true strain curve data of sintered Al–4wt.%B4C composites. The upsetting tests were carried out at different IRDes of 80%, 85% and 90% for various temperatures of 300 oC, 400 oC and 500 oC and strain rates of 0.1 s-1, 0.2 s-1 and 0.3 s-1. It clearly shows that the effect of IRD, deformation temperature, and strain rate on flow stress curves is significant. The predicted flow stress results are well satisfied with the experimental flow stress result, which verifies the accuracy of the developed constitutive model for sintered Al–4wt.%B4C composite during the hot upsetting test. In addition, the required activation energies (Q) of sintered Al–4wt.%B4C composites during the hot upsetting, calculated for various IRDes of 80%, 85% and 90% were 161.06, 172.28 and 181.05 KJ/mol, respectively and compared with published literatures.

It is essential to understand the microstructure evolution of sintered Al–B4C preforms during the hot deformation for controlling the grain size. Hence, the aim of this work is to evaluate the microstructure of sintered Al–4wt.%B4C composite for different deformation conditions such as temperature, strain rate, initial relative density and deformation degree during the hot compression test by metallurgical analysis. The compression tests were performed on a 50 ton capacity hydraulic press for different temperatures (300 oC, 400 oC and 500 oC), strain rates (0.1 s-1, 0.2 s-1 and 0.3 s-1), initial relative densities (80%, 85% and 90%) and deformation degree (reduction in preforms height of 10%, 20%, 30%, 40% and 50%). The microstructures of compressed sintered Al–4wt.%B4C preforms were evaluated by an optical microscope (OM) for different deformation conditions. Intercept line method was used to measure the grain size of the compressed preforms. The dynamic recrystallization grain of sintered Al–4wt.%B4C preforms are significantly sensitive to the deformation condition such as temperature, strain, strain rate and initial relative density. The average DRX grain size increases with increase in deformation temperature and IRD and with decreasing strain rate and deformation degree. The finer DRX grain size was found in hot forming process at lower deformation temperature and IRD, and at a higher strain rate and deformation degree.

In the final phase of this work, a mathematical model was developed between dynamic recrystallization grain size and Zener–Hollomon parameter, which helps in calculating the DRXed grain size for various IRDes, temperatures and strain rates. For this, experimental work was performed on sintered Al–4wt.%B4C preforms at various initial relative densities (IRD) of 80%, 85% and 90%, and over the temperature range of 300 oC – 500 oC and strain rates range of 0.1 s-1 – 0.3 s-1. The activation energy and Zener–Hollomon parameter of sintered Al–4wt.%B4C preforms were calculated for different temperatures, strain rates and IRDes. The correlation between Zener–Hollomon parameters and average DRX grain size of sintered Al–4wt.%B4C composite were established by fitting power law for different initial relative densities. The calculated DRXed grains (dc) are compared with measured DRXed grains (dm) to evaluate the accuracy of the developed mathematical model of sintered Al–4wt%B4C composite for different IRDes. It is observed that the calculated DRXed grains well agreed with the measured DRXed grains for tested deformation conditions. And the average percentage error for various IRDes and deformation conditions were not exceeding 9.92% and mean absolute error does not exceed 8.58%. This proves the precision and reliability of the developed mathematical model for sintered Al–4wt.%B4C composite for various IRDes. The results of this work can be used to develop hot deformation regimes of Al–4wt.%B4C preforms, providing a required DRXed grain size.

**MECHANICAL ENGINEERING**

Author : **RAMESH BABU BEJJAM**

Title of the thesis : **NUMERICAL AND EXPERIMENTAL STUDIES ON**

 **NANOFLUID BASED NATURAL CIRCULATION LOOP**

Guide : **Dr. K. KIRAN KUMAR**

Degree: **Ph. D.**

Student ID No.: **701344**

**ABSTRACT**

Natural circulation loops (NCLs) offer a very efficient option of heat transport from source to sink without any prime mover. In the NCL, buoyancy is the driving force to circulate the working fluid in the entire loop. The buoyancy force is developed due to a temperature gradient between source and sink which causes the fluid to circulate and hence no pump is required. Due to the absence of a pump, NCLs offer advantages such as high reliability, safety and low maintenance cost. Thereby, it offers some unique and distinctive applications such as nuclear reactor core cooling, geothermal heat extraction, solar water heaters, refrigeration systems, electronic cooling systems etc.

The present scenario of high thermal loading coupled with high flux levels demands exploration of new heat transfer augmentation techniques. In this context, ‘Nanofluid’ emerged as alternative heat transfer fluid. The term ‘Nanofluid’ is used to indicate a special class of heat transfer fluids that contain nanoparticles (≤ 100 nm) of metallic/non-metallic substances uniformly and stably suspended in a conventional fluid. This opens the possibility of enhancing the thermo-physical properties of the base fluid in a desired manner. The idea of suspending some solid phase material in conventional liquids is to enhance its heat transfer properties. With this background, the present dissertation focuses to study the thermal performance of natural circulation loop working with nanofluids.

