EASWARI ENGINEERING COLLEGE
An AUTONOMOUS Institution
Affiliated to ANNA UNIVERSITY
RAMAPURAM CHENNAI

DEPARTMENT OF MECHANICAL ENGINEERING

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VISION

To be an acknowledged leader in imparting Mechanical Engineering education, research and be a recognized resource center for industry and society

MISSION

M1:To make the students understand the basic and advanced Engineering concepts in the core fields of Mechanical Engineering through Under-Graduate and Post-Graduate Courses.

M2:To prepare the students and expose them to the basic and applied research, thus fostering creativity through recognized research centers.

M3:To make the students undergo training in the Industries, identify the current problems and solve them with multidisciplinary and professional approach.

M4:To prepare the students to integrate Engineering with business that encourages technological commercialization by inviting eminent entrepreneurs for seminars and workshops.

M5:To make the students do application oriented projects which identify the current problems, solving them and thus contribute to the societal needs.

M6:To inculcate the value of ethics, lifelong learning and widening the knowledge frontiers through long term interaction with other academia and industry.

PROGRAM OUTCOMES (PO)

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The Engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

PROGRAM EDUCATIONAL OBJECTIVES (PEO)

PEO1: Our graduates will have fundamental technical knowledge and develop core competency in diversified areas of Mechanical Engineering along with Mathematics, Science and other allied engineering subjects in a view to expand the knowledge horizon and inculcate lifelong learning.

PEO2: A fraction of our graduates will pursue advanced studies, research and develop products in the field of Mechanical engineering by developing partnerships with industrial and research agencies thereby serving the needs of the industry, government, society and scientific community.

PEO3: Our graduates will be capable of building their own career upon a solid foundation of knowledge and with a strong sense of responsibility serve their profession and society ethically.

PEO4: Our graduates will be prolific professionals with effective communication, leadership, teaming, problem solving, decision making skills by understanding contemporary issues and improve their overall personality for career development

. PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1: Students will be competent in design and analysis of thermal and fluid systems.

PSO2: Students will possess the skill to apply design concepts for mechanical structures and systems.

PSO3: Students will be able to design and develop industrial products using modern machines in the field of manufacturing.

PSO4: Students will be able to use software to solve structural, thermal, fluid and manufacturing problems.

JOURNAL ARTICLE

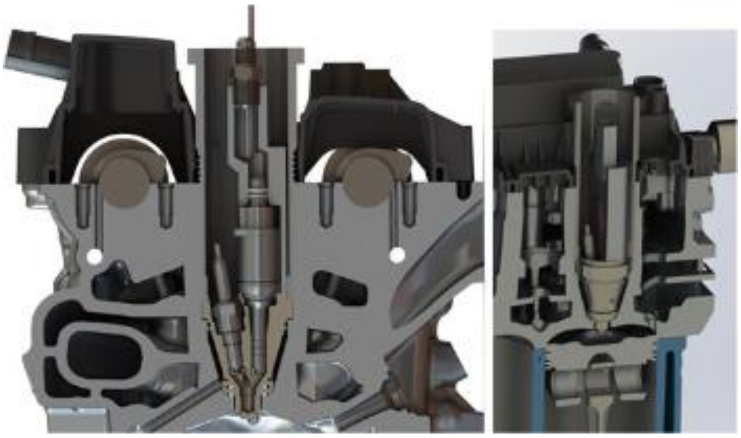
WILL FUTURE MICROBOTS BE TASK-SPECIFIC CUSTOMIZED MACHINES OR MULTI-PURPOSE "ALL IN ONE" VEHICLES?

Though there are multiple viable powertrain options available for the automotive sector, those that contain internal combustion engines will continue to account for the majority of global sales for the next several decades. It is therefore imperative to continue the pursuit of novel combustion concepts that produce efficiency levels significantly higher than those of current engines. Introducing high levels of dilution in spark ignited (SI) engines has consistently proven to produce an efficiency benefit compared to conventional stoichiometric engine operation. However, this combustion mode can present challenges for the ignition system. Pre-chamber jet ignition enables stable, highly dilute combustion by both increasing the ignition energy present in the system and distributing it throughout the combustion chamber. Previous work by the authors have shown that jet ignition produces 15–25% increases in thermal efficiency over baseline SI engines with only relatively minor changes to engine architecture. Lean combustion in general and jet ignition in particular represent fundamentally different engine operating modes compared to those of conventional stoichiometric SI engines. Therefore, there are some system sensitivities not present in stoichiometric engines that must be investigated in order to fully optimize the jet ignition system. Differing types and magnitudes of charge motion are incorporated in SI engines to aid with mixture preparation but the influence of charge motion over lean combustion performance, particularly in jet ignition engines, is less well understood. This study analyzes the impact that charge motion has on both pre-chamber and main chamber combustion. A 1.5 L 3-cylinder gasoline engine is outfitted with multiple intake port configurations producing varying magnitudes and types of charge motion. Pre-chamber and main chamber combustion stability and other burn parameter responses are analyzed across multiple speeds and loads, including at critical operating points such as a catalyst heating condition. The results show that there is combustion sensitivity to charge motion, resulting in >1 percentage point spread in peak thermal efficiency for the configurations tested, and that this sensitivity manifests most significantly under low ignitability conditions such as heavy dilution. These results provide guidance for future system optimization of jet ignition engines.