The main objective of this research was to carry out theoretical and experimental studies on nanofluid based single phase natural circulation loops (NCL). For this research work, three water based nanofluids such as SiO2-water, Al2O3-water and CuO-water at different particle concentrations were used. Initially a comparative study was made between water and nanofluids that can be used in natural circulation loops for various heat transfer applications. At the same operating conditions, the enhanced thermophysical properties of the nanofluid facilitate to reduce the size of NCL compared to that of water. Analytical studies were conducted at laminar and turbulent flow conditions, the results show that in both flow conditions the improved thermo-physical properties of the nanofluid brings compactness to the NCL. Experimentally, the effect of temperature on viscosity and thermal conductivity of nanofluids was also studied.

Further, a one-dimensional (1-D) numerical modelling was carried out to analyse rectangular NCL with end heat exchangers operating at steady-state conditions. This study predicts the balanced mass flow rates of NCL for different design and operating conditions. From the results, it was concluded that, for given input conditions, there exist an optimum value of heat exchanger length and loop pipe diameter. The noteworthy conclusion drawn from the result was, the external fluid (water) flow rate does not influence the loop performance. However, the external fluids temperatures affect the loop performance strongly.

In extended work, a three-dimensional (3-D) numerical modelling was carried out for single phase natural circulation loop with heater as heat source. For this study, a 3-D NCL model was developed and simulated using Ansys-Fluent 14.0. The effect of power input, particle concentration, loop inclination angle and multiple channels (double riser and double downcomer-DRDD) on thermal performance of the NCL were studied. The results show that as particle volume concentration increases the temperature difference at the heater decreases hence, the steady-state mass flow rate increases. Another notable outcome from the analysis was, as the particle concentration increase from 0% to 5%, the mass flow rate in the NCL increases, but further increment in particle concentration reduces the mass flow rate due to viscous forces that dominate the buoyancy forces. Therefore, for this NCL geometry, 5% particle concentration was considered as an optimum value. Effectiveness of the nanofluid based NCL is more than the water based NCL. The effectiveness increases with the loop inclination angle. One more important conclusion from this analysis was lower inclination angles up to 15° will be preferable without much effect on Rayleigh number and average heat transfer coefficient. The performance of the NCL with multiple channels (DRDD) was enhanced by 2.5% when compared with single channel NCL (SRSD) in terms of the mass flow rate.

Based on the numerical studies, two perfectly instrumented rectangular NCLs were fabricated with heater as heat source and heat exchanger as heat source, separately. Experiments were conducted on both the test rigs with nanofluids as loop fluid and results were compared with water. The experimental results were validated with the numerical results as well as with the published data. The experimental results show that NCL operated with nanofluid quickly reaches a steady-state condition compared with that of water. Stability of NCL was studied by the sudden perturbation of power input to heater. Within the scope of this study, oscillatory or reversed flow in NCL was not found. Finally based on the theoretical and experimental work, several conclusions were drawn and recommendations were made for future studies.

**MECHANICAL ENGINEERING**

Author : **D.** **RAVICHANDRA**

Title of the thesis : **EXPERIMENTAL ANALYSIS OF PERFORMANCE,**

 **COMBUSTION AND EMISSION CHARACTERISTICS**

 **OF VGT ENGINE FUELED WITH DIESEL AND**

 **BIODIESEL**

Guide : **Dr. RAVI KUMAR PULI**

Degree: **Ph. D.**

Student ID No.: **714016**

**ABSTRACT**

Diesel engines are widely used in agriculture, industrial and transport sectors. The rapid and over-utilization of fossil fuel resources, especially in the transport sector are making the researchers search for alternative energy sources to internal combustion (IC) engines. But lower volatility, unsaturated fats and higher viscosity of the crude oil are the major problems to use as straight vegetable oil (SVO). The present work aims to conduct experiments with different proportions of neem (Azadirachta Indica) oil with diesel. The biodiesel used for the experimentation was prepared by two-step transesterification process by considering optimum parameters and by maintaining the resultant fuel thermo-physical properties within ASTM standards. With different trials of reaction times (90 and 120 min) and concentration of catalyst (0.75 and 1 %) to produce a pure biodiesel reaction time of 90 min. and 1 % concentration of catalyst had been chosen. Experiments were conducted on a variable compression ratio (VCR) diesel engine to determine the various performance parameters and its exhaust emissions for different blend proportions at various loads. Brake thermal efficiency (BTE) of the biodiesel blends with partial loads was very close to diesel. Higher brake specific fuel consumption (BSFC) was noticed for biodiesel blends than for mineral diesel. At maximum load, BSFC was same for all percentage of blends along with mineral diesel. The exhaust emissions CO and UHC were found to be lower for different blends while NOx was more. By analyzing all the results it can be concluded that the different blends of Azadirachta Indica biodiesel, can be utilized as a substitute fuel for diesel engine without even the need for any engine adjustments.

This study investigates the biodiesel from Deccan hemp (Hibiscus Cannabinus) oil and its blends for the purpose of fuelling diesel engine. The performance, combustion and emission characteristics of Deccan hemp biodiesel were estimated and were compared with diesel fuel. Experimental investigations were carried out with different blends of Deccan hemp biodiesel. According to the results, the brake thermal efficiency (BTE) of fuel with 50 BDH was improved significantly by 4.15 % when compared with diesel fuel. The Deccan hemp biodiesel reduces NOx, HC and CO emission along with a marginal increase in CO2 and smoke emissions with an increase in the biodiesel proportion in the diesel fuel. The improvement in heat release rates shows an increase in the combustion rate with different percentage blends of Deccan hemp biodiesel. From the engine test results, it has been established that 30 – 50 BDH of Deccan hemp biodiesel as a promising alternative for diesel. The comparison was done for both (Neem and Deccan hemp) biodiesels blends with a standard fuel (diesel). The comparison results show that BTE of neem biodiesel B20 blend has a higher value compared to Deccan hemp biodiesel blends and lower BSFC was noticed. So, neem biodiesel B20 blend had been chosen as an optimum blend for further experimentation on variable geometry turbocharger (VGT) diesel engine.