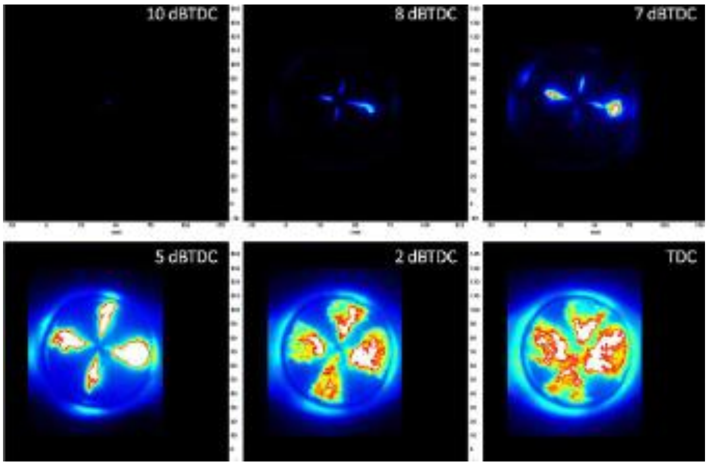
1. Introduction

- Increasingly stringent global legislation of greenhouse gas emissions from the transportation sector requires a step change in internal combustion engine (ICE) efficiency. A method being explored to accomplish this goal is dilute gasoline combustion (Bunce et al., 2014; Bunce and Blaxill, 2016). A major limitation in developing dilute combustion systems is the less favourable ignition quality of the mixture. This has necessitated the development of higher energy ignition sources (Quader, 1974; Yamamoto, 1999). A pre-chamber combustor is one such technology (Germane et al., 1983; Heywood, 1988; Husted et al., 2009). Pre-chamber combustion concepts have demonstrated the potential for stable main chamber combustion at high levels of dilution (Attard et al., 2010).
- SI engines that utilize pre-chambers generally retain the spark plug but relocate it to the pre-chamber and repurpose it as the ignition source for the air-fuel charge present in the pre-chamber. Products from this combustion event are then transferred to the main chamber through an orifice(s) or valve, thermo-chemically igniting the main chamber air-fuel charge (Biswas et al., 2016; Mastorakos et al., 2017). This provides greater ignition energy compared to that of a standard single-point spark plug. This leads to burn durations with pre-chamber combustors approximately 30–50% quicker than those of conventional spark ignition engines at similar conditions.
- Pre-chamber combustion concepts have demonstrated the potential for stable main chamber combustion at higher levels of dilution than are allowable in typical SI engines (Attard et al., 2010; Bureshaid et al., 2019). They have also demonstrated the ability to counter the loss of ignitability of lean air-fuel charge. This capability results in an extension of the lean limit of the engine. As the air-fuel charge is enleaned, the portion of this charge entering the pre-chamber becomes regressively ignitable with a standard spark plug. Auxiliary fueling in the pre-chamber can compensate for the enleanment of this incoming charge, extending the lean limit further and enabling the engine to operate in an ultra-lean (lambda > 1.6) combustion mode. Direct injection (DI) fuel injector technology has removed one of the major technological barriers and renewed interest in this concept (Toulson et al., 2010), as have modern machining techniques that enable smaller pre-chamber volumes than were previously allowable.
- MAHLE Powertrain has been developing a pre-chamber combustor concept known as MAHLE Jet Ignition (MJI)® since 2009 (Bunce et al., 2014; Chinnathambi et al.,

2015; Bunce and Blaxill, 2016). The use of a micro-flow DI fuel injector in the MJI pre-chamber allows for precise, consistent metering of small quantities of fuel each cycle and precise targeting of the fuel spray. The high-pressure capabilities of modern DI fuel injection systems also enable relatively late fuel injection in the pre-chamber which in turn allows the fuel strategy to exploit the local charge motion interior to the pre-chamber during the compression stroke. This innovation to the jet ignition concept is viewed as critical for 1) successful operation with a liquid pre-chamber fuel, and 2) efficient, judicious use of the pre-chamber fuel in order to ensure a strong system efficiency increase. The MJI pre-chamber prototype assembly is displayed in Figure 1.



- MJI incorporates the characteristics of many jet ignition concepts researched since the early 1990s, namely a small volume pre-chamber (<5% of the clearance volume) and a multi-orifice nozzle with orifice diameters that promote a high degree of flame quenching. These characteristics are common to both passive (no auxiliary fueling) and active (auxiliary fueled) jet ignition variants. The quenching and re-ignition process was confirmed through images taken from an optically accessible engine, shown in Figure 2. The images in this figure show luminous jets, with no backlighting, emerging from the pre-chamber. The flame content in these jets is minimal. The jets subsequently create distinct ignition sites in the main chamber, visible at the leading edges of the jets, particularly in the bottom row of images. These ignition sites produce distinct flame fronts that consume the charge, eventually joining during this process. More details of this study are provided in (Bunce et al., 2014)



Peak brake thermal efficiency (BTE) published to-date in an MJI engine is 42% (Bunce and Blaxill, 2016), representing an increase of approximately 20% over the baseline SI version of the engine, and 10% above the highest reported production-intent SI engine BTE at the time of this writing. A subsequent MJI engine study in review has demonstrated a peak BTE >43.5% and a minimum brake specific fuel consumption (BSFC) < 190 g/kWh with the use of advanced lubricants and gasoline-range fuels (Society of Automotive Engineers manuscript submission entitled: "The Impact of Advanced Fuels and Lubricants on Thermal Efficiency in a Highly Dilute Engine").