Till now the experiments were done with both the biodiesels on VCR diesel engine to found out the optimum biodiesel blend to carry out further experiments on variable geometry turbocharger (VGT) diesel engine. VGT was the advanced technology in automated vehicles. This was used to improve the engine efficiency by allowing more amount of air into the combustion chamber and reduces the exhaust gas emissions. With this experimentation can check the feasibility of utilization of biodiesels in advanced technologies like VGT diesel engines. Before started, any of the experiments, first to specify the important operating conditions of the particular diesel engine. For that, initial experiments were done with base fuel diesel and optimum blend NB20 on VGT diesel engine.

In a diesel engine with variable geometry turbocharger (VGT), fuel injection strategies such as fuel injection pressure (FIP), and start of main injection (SoMI) timings play a vital role as these were significant parameters to evaluate combustion, engine performance, and emission analysis of a VGT diesel engine. A four-cylinder water cooled VGT engine was used to study the effects of fuel injection strategies. Experiments were conducted with different FIPs (600, 800, and 1000 bar) and various start of main injection (SoMI) (2º, 4º, 6º, 8º, and 10º bTDC) timings. Cylinder pressure (CP), and heat release rate (HRR) were observed to be maximum for higher FIPs. As the FIP increased the brake thermal efficiency (BTE) was found to increase where the exhaust gas temperature slightly reduced. For advanced SoMI timings, BTE and BMEP were seen to be higher, while brake specific fuel consumption (BSFC) reduced substantially. With increasing FIP and advance SoMI timings, carbon monoxide (CO) and carbon dioxide (CO2) emissions were seen to decrease at the same time nitrogen oxide (NOx) emissions were enriched. From the experimental results, a FIP of 800 bars and 10º bTDC SoMI timing provides the best BTE with lower exhaust emissions.

Neem biodiesel was prepared by esterification and transesterification process. It was found that NB20 gives optimum performance and emission characteristics. Therefore, for further study NB20 blend had been considered for experiments. Engine performance parameters were estimated and compared with both the standard fuel (diesel) and with NB20 blends in a VGT engine. Effect of exhaust gas recirculation (EGR) was analyzed. Effect of advanced SoMI timings was also analyzed at 2º, 4º, 6º, 8º, and 10º bTDC for a fuel injection pressure (FIP) of 800 bar and at by maintaining a constant speed of 1700 rpm. Cylinder pressure (CP), and heat release rate (HRR) were observed and found that they were maximum for diesel fuel compared to NB20 blend. For the advanced start of main injection (SoMI) timing, brake thermal efficiency (BTE) and brake mean effective pressure (BMEP) were improved, but brake specific fuel consumption (BSFC) reduced substantially. It was found that the addition of neem biodiesel NB20 blend to diesel fuel decreased the carbon involved exhaust emissions but NOx increased. By adding the provision of EGR the NOx emission was considerably reduced and BTE was improved without any further modifications of engine. From the results, it can be concluded that an EGR of 10 % with 8º bTDC SoMI timing resulted in 13 % improvement in BTE, and 21 % decrement in BSFC, 27.5 % reduction in NOx emissions.

**MECHANICAL ENGINEERING**

Author : **S.V.B.VIVEKANAND**

Title of the thesis : **FLUID FLOW AND HEAT TRANSFER STUDIES OF**

 **TWO−PHASE FLOW INSIDE MICROCHANNELS**

Guide : **Dr. V.R.K. RAJU**

Degree: **Ph. D.**

Student ID No.: **714012**

**ABSTRACT**

Two-phase heat transfer in microchannel has been an interesting topic of research to many researchers since the increasing loads of heat fluxes in the electronic components are reaching the limits of single-phase cooling techniques. The two-phase flow and heat transfer inside microchannels are affected by several factors, such as wettability, wall boundary conditions, wall motion, and channel orientation. Most of the studies available in the literature deal with: (i) stationary walls of the channel, and (ii) constant heat flux or isothermal wall boundary conditions. Apart from that the effect of (a) contact angle on the flow physics, and (b) channel orientation on the evaporation heat transfer characteristics have also not been explored in detail earlier.Thus, the present study aims at exploring the two-phase flow and heat transfer behavior at microscale,through which higher heat fluxes can be removed.

This thesis addresses the flow physics and heat transfer characteristics of the two-phase flow with and without undergoing any phase changing process. Gas-liquid and liquid-liquid Taylor flows represent the cases where the phase change does not take place. Whereas, flow boiling of water inside a microchannel has also been studied in which the phase change takes place. A wide range of parameters affecting the two-phase fluid flow and heat transfer behavior has been identified and new methods have been conceived for achieving better enhancement in the two-phase heat transfer rates.