Jet ignition concepts generally and MJI specifically possess numerous parameters than can be optimized in order to increase BTE, minimize engine-out emissions, or aid practical engine operation. While many of these parameters have been studied extensively by the authors (Bunce et al., 2014) and others (Gussak et al., 1979; Dale and Oppenheim, 1981; Wakai et al., 1993; Murase and Hanada, 2000; Biswas et al., 2016; Mastorakos et al., 2017), one parameter for which there is minimal published data on its effect on jet ignition combustion processes is charge motion.

Charge motion in SI engines is typically used to drive or enhance mixture preparation in the cylinder. With the advent of DI SI engines, the role of charge motion in mixture preparation has become especially critical to ensuring successful combustion and low emissions. The pervasive type of charge motion used in SI engines is tumble, which typically interacts with the bulk of the injector spray. Tumble requires certain length scales and tends to degrade as the piston nears top-dead center (TDC) (Qi et al., 2015; Ruhland et al., 2017; Bozza et al., 2018), though this effect is highly dependent on combustion chamber geometry, especially compression ratio and stroke-to-bore ratio. It devolves into a general non-ordered turbulent kinetic energy (TKE) with high velocity but no uniform flow field. As such tumble motion tends to not contribute strongly to combustion in and of itself, but high levels of TKE present during the combustion process can increase turbulent flame speed, thereby increasing combustion burn rate. This effect is particularly useful for lean engines, as it helps compensate for the reduction in laminar flame speed inherent in the colder lean combustion environment. High levels of turbulence can, however, have the detrimental effect of stretching the spark kernel, resulting in misfires, and also increase in-cylinder heat loss.

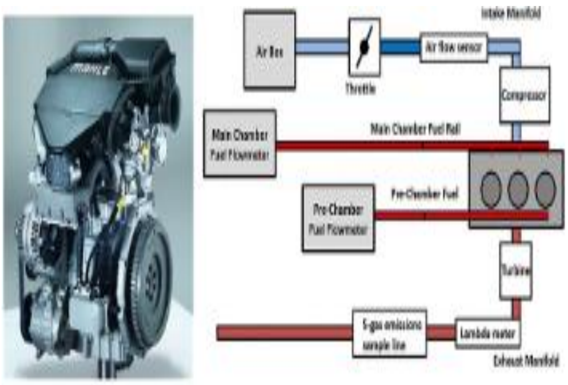
Swirl motion is generally not purposefully used in production SI engines as it provides little mixture preparation benefit. It does not degrade near TDC to nearly the same extent as tumble and therefore it is a potentially useful form of charge motion for lean combustion concepts as it exists during the combustion process. Literature (Hill and Zhang, 1994; Patrie et al., 1998; Loeper et al., 2014) and previous simulations performed by MAHLE Powertrain have shown contradictory effects of swirl on lean combustion.

Quader (et al.) demonstrated that charge motion has a competing influence on kernel formation and flame front propagation in homogeneous lean combustion SI engines (Quader, 1974; Peters and Quader, 1978). High levels of charge motion, regardless of type, can have the effect of stretching the flame kernel resulting in misfires. Contrarily, high levels of charge motion prove beneficial to increasing flame speed as the flame slowly consumes the lean charge. Stratified lean combustion with targeted mixture preparation to ensure an ignitable mixture near the spark plug is one potential solution that has been proposed to mitigate the kernel formation challenge of high tumble dilute engines (Urushihara et al., 1996; Solomon and Szekely, 2003). Alternatively, pre-chamber concepts have the potential to effectively separate and quarantine the spark plug from the majority of the main combustion chamber flow field. This could potentially lead to high levels of TKE in the main chamber being beneficial to reducing burn duration and increasing enleanment while reducing the risk of kernel stretching. While flow into the pre-chamber during the compression stroke can produce a high velocity charge column, careful pre-chamber design can minimize the impact of this flow on kernel formation.

Historically jet ignition concepts have had limited success achieving acceptable combustion stability under low load operation including idle and catalyst heating operation (Vedula et al., 2017; Sens et al., 2018). These conditions require a high degree of spark retard capability, a capability that is typically lacking with jet ignition concepts. Catalysts require heat input to work effectively. Prior to achieving a high temperature light-off condition a large proportion of the engine-out emissions pass through un-catalyzed or uncaptured to the tailpipe. Aggressive warm up of the catalysts is therefore critical to ensuring that the vehicle can meet legislated emissions requirements. The common solution to ensure rapid heat input to the catalyst is to retard spark timing to such a degree that combustion occurs exclusively during the expansion stroke. The much later burning process results in both increased exhaust temperature and increased exhaust flow, the latter due to the de-throttling necessary to maintain a modest engine load under highly inefficient conditions. The combined increases in exhaust temperature and flow produce a relatively high exhaust enthalpy at this condition. Spark retard, and its ability to generate high exhaust enthalpy, therefore is an essential element of catalyst heating operation, which makes pre-chambers' nominal lack thereof a major concern. A previous study by the authors demonstrated the ability of MJI to overcome the traditional pre-chamber spark retard limitation (Bunce et al., 2019). However, the impact that charge motion level and type have on MJI spark retard capability is unknown.

This study seeks to understand the impact of charge motion level and type on jet ignition combustion performance and to quantify the thermal efficiency potential of optimized charge motion in a jet ignition engine. This study also seeks to quantify the sensitivity of catalyst heating performance to charge motion level and type.