The hydrodynamics of gas-liquid Taylor flow in a two-dimensional T-junction microchannel has been numerically examined, where the volume of fluid interface capturing technique is employed. The effect of inlet fluid velocity and the wall contact angle on the flow parameters such as gas and liquid slug lengths, and pressure drop has been studied. The wall wettability is found to have a significant effect on the pressure drop inside the channel. The pressure drop decreases with the contact angle in hydrophilic channels. Whereas, in hydrophobic cases the pressure drop increases. In addition, the bubble shape becomes asymmetric due to the increase in drag forces in the hydrophobic channels.

In this thesis, the flow physics and thermal behavior of liquid-liquid Taylor flow in a two-dimensional, axi-symmetric circular microchannel is presented. The gradient-adaptation technique has been employed for the capturing of thin liquid films. The wall of the circular microchannel is subjected to isothermal and constant heat flux boundary conditions in individual cases in order to determine the influence of thermal wall boundary conditions on the heat transfer rates during the flow. A significant increase in the Nusselt number in slug flow in contrast to single-phase flow has been witnessed by using both the boundary conditions individually.

Further, the heat transfer characteristics of liquid-liquid Taylor flow inside the rectangular micro-parallel plates prescribed with modulated temperature boundary conditions have been examined. The effects of amplitude and frequency of the sinusoidal wall temperature profile of the time-averaged Nusselt number have been investigated. The temperature modulation has been found to increase the average heat transfer of the two-phase flow in contrast to liquid-only flow as well as the two-phase flow without modulation.

The thermal behavior of a liquid-liquid Taylor flow in rectangular microchannel having its walls imposed by small modulated motion in the transverse direction of the fluid flow under constant heat flux boundary condition has also been studied. The effects of amplitude and frequency of the modulated wall motion on the film thickness, droplet shape, and time-averaged Nusselt number have been investigated. The modulated wall motion has a significant effect on the two-phase heat transfer rate due to the presence of small vortices of the two-phase interface at a particular value of frequency. The average Nusselt number increased with the increase in amplitude when the frequency of modulated wall motion was kept constant.

The heat transfer studies of the two-phase flow of water undergoing evaporation inside a rectangular microchannel have been carried out. The purpose of this work is to investigate computationally effect of gravity on the heat transfer behavior of the two-phase flow of water undergoing phase change. The inclination of the channel varied from -900 (vertically downward) to 900 (vertically upward) to study the effect of gravity on the two phase heat transfer during the flow. The heat transfer coefficient was found to be the highest for an inclination angle of 450 as compared to all other orientations. It was observed that for a given heat flux, the boiling heat transfer coefficient increases significantly at a very high quality region, in contrast to the low quality region where it remains roughly unchanged due to partial dry out.

This research provides some important results and discussion on various parameters influencing high amounts of heat fluxes, which further could be used for optimizing engineering devices, such as semiconductor devices.

Keywords: Evaporation, Heat transfer, Microchannel, Modulation, Pressure drop, Taylor flow.

**MECHANICAL ENGINEERING**

Author : **SANGAMESH GONDEGAON**

Title of the thesis : **A NOVEL METHOD FOR PARAMETERIZATION AND B-**

 **SPLINE MODELLING OF COMPLEX PLANAR**

 **DOMAINS FOR ISOGEOMETRIC ANALYSIS (IGA)**

Guide : **Dr. HARI KUMAR VORUGANTI**

Degree: **Ph. D.**

Student ID No.: **701347**

**ABSTRACT**

Computer aided design (CAD) models use Non-Uniform Rational B-splines (NURBS) for the geometry representation. Great flexibility and precision for handling both analytic (surfaces defined by common mathematical formulae) and free-form shapes is the reason for the wide use of NURBS. So, when a CAD model is considered for simulation using finite element analysis (FEA), the NURBS model is approximated by set of finite elements (line, triangle, tetrahedron, etc.). This process of dividing a CAD model into a set of elements is called meshing. B-spline modelling is a continuous representation of the geometry, whereas mesh is the discrete representation, which results in loss of information. In iso-parametric formulation of FEA, the basis functions used for interpolation of field variables are employed for interpolation of geometry as well, which is the reason for inaccurate approximation of geometric model for complicated shapes.

Apart from inaccurate geometric modelling, it is observed that, 80% of the total analysis time is consumed by mesh generation itself. To avoid the bottleneck of meshing, a new method called Isogeometric Analysis (IGA) is proposed recently which integrates both modelling and analysis. The idea of IGA is to use parametric form of the geometry as input for the analysis. Therefore, NURBS basis function are used for representation of both geometry and field variable. Geometry can be exactly represented in IGA using NURBS basis functions.

But one major challenge in IGA is to find the analysis suitable B-spline model of the complicated domains. This is still an open problem. IGA requires parameterization of the entire domain including the interior of the object. But model generated using CAD software packages contains information only about its boundaries. Modelling of parametric surface for a general non-convex region is still a challenging problem. This is the inspiration to develop an efficient method for planar surface modelling using domain mapping method. Finding a spline representation for the domain involves two sets of unknowns, namely parameter values and control points. In this work, a new method is proposed to find them in two stages for planar domains.

The idea of the proposed method is to develop a bijective mapping between the given non-convex domain onto a topologically equivalent convex domain. First, an artificial potential field is created over the domain with the use of harmonic functions. It is accomplished by solution of Laplace equation with appropriate boundary conditions. Potential field provides a potential value for every point of the domain. This potential value is the one of the two parameters required for complete representation of the domain in the parametric form. Next step is streamlines tracking. The streamlines are the gradient lines of the potential which originate from the boundary and terminate at shape centre. These lines intersect iso-potential contours orthogonally and subtend a unique angle called streamline angle. Streamline angle is the required second parameter. Using these two parameters, a given domain is bijectively mapped to a circle. Further, circular parametric domain is mapped to a square to make it apt for B-spline surface modelling. The B-spline control points for the domain are computed by solving a tensor-product B-spline equation. The main strength of the proposed method is that irrespective of the complexity of the domain, the B-spline model results in valid and feasible parameterization.

Most existing methodologies for geometric modelling involve iterative optimization based methods which makes them computationally expensive. In some of the other reported works, parameterization is developed by projecting the given domain onto a base surface. But finding the base surface for complicated geometries is not feasible.

The way quality of a mesh affects the results in finite element analysis; an effective parametrization is a key for accurate results and computational efficiency. The parameterization quality of the B-spline model depends on the three conditions: a bijective mapping between physical and parametric domain to ensure no self-intersection, ii) orthogonality of iso-parametric net and iii) uniform distribution of iso-parametric lines of the B-spline surface. In this thesis, the idea to use first fundamental matrix as parameterization metric is proposed. Methodology to check the above mentioned conditions using first fundamental matrix is presented. Apart from first fundamental matrix, existing metric named scaled Jacobian is also used for quality assessment. With the use of these two metrics, parameterization quality of complex B-spline surfaces is evaluated. The quality of B-spline parameterization is compared in three different categories: a regular prismatic shape (L-shape) and an irregular domain; domain developed using discrete Coon’s method and proposed method; an irregular domain developed using proposed method and re-parameterization method. The proposed method of parameterization and the proposed metric both are found to be performing well even in complicated cases.

In this thesis, the proposed method is validated by solving benchmark problems like a heat transfer problem governed by Poisson’s equation. IGA results are then compared with exact solution. Results of few cases for complex domains are developed to demonstrate the effectiveness of the method in comparison to other methods. Moreover, a practical case of finding the deflections and stress for a culvert is solved using IGA and the results are compared with FEM. In all the cases, proposed method is able to model the geometry exactly and produce the results in good agreement with exact solutions/FEM solutions with lesser number of degree of freedom or better computationally efficiency.

The proposed B-spline modelling methodology is applicable for planar domains. But it can be extended for tri-variate modelling of B-spline volume by developing a bijective mapping between given non-convex domain and a sphere.

**MECHANICAL ENGINEERING**

Author : **SANTOSH KUMAR MALYALA**

Title of the thesis : **DESIGN OF PATIENT SPECIFIC SURGICAL**

 **TEMPLATES AND IMPLANTS WITH ADDITIVE**

 **MANUFACTURING FOR ORAL AND MAXILLOFACIAL**

 **SURGERY**

Guide : **Dr. Y. RAVI KUMAR**

Degree: **Ph. D.**

Student ID No.: **714131**

**ABSTRACT**

Additive Manufacturing (AM) initially known as Rapid Prototyping is a process by which physical model can be directly fabricated with the help of a Computer Aided Design (CAD), Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) data and other reverse engineering techniques. These systems also provide lot of flexibility in case of material choice from polymer to metal and paper to ceramic. The procedure from acquiring patient CT data to fabrication of patient specific medical model, surgical template or implant consists of various stages.

The primary aim of this study is to minimize the error at each and every step by optimizing parameters or selection of appropriate parameters in case of AM made surgical templates, medical models or implants. During the acquisition of CT data and reconstruction of the image acquired, a 128 slice CT scanner was used and the study was conducted on a dry

skull or phantom. A statistically significant skull was scanned and results were analyzed. Parameters such as minimal dimensional error, volumetric error and radiation exposure were optimised compared to default settings. Once this was achieved to optimization, the reconstruction was achieved with minimal dimensional error and least compromise on quality of data.

Data was reconstructed in the Digital Imaging and Communications in Medicine (DICOM) format. This data consisted of 2D information with equal slice thickness and when these slices are stacked together and the virtual 3D image of the patient will be reconstructed.

This DICOM data is then processed through MIMICS and 3-matic softwares. MIMICS software is useful in segregating a particular region of interest from the patient data. 3- matic software can be used to perform surgical simulation and to design patient specific implants. After obtaining the planned results using the software, the DICOM data is converted into an STL format. All the AM machines globally accept STL file format for model fabrication.

The STL file is a representation of surface information of model or anatomy using triangles, where all the curved information of patient anatomy is converted to lines or the side of a triangle. To improve the quality of the STL file and achieve better surface smoothness an algorithm is developed using Matlab software. The uniqueness of the developed algorithm is to improve the quality of the STL model by increasing the number of triangles with a unique technique of three directional slicing. Using this technique the surface quality of the AM model is improved.

To fabricate the AM medical model with optimal fabrication parameters an experimental

analysis has been conducted as a bench mark by varying fabrication parameters to minimize dimensional error of the AM model. The measurements on the AM benchmark model were conducted using the Coordinate Measuring Machine (CMM) to obtain accurate results.