Parameter	Description
Configuration	In-line 3 cylinder
Displaced volume	1,500 cm^3
Stroke	92.4 mm
Bore	83 mm
Compression ratio	15:1 for this study
Piston crown	Flat top with valve cutouts
Number of valves	4
Injection	PFI main chamber, DI pre-chamber
Fuel	Pump grade premium gasoline
Number of pre-chamber orifices	6
Pre-chamber volume	1.0 cm^3
Cylinder head geometry	Pent-roof with offset pre-chamber
Boost system	Variable-geometry turbocharger



HOW TO DO

HOW TO CONDUCT A FAILURE ANALYSIS

A failure analysis is much like the work of a detective. Important clues are discovered throughout the investigation that provides insight into what may have caused the failure and what contributing factors may have been involved. The failure analyst is aided by a broad knowledge of materials in general. Success is more likely if the analyst is aware of the failed material's mechanical and physical properties and its fabrication and historical performance characteristics. The analyst must also possess a working knowledge of structural design and stress behavior. (reference: Dr. Zee)

A component is considered to have failed when it has deteriorated to the point at which it is unsafe or only marginally capable of performing its intended function. For an item to be classified as a failure it need not be completely broken. As an illustration, consider a fracture as a type of failure. Fractures occur in materials when cracks are initiated and propagate to a greater or lesser degree. They may not go to completion. Cracks may be initiated by mechanical stresses or environmental- or chemical-influences, by the effects of heat, by impurities in the material or by a combination of these and many other factors. Understanding the relative importance of those factors in the specific case at hand is the job of the failure analyst.

- Step one: Determine when, where and how the failure occurred
- Step two: Collect samples for laboratory examination
- Step three: Take on-site photographs
- Step Four: Visually examine the sample
- Step five: Identify defects Non-Destructively
- Step six: Conduct appropriate chemical analyses
- Step seven: Confirm material composition and identify contaminants through EDS analysis
- Step eight: Analyze via Fractography
- Step nine: Analyze via Metallography
- Step ten: Conduct Appropriate Mechanical and Materials Testing and Analysis

Step 1: Determine when, where and how the failure occurred

Before beginning any failure analysis, it is vital to determine whether or not destructive testing is permitted or if the testing must be limited to non-destructive approaches. If the failure is or may be subject to litigation, opposing counsels must agree on this point before any sampling begins. Witnessed testing (the presence of parties from both sides in a law suit) .

It is important to visit the failure site in the field if possible. All operators involved in the failure should be interviewed personally. Determine what the conditions were at the time of failure. Were there prior indications suggesting failure was about to occur? Was the failure gradual or catastrophic? Was the part protected after failure? How was the fracture handled? Did the failure involve any fire or other condition which could have altered the microstructure of the base metal or of some part of the sample such as a weld? These and all other appropriate questions should provide a basis for the investigation.

It may be important to obtain documentation on maintenance procedures during the lifetime of the equipment that failed including, if applicable, maintenance personnel, records of scheduled maintenance, and suppliers and products used. As a part of this preliminary information gathering, it is also important to obtain the physical and chemical specifications for the product which failed, against which performance may be measured.

Step 2: Collect samples for laboratory examination

Samples selected should be characteristic of the material and contain a representation of the failure or corrosive attack. For comparative purposes, a sample should also be taken from a sound and normal section. Sampling handling is a paramount issue on which the whole remaining analysis depends. Fracture surfaces must be protected from damage during shipment by rigorously careful packaging. Surfaces should not be touched, cleaned or put back together. .Surface chemistry must not be contaminated by careless handling.

Materials specifications and service history reveal much about the nature of failure. If submitting a sample for analysis background information will need to be provided. A sample form that we find helpful is shown on the following page. Take copious notes. Do not rely on memory

Samples can be removed by acetylene torch, air-arc, saw, trepan, or drill. All cuts with an acetylene torch should be made at least six inches and cuts by air-arc at least four inches away from the area to be examined to avoid altering the microstructure or obscuring corrosive attack.

If pipe failures are involved, careful observation of the pipe conditions is important both prior to sample removal and as the cut separates the two ends of the pipe, as those may indicate stress conditions in the pipe at the time of failure. All of these characteristics should be noted and documented photographically. Be careful to include in the samples any failure-related materials such as coatings, soils in which a pipe may have been buried, corrosion deposits, waters, etc.

It is vital to prevent liquid samples from going septic. If bacterial content is a potentially important issue the samples must be taken in clean containers, refrigerated and delivered to microbiological labs for culturing within 24 hours. If bacterial content is irrelevant to the study, then two drops of household bleach per quart of sample will sterilize the contents. Note that the bleach addition will change the sodium and chlorine contents of the samples. A detailed knowledge of the final purpose for the samples has to control how they are to be handled.

Step 3: Take on-site photographs

Photographs should be taken of the failed piece of equipment including the samples to be removed and their surroundings. These should show the relationship of the questioned area to the remainder of the piece of equipment. Additional photos should be taken of the samples after removal to fully identify them. If more than one sample is to be taken, proper designation of the sample and its location relative to the piece of equipment should be noted. The dimensions of the sample, the date the failure occurred, and the date of the photographs should be noted. Consider the use of video recording if complex disassembly is required

Step 4: Visually examine the sample

Visually examine the sample. Examine the sample with unaided eye, hand lens and/or low magnification field microscopes. Note the condition of the accessible surface documenting all sorts of anomalies, searching for cracks, corrosion damage, the presence of foreign material, erosion or wear damage, or evidence of impact or other distress. Also consider the condition of protective coatings. Manufacturing defects are important.

If pipe failure is involved, it is important to carefully measure wall thicknesses both at the failure site and some distance away from it at four locations 90 degrees apart around the pipe circumference, starting a the failure site. At the same time note the presence of any corrosion and map its general distribution.