The findings from the above stage were utilized and implemented in two live oral and

maxillofacial case studies. The first case study for the genioplasty surgery, where a customized AM surgical template was designed for patient specific requirement. The design of template was unique and first one of this kind for surgery. A surgical template was fabricated in AM using SLA process, which was used as a pattern for investment casting with medical grade SS316 material.

The second case study was the design and fabrication of a patient specific Basal Osseointegrated implant (BOI), with custom connection lengths and a custom abutment size. The base plate of BOI implant was designed to have best ossieointegration. The pre surgical models were fabricated using FDM technology and final implant was fabricated using medical grade Titanium (Ti-64) from an authorized medical metal implant manufacturer (CEIT Bio Medical Engineering, Slovak republic).

Both the clinical cases were observed for a period of six months duration and no complications were recorded. Surgeons who conducted both the surgeries certified that this procedure gave them satisfactory results.

**MECHANICAL ENGINEERING**

Author : **SRINU GUGULOTHU**

Title of the thesis : **PERFORMANCE EVALUATION OF VEGETABLE OIL**

 **BASED HYBRID NANO CUTTING FLUIDS IN**

 **TURNING OF AISI 1040 STEEL**

Guide : **Dr. P. VAMSI KRISHNA**

Degree: **Ph. D.**

Student ID No.: **714125**

**ABSTRACT**

The survival of present day industry is decided by its ability to produce high quality cost effective products in order to meet the challenges. However, several factors that contribute to the idle and down times associated with production processes have been hindrances in realizing this dream.

Machining is one of the widely used processes in manufacturing industries due to its ability to produce components to precision. Enormous amount of heat is generated in deformation zones of machining due to friction and rubbing of tool and workpiece, which affects the accuracy of machined surface, tool life and surface finish. In this context application of cutting fluids in machining play an important role through cooling and lubrication. Lubrication minimizes heat generation by reducing the friction between chip-tool and tool-workpiece interfaces and cooling action control the temperature at chip –tool interface by dissipating the heat.

Metal working fluids are the type of lubricants, which improves the product quality and production rate in machining sectors by lubricating and cooling action. With that fact in machining Industries, consumption of metal working fluids is rising day to day. The wide use of cutting fluids in machining is due to the reasons, which prevents corrosion of the machined surface, flushing away the chips from cutting area, cool the workpiece, chip tool interface, avoids the built-up edge formation on cutting tool, increase the tool life and improve the surface integrity. But they do create several adverse effects such as environmental pollution, dermatitis to workers in machining industries etc. Alternatives to these cutting fluids are being searched for manufacturing industries by several investigators. In the present work, an attempt is made to assess the performance of vegetable oil based hybrid nano fluids as cutting fluids in turning of AISI 1040 steel.

In the present work, nanoparticles used are multi walled carbon nanotube (MWCNT) of 30 nm outer diameters, boric acid (BA) of 80 nm and molybdenum disulphide (MoS2) of 30 nm respectively. Sesame oil, neem oil and mahua oils are used as base oil in preparation of vegetable oil based hybrid nano cutting fluids. Triton x100, Tween80 and SDS surfactants are used for dispersion of nanoparticles in vegetable oils. Different / various combinations of hybrid nano cutting fluids are prepared according to Taguchi’s L9 orthogonal array. The nanoparticles combinations of CNT/BA and CNT/MoS2 at 1 % weight in hybrid ratio (1:1; 1:2; 2:1) along with surfactant are dispersed in the above mentioned three oils. Stability test is performed for the prepared samples of CNT/BA and CNT/MoS2 hybrid nano cutting fluid by using sedimentation method and zeta potential test. Machining experiments are conducted at constant cutting conditions during turning of AISI 1040 steel under MQL mode of CNT/MoS2 hybrid nanofluid. Optimal factors for stable hybrid nano cutting fluids are found to be sesame oil, 15% content SDS surfactant and 1:2 hybrid ratio. Machining performance is improved with CNT/MoS2 hybrid nano cutting fluid under MQL mode in terms of reduction in main cutting force, temperature, surface roughness and tool flank wear compared to dry and conventional cutting fluid respectively.

In the second stage, CNT/MoS2 (1:2) hybrid nano cutting fluids are prepared by varying concentration of nanoparticle inclusion in sesame oil (i.e. 0.5%, 1%, 1.5%,2%,2.5% and 3%) by weight. Thus fluids are subjected to measurement of basic properties such as thermal conductivity, specific heat and dynamic viscosity to assess their performance in machining. Machining experiments are conducted in turning of AISI 1040 steel at constant cutting conditions by varying concentration of hybrid nano cutting fluids and machining performance are compared with dry and conventional cutting fluid. Coefficient of friction test was also performed for the same nanofluids by using Pin on disc apparatus. It is found that the thermal conductivity and dynamic viscosity are increased with increase in particle concentration. Dynamic viscosity is found to decrease with increase in temperature.