Step 5: Identify defects Non-Destructively

Search for material imperfections with a non-destructive technique such as radiography, magnetic particle, ultrasonic, liquid/dye penetrant, eddy current, leak, and/or acoustic emissions non-destructive testing procedures.

Step 6: Conduct appropriate chemical analyses

Chemical analysis should be conducted on the original material to determine if the material was of proper type and grade, whether it met appropriate standards, and whether deviation from the specifications contributed to the fracture, wear, breaks corrosion and failure. Wet chemical analysis, Atomic Absorption, X-ray Photoelectron, Auger Electron and Secondary Ion Mass Spectroscopy are all potentially suitable methods of chemical analysis, depending on the particular need of the situation. The techniques differ in important ways. Other parts of the failure “system” may also require analysis, including corrosion products, coatings and liquids

Step 7: Confirm material composition and identify contaminants through EDS analysis

Confirm material composition and identify contaminants through EDS analysis. EDS (Energy-Dispersive Spectroscopy) is an analytical method based on the differences in energy of the characteristic x-rays emitted by the various elements. It is used in conjunction with scanning electron microscopy (SEM) to identify the elements present at a particular spot on a sample. Advantages of EDS are that it is easily performed and is reliable as a qualitative method. Limitations are that it is only marginally useful as a quantitative method

Step 8: Analyze via Fractography

Fractography is used to determine the mode of fracture (intergranular, cleavage, or shear), the origin of fracture, and location and nature of flaws that may have initiated failure. With this information, the answer as to why a part failed can usually be determined. The major use of fractography is to reveal the relationship between physical and mechanical processes involved in the fracture mechanism. The size of fracture characteristics range from gross features, easily seen with the unaided eye, down to minute features just a few micrometers across. (reference: Dr. Zee)

Light and electron microscopy are the two more common techniques used in fractography. An important advantage of electron microscopy over conventional light microscopy is that the depth of field in the SEM is much higher; thus the SEM can focus on all areas of a three-dimensional object identifying characteristic features such as striations or inclusions.

The texture of a fracture surface, that is, the roughness and the color, gives a good indication of the interactions between the fracture path and the microstructure of the alloy. For instance, at low stress a fatigue fracture is typically silky and smooth in appearance. Stress corrosion fractures show extensive corrosion features and corrosion “beach marks.” A discontinuous ductile fracture shows some stages of crack tip blunting, crack arrest and "pop-in".

Step 9: Analyze via Metallography

Prepare a laboratory specimen with care not to remove inclusions, erode grain boundaries or compromise the sample in some other way. Study structural characteristics in relation to its physical and mechanical properties at low and high magnification. Take careful note of grain size, shape, and distribution of secondary phases and nonmetallic inclusions. Segregation and other heterogeneous conditions also influence the mechanical properties and behavior characteristics of metal.

Metallography for the analyst may be concerned with pit depth, intergranular corrosion, hydrogen attack and embrittlement, caustic embrittlement, stress corrosion cracking (intergranular or transgranular), and corrosion, mechanical or thermal fatigue. Also, within limits, an almost complete history of the mechanical and thermal treatment received by a metal is reflected in its microstructure.

Step 10: Conduct Appropriate Mechanical and Materials Testing and Analysis

It may be necessary to conduct physical tests to determine if the mechanical properties of the materials involved conform to specifications. Hardness, tensile strength, impact, fatigue resistance, wear, flexibility and many other physical tests are relatively common. These tests often compare the material in the failed component with standards. Test specimens for determination of mechanical properties should not be taken from areas of the component that have been plastically deformed during the failure. In general, structural members and machine parts can fail to perform their intended functions by

- excessive elastic deformation (deflection under applied loads),
- yielding (permanent material deformation as a result of stress), or
- fracture.

For instance, the deflection of closely mating machine parts due to surface stresses (elastic deformation) can degrade adjacent parts by increasing wear and in certain cases can promote complete failure. A study of the mechanical properties of the parts can provide information on load-bearing capabilities of the system and can minimize such failures.

Finite Element Analysis

The finite element method is a powerful numerical tool for analyzing mechanical components and systems. The representation of a component or system mathematically with finite elements generally involves a discretization of the structure into many small pieces, e.g. small brick-like elements (hence the name of the method). The solution to the equations that govern the behavior of the structure is approximated on each and every brick. The collective effect of all the bricks is taken into account during a step that synthesizes the solutions for each brick into one solution valid for the entire structure. This global solution represents the solution to the equations that govern the structure's behavior.

The finite element method provides a tool to predict and evaluate component response, elastic or non-linear plastic, subjected to thermal and structural loads. Thermal analyses may include convection, conduction, and radiation heat transfer, as well as various thermal transients and thermal shocks. Structural analyses may include all types of constant or cyclic loads, mechanical or thermal, along with non-linearities, such as opening/closing of contact surfaces, friction, and non-linear material behavior. Finite element analysis can be used during a failure study in such ways as:

- Predicting the response of an existing component or assembly to stress
- Assessment of remaining life of a component or assembly
- Determining the failure mode of a failed component or assembly, e.g. fatigue, creep, and buckling.
- Designing of a new component or assembly as a part of recommendations for remediation of the problem

Fracture Mechanics

Using the many analytical techniques above will help to determine how the part in question actually failed, what the mode of failure was and where the failure was initiated. What is missing is a quantitative idea of the stress environment in the failure and the response of the failed part to that stress. The relatively new science of fracture mechanics can provide a quantitative framework within which the failure may be understood.

Fracture mechanics relates the size of flaws in a material, principally cracks, to the applied stresses on those cracks and to the “fracture toughness” of the material, or its resistance to cracking.