From the machining results, concentration 2wt% of CNT/MoS2 hybrid nano cutting fluid has shown better performance in reducing forces, temperature, surface roughness and tool flank wear than that of dry and conventional cutting fluid. Subsequently, comparative assessment of machining performance is made in terms of main cutting force, cutting temperature, surface roughness and tool flank wear in turning of AISI 1040 steel using the concentration 2 wt% of vegetable oil based pure CNT, pure MoS2 nanofluids and CNT/MoS2 hybrid nano cutting fluid at constant cutting conditions. The significant reduction in main cutting force is observed to be 22% and 17.3%, cutting temperature is observed to be 8% and 12.5%, surface roughness is observed to be 13% and 9% and tool flank wear is observed to be 63% and 68% with use of 2 wt% of hybrid nano cutting fluid than that of pure CNT and Pure MoS2 nanofluids.

Finally, turning experiments are conducted by varying cutting conditions in turning of AISI 1040 steel with use of only 2wt% of CNT/MoS2 (1:2) hybrid nanofluid under MQL condition. Experiments are designed using response surface methodology by taking three factors at each 3 levels and analysis of variance (ANOVA) is performed to study the significant effect of each individual factor on machining responses. Optimization is performed for multiple responses by using desirability function which converts multi objective into single objective and optimal setting parameters for single objective is found. Cutting force Fz is found to increase with increase in cutting speed, feed and depth of cut and then slightly decrease with cutting speed of 100 m/min. Cutting temperature and tool flank wear are observed to increase with increase in cutting speed, feed and depth of cut. Surface roughness value is found to decrease with increase in cutting speed and it increased with increase in feed and depth of cut. Desirability approach confirms that single combination of optimal setting parameters for cutting force, cutting temperature, surface roughness and tool flank wear is 70.25 m/min, 0.13 mm/rev and 0.5 mm at desirability value of 0.907.

**MECHANICAL ENGINEERING**

Author : **V. PHANINDRA BOGU**

Title of the thesis : **MODELLING, ANALYSIS AND DEVELOPMENT OF**

 **HOMOGENOUS SCAFFOLD-BASED CUSTOMIZED**

 **CRANIAL IMPLANTS**

Guide : **Dr. Y. RAVI KUMAR**

Degree: **Ph. D.**

Student ID No.: **714018**

**ABSTRACT**

Cranioplasty is one of the oldest and lifesaving surgical procedure in order to repair cranial defects and extremely challenging for most experienced neurosurgeons. Cranioplasty often performs an aesthetic purpose, improves neurological function of brain tissue, and arrest cerebrospinal fluid leak (CSF). Earliest, the cranial defect reconstruction is performed through autografts, allografts and biocompatible materials such as gold, stainless steel, titanium and various polymer materials. These surgical procedures are gradually improved and enhanced with the help of computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies. Recently, these surgical procedures are notoriously enhanced with 3D printing technology which helps to manufacture large-sized cranial defects with contour surface.

The main objective of this research work is to develop the customized cranial implants for severely injured patients. The computer-aided modelling and reconstruction techniques are creating an essential role in various cranial defects such as symmetrical and asymmetrical defects respectively. The symmetrical defects are modelled through mirroring technique, however, modelling of cranial implants for asymmetrical defects is quite difficult such as beyond midline deformities, multipoint defects and frontal bone defects. The complexity depends upon the surface area of the implant and curvature, whenever these defects are less than 5 cm2 almost flat surface, which is considered as small defects and the large defects are in the order of >100 cm2 .

The first part of this research is started with modelling of the cranial implant through mirroring technique. The skull is damaged in frontal, parietal and temporal regions and a small portion of frontal region damaged away from the sagittal plane. The cranial bone thickness is calculated at different regions such as temporal and parietal regions etc. The implant is modelled at a thickness of 2.5mm and the edges of the implant are corrected to arrest the CSF leak. Here, the complexity is to maintain the curvature and implant thickness is constrained. To overcome these limitations the computer-aided reconstruction technique is developed.

In the second part of the research, the above mentioned limitations are overwhelmed through computer-aided reconstruction technique, which can handle various cranial defects such as symmetrical and partially asymmetrical defects. This technique is involved with systematic steps such as section the skull, draw the line at each section and develop the surface patch, which can fit damage skull. This surface is extruded longitudinally at 4 mm of thickness to withstand at intracranial pressure (ICP) and the normal ICP range is varying from 7 to 15 mm of Hg. Additionally, the finite element analysis is conducted on the cranial implant under ICP with a minimum number of anatomical locations. The anatomical locations allow the implant behaviour with respect to intracranial pressure conditions. However, increased anatomical locations lead to variation in deformation and equivalent stress. The implant is designed with eight fixation points and ten fixation points respectively. Consequently, the mechanical deformation and equivalent stress (von Mises) are calculated in ANSYS 15 software with distinctive material properties such as titanium alloy (Ti6Al4V), polymethyl methacrylate (PMMA) and polyether ether ketone (PEEK). It is observed that Ti6Al4V material shows low deformation and PEEK material shows less equivalent stress. However, this implant is completely solid one which required to promote tissue regeneration. In this aspect, the implant is embed with optimum permeable scaffold structures.

The third part of the research is discussed with the permeability of scaffold structures. The tissue engineering aims at the development of biological substitutes that restore, maintain and improve tissue function. The tissue scaffolds provide structural support for cell attachment and subsequent tissue growth. In this work, homogeneous interconnected scaffold structures are modelled by variable pore-size, porosity, various strut cross-section and keeping the uniform unit cell size. The CFD analysis is done in ANSYS 15 software to know the permeability of scaffold with blood properties as a fluid. The Permeability is found to be in the range of 4.8×10-9 m2 – 2.3×10-8 m2 for strut cross-section 300 to 500 μm. the cross-section of the strut and porosity are the influencing parameters and plays important role in scaffold design. Among all cross sections, the circular section shows effective permeability. The solid implant is embedded with unit cell based scaffold structures to mimic the original cranial bone.