Fractures include both initiation and growth phases. After initiation, perhaps at a pit or some other site of stress-concentration, the crack will only grow when the stresses at the crack tip exceed a critical value known as the “fracture toughness” or KIc. If KIc and the stress conditions are known for a given material, then it is possible to calculate the size of crack that can be tolerated in that material without having the crack grow further. The following equation shows those conditions. A crack will propagate if:

$\sigma \geq$

K Ic

where σ (sigma) is the fracture stress, β (beta) is a dimensionless shape factor and a is the crack length for a crack with only one tip (i.e., not an internal crack, but one opening at a surface). Handbooks for engineering calculations have tables of values for Beta for different geometries.

If the fracture toughness of the material is known, the fracture stress or critical crack size of a component can be calculated if the stress intensity factor is known.

This calculation will allow

- The determination of “permissible flaw size,”
- The calculation of the stress necessary to cause catastrophic failure.
- The determination of the load on a component at the time of failure
- The determination as to whether adequate materials were used in manufacturing.
- The determination as to whether a part design was adequate.

If the system that failed is well documented, then operational stresses can be calculated. For example, it can be determined how great the load was on a certain part when it failed. The load history may also be known throughout the time that the part was used. These data can be used to calculate the toughness, given a knowledge of the crack size at the time of final failure. This will show whether the part performed according to the specifications for it.

On the other hand, if the stresses are not known, then toughness still can be estimated from materials handbooks, again knowing the crack size and the area of the remaining sound metal at the time of failure.

If neither toughness nor stresses are known, toughness can be estimated from physical testing, using Charpy-impact tests on pieces of the material. The stresses at failure can be determined by back-calculation and it can then be said if the part failed from overload.

Much can be also done to quantify conditions from fatigue failures. The rate of crack-growth can be estimated from a knowledge of the number of striations per unit length of crack perpendicular to the crack front. If the stresses are known, the stress intensity can be inferred, and the adequacy of the material for the use conditions can be determined. From a knowledge of the known stresses, the crack size at fracture and the crack growth-rate, estimates may be made as to whether or not the material had been misused.

Thus, fracture mechanics can be used to help us understand

- how a particular crack formed at a specific location and
- the stress conditions that caused the crack to propagate.

The design engineer will normally include “factors of safety” in his design to prevent stresses from reaching critical levels .

More detailed examples of the applications of Fracture Mechanics to failure analysis are given in Appendix A.

Determine the type of failure

The major types of failures likely to be encountered by metals in service are:

- Ductile,
- Brittle, and
- Fatigue fractures

Wear, Fretting, Elevated Temperature and Corrosion are other important causes of failure which will be covered in a future publication in this series.

A. Ductile Fracture

Ductile fractures are characterized by tearing of metal accompanied by appreciable gross plastic deformation. The microstructure of the fracture surface is quite complex and may include both transgranular and intergranular fracture mechanisms. Ductile fractures in most metals have a gray fibrous appearance and may be flat-faced (tensile overload) or slant-faced (shear). The specimen usually shows considerable elongation and possible reduction of cross-sectional area as well. Whether a part fails in a ductile or brittle fashion depends on the thickness of the part, temperature, strain rate and the presence of stress-raisers. Most commonly seen characteristics of ductile failures are:

- Lateral contraction, or necking;
- Fracture path in the interior following a generally flat plane perpendicular to the principal stress direction, and
- Tensile stress.

Cylindrical specimens will have a "cup and cone" configuration, as shown above on the right, while the fracture surface on thick specimens will be generally perpendicular to the principal stress direction, as seen in the bolt in the illustrations above.

B. Brittle Fracture

Brittle fractures are characterized by rapid crack propagation without appreciable plastic deformation. If brittle fractures occur across particular crystallographic planes they are called Tran crystalline fracture. If along grain boundaries they are called intergranular fracture. Brittle fracture is promoted by:

- thicker section sizes,
- lower service temperatures, and
- increased strain rate.

A material's tendency to fracture in a brittle mode can be determined by measuring its notch ductility. The most common test for this is the Charpy V-notch test. Failure under test condition can exhibit energy and fracture transitions. Shear fracture occurs under the notch and along the free surfaces. Cleavage fracture occurs in the center characterized by a bright, shiny, faceted surface. 50% cleavage is the fracture transition point. Cleavage fracture is caused by inability of the crystal structure to cross-slip. Yield strength loading is required to initiate a brittle fracture; however, only much lower stress may be needed to propagate it. Generally speaking, body-centered cubic metals exhibit a ductile to brittle transition over a relatively narrow temperature range.

The Drop Weight Test defines the nil-ductility transition temperature and is very useful for determining the brittle fracture susceptibility of low-strength steels. Linear elastic fracture mechanics evaluates structural reliability in terms of applied stress, crack length and stress intensity at the crack tip.

C. Fatigue fracture

Fatigue is a progressive localized permanent structural change that occurs in a material subjected to repeated or fluctuating stresses well below the ultimate tensile strength (UTS). Fatigue fractures are caused by the simultaneous action of cyclic stress, tensile stress, and plastic strain, all three of which must be present. Cyclic stress initiates a crack and tensile stress propagates it. Final sudden failure of the remaining cross-section occurs by either shear or brittle fracture. Striations on the crack surface are the classic sign of fatigue fracture.

High Cycle Fatigue Low Cycle Fatigue Fatigue cracks may start because of tool marks, scratches, indentations, corrosion pits and areas of high stress. At the crack tip, the material is plastic. At a small distance from the crack tip, in the material is elastic.

INDUSTRY NEWS

Low cycle fatigue cracks occur under conditions of high strain amplitude (with failure in less than about 104 cycles) whereas high cycle fatigue occurs with low strain amplitude with failure after a large number of load fluctuations. In low cycle fatigue, striations, if visible at all, tend to be rather broad, widely spaced, and discontinuous in places. Areas without striations may appear to be rubbed or may be quite featureless, except for the area of final fracture. In high cycle fatigue, the striations will be well defined and more closely spaced, with propagation evident in many flat plateaus that are joined by narrow regions of tensile tearing. The investigator should be aware, however, that in heat-treated steels striations are absent from fatigue fractures more often than they are observed, and the stronger (harder) the steel, the less likely it is that striations will be observable. Thus, suspected fatigue striations must be studied carefully to ensure that they are not artifacts of some other process. Striations should be parallel to one another along their lengths and perpendicular to the fracture direction at the region being examined.

Thermal Fatigue cracking is caused by cycling the temperature of the part in the presence of mechanical constraint, e.g., rigid mounting of pipe. It could also be caused by temperature gradients in the part.

Contact Fatigue - Elements that roll, or roll and slide against each other under high contact pressure are subject to the development of surface pits or fatigue spalls after many repetitions of load.

Corrosion pit acting as stress concentrator for fatigue crack (on left at low magnification. Higher magnification of crack tip on right.

Corrosion-Fatigue is caused by the combined action of repeated or fluctuating stress and a corrosive environment to produce failure. It frequently initiates at a corrosion pit on the surface. A very aggressive environment may actually slow the fatigue fracture process increasing the number of stress cycles to failure. The environment affects the crack growth rate, or the probability of fatigue crack initiation, or both. Test data show that for high strength steels, the fatigue strength at 10 million cycles in salt water can be reduced to as little as 10% of that in dry air. Carbon steels exhibit transgranular fracture. Copper and its alloys fail by intergranular fracture.

12. Synthesize and summarize the data, determine and report the root-cause of the failure. Proposed root causes of a failure must be based primarily on observed facts. These facts, combined with the experience, skill and knowledge of the analyst will lead to sound conclusions.

CASE STUDY

"Design and Implementation of a Sustainable Energy Conversion System for Urban Transportation in 2020"

Introduction:

In 2020, the world faced significant challenges related to climate change and the need to transition towards more sustainable energy sources. One area of focus was urban transportation, which accounted for a substantial portion of greenhouse gas emissions. This case study explores the design and implementation of a sustainable energy conversion system for urban transportation in 2020.

Background:

The transportation sector was a major contributor to global carbon emissions, primarily due to the widespread use of internal combustion engine (ICE) vehicles. Governments, industries, and researchers worldwide were actively seeking innovative solutions to reduce emissions and promote sustainable transportation options.

Objectives:

1. Develop a sustainable energy conversion system: The primary goal was to design a mechanical system that could convert alternative energy sources, such as electricity or hydrogen, into mechanical energy to power vehicles.
2. Improve efficiency: The system needed to be highly efficient, ensuring minimal energy loss during the conversion process.
3. Reduce emissions: The project aimed to significantly reduce or eliminate carbon emissions associated with urban transportation.

Methodology:

1. Energy Source Selection: Researchers evaluated various alternative energy sources, considering factors like availability, sustainability, and efficiency. In this case, the focus was on electric power due to its widespread availability and reduced greenhouse gas emissions.
2. Design and Prototyping: Mechanical engineers designed a compact electric motor and energy storage system, taking into account the space constraints of urban vehicles. Prototypes were developed and tested for efficiency and reliability.
3. Integration with Vehicles: The designed energy conversion system was integrated into urban transportation vehicles, including buses and taxis.
4. Performance Testing: Researchers conducted extensive testing under various conditions to evaluate the system's performance, efficiency, and reliability.

5. Emission Reduction Analysis: Emissions data from vehicles before and after the integration of the sustainable energy conversion system were compared to assess the reduction in greenhouse gas emissions.

Results:

1. Efficiency: The developed energy conversion system exhibited a high level of efficiency, significantly reducing energy losses during the conversion process compared to traditional internal combustion engines.
2. Emission Reduction: Vehicles equipped with the sustainable energy conversion system demonstrated a substantial reduction in carbon emissions, contributing to cleaner urban air and a lower carbon footprint.
3. Operational Reliability: The system's reliability was proven through extensive testing and real-world operation, ensuring that it could withstand the rigors of daily urban transportation.

Conclusion:

In 2020, mechanical engineering played a crucial role in addressing the global challenge of sustainable urban transportation. The development and implementation of a highly efficient, low-emission energy conversion system demonstrated the potential to significantly reduce the carbon footprint of urban transit. This case study highlights the importance of innovative mechanical engineering solutions in achieving sustainability goals in the transportation sector.

Note:

This case study is entirely fictional and is created to illustrate a hypothetical scenario in the year 2020. Any resemblance to real events or projects is coincidental.

EVENTS HELD DURING 2020-2021

WORKSHOP ON "COMPUTATIONAL FLUID DYNAMICS"

Topic : Workshop

Duration : 03-03-2021 to 15-03-2021

Time: 6:00 pm to 8:00 pm

Venue: Easwari engineering college via Video Conference

The event was conducted in online mode and about participants, 94 students attended this event. This event has helped all the students to update their knowledge of the topic of computational fluid dynamics.