The final part of the research is discussed with a novel free-form closed curve network (FCN) technique which is successfully developed to model the cranial implant. This modelling methodology is the easiest one and addressing both the symmetrical and asymmetrical defects. The implant is embedded in a unit cell based porous structure with the help of an algorithm, and this algorithm is simple to manage the consistency in porosity and pore size of the scaffold. Totally six types of implants are modelled with variation in porosity and replicate the original cranial bone. Among six implants, Type 2 (porosity 82.62%) and Type 5 (porosity 45.73%) implants are analysed with the meshless approach under ICP. The total deformation and equivalent stress (von Mises stress) of porous implants are compared with the solid implant under same ICP conditions. Consequently, distinctive materials are used for structural analysis such as titanium alloy (Ti6Al4V) and polyether-ether-ketone (PEEK), respectively. It is observed from the results that the titanium-based solid implant is showing optimum results in deformation aspect while considering weight and cost the PEEK based Type 5 implant is most appropriate.

The entire research work made an attempt to develop innovative possibilities in cranial implant modelling techniques. These techniques can handle symmetrical and asymmetrical defects and effectively model the cranial implant with optimum number of fixation points, which help to arrest the CSF leak. Finally, to develop the porous cranial implant, which mimics the cranial bone in order to enhance tissue regeneration.

**MECHANICAL ENGINEERING**

Author : **VENKATESWARLU VELISALA**

Title of the thesis : **COMPUTATIONAL AND EXPERIMENTAL**

 **EVALUATION OF PEM FUEL CELL PERFORMANCE**

 **USING SERPENTINE FLOW FIELDS**

Guide : **Dr. G. NAGA SRINIVASULU**

Degree: **Ph. D.**

Student ID No.: **701416**

**ABSTRACT**

Fuel cell is a electro-chemical energy conversion system, which converts the chemical energy of fuel, directly into electrical energy. The ever increase in energy demand, non-polluting energy generation, and other environmental issues have persuaded many researchers to look for new efficient energy conversion technologies. Proton exchange membrane (PEM) fuel cells have many unique features compared with other types of fuel cell, such as relatively low operating temperature (around 80 oC), high power density, quick start, rapid response, and high modularity which makes them as the most promising system in the applications such as automotive, distributed power generation and portable electronic devices.

The aim of the present work is on evaluation of PEM fuel cell performance using serpentine flow fields with round corner by numerical modeling and experimentation. Three dimensional PEM fuel cell cell models of size 7x7, 7x12 and 7x17 cm are developed. Three types of flow field designs such as single, double and triple serpentine were considered for the supply of reactants. Computational fluid dynamics (CFD) based simulations were carriedout to analyse the pressure drop, distribution of reactants (H2 and O2), liquid water activity in the flow channels, current flux density and water content in the membrane. Further the effect of flow field design on the performance of PEM fuel cells were examined. Single, double and triple serpentine flow field plates were fabricated and experiments were conducted to validate the simulation results. Based on simulation and experimental results, it is observed that triple serpentine flow field performance is better than single and double serpentine flow field as it offer less pressure drop and uniform distribution of reactants.

The experimental tests were conducted by incorporating triple serpentine flow field in fuel cells to investigate the influence of cell design parameters such as membrane thickness and catalyst loading. The available membrane thicknesses are taken as 50, 51 and 175 μm. Similarly, the catalyst loadings are considered as 0.6, 0.8 and 1.0 mg/cm2. The results revealed that the cells performance is increased with decreasing membrane thickness and increasing the catalyst (Pt) loading. Peak powers were obtained with a thin membrane (50 μm thickness) having 1.0 mg/cm2 platinum loading.

Further, the experimental tests were conducted by incorporating triple serpentine flow field and 50 μm thickness membrane with 1.0 mg/cm2 Pt loading to investigate the influence of cell operating parameters such as cell temperature (40, 50, 60, 70 and 80oC), reactants humidification temperatures (40, 50, 60, 70 and 80oC), and reactants flow rate on the performance of PEM fuel cells. The cell operating temperatures, reactants humidification temperature are same for three active area PEMFCs and the reactants flow rates are different for three areas of PEMFC.

The fuel cell of active area 49 cm2 with 50 μm membrane thickness and 1.0 mg/cm2 platinum loading produced a peak power density of 418 mW/ cm2 at 0.5 V when the cell was operated at 70oC cell temperature, 70oC anode humidification temperature, 60oC cathode humidification temperature, 400 ccm H2 flow rate and 800 ccm O2 flow rate. In the same way, the cell of active areas 84 cm2 and 119 cm2 produced a peak powers of 395 mW/cm2 and 374 mW/cm2 respectively at 0.5 V. From this analysis it is observed that the power density of smaller active area (49 cm2) cell is higher than the larger active area (84 and 119 cm2) fuel cells. From this investigation, it is concluded that instead of going for larger active area cell one can choose smaller active area cell with more number (i.e stack) of cells.