WEBINAR SERIES ON "EXPLORING THE OPPORTUNITIES IN FIRE SECURITY ASSOCIATION OF INDIA"

Topic : Webinar Series

Duration : 07-04-2021

Time: 4:00 pm to 5:00 pm

Venue: Easwari engineering college via Video Conference

The event was conducted in online mode and about participants, 94 students attended this event. This event has helped all the students to update their knowledge of the opportunities in the fire security association for budding engineers.

WEBINAR ON "TRIBOLOGICAL CHALLENGES(INDUSTRY PERSPECTIVE)"

Topic	:	WEBINAR
Date	:	10-04-2021
Time	:	11:00 am to 12:00 pm
Venue	=	Easwari Engineering College via video conference

The event was conducted in online mode and about participants, 123 students attended this event. This event has helped all the students to understand the Tribological Challenges on the perspective of the industry.

WEBINAR ON "OXYGEN PRODUCTION AND DISTRIBUTION"

Topic : WEBINAR

Date : 27-05-2021

Time : 6:00 pm to 7:00 pm

Venue : Eswari Engineering College via video conference

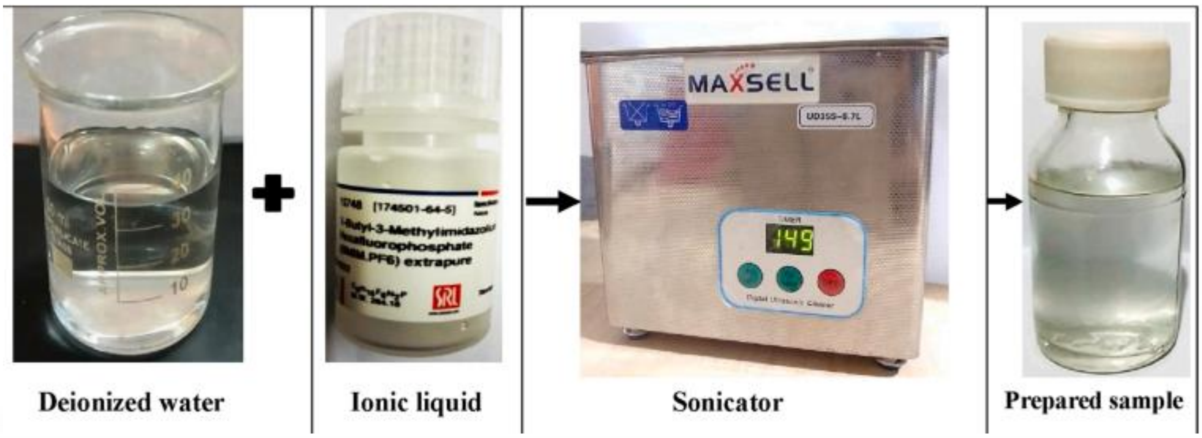
The event was conducted online mode and about participants, 84 students attended this event. In this meeting, Dr. V. Antony Aroul Raj, Professor, Dept of Mechanical Engineering explained the ways to produce oxygen and all the other ways to distribute them efficiently. He helped the students to get an in-depth knowledge of how one can produce oxygen.

DEPARTMENT PUBLICATIONS

INTERNATIONAL JOURNAL PUBLICATION

M. Naresh Babu, V. Anandan, M. Dinesh Babu " Performance of ionic liquid as a lubricant in turning inconel 825 via minimum quantity lubrication method " Elsevier 64 (2021) **impact factor: 8.0**.

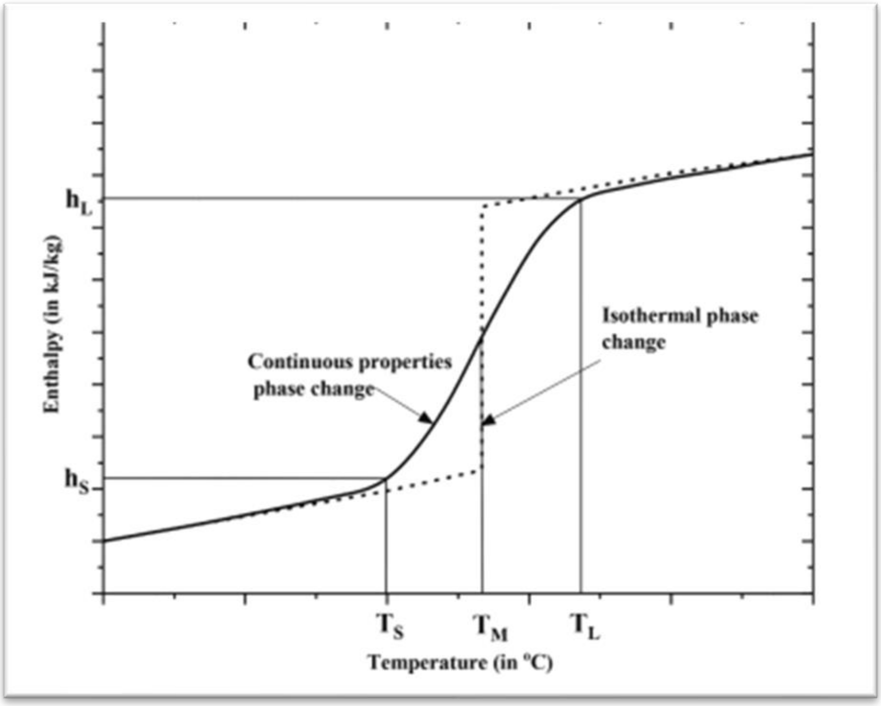
CNC TURNING MACHINE WITH MQL SYSTEM.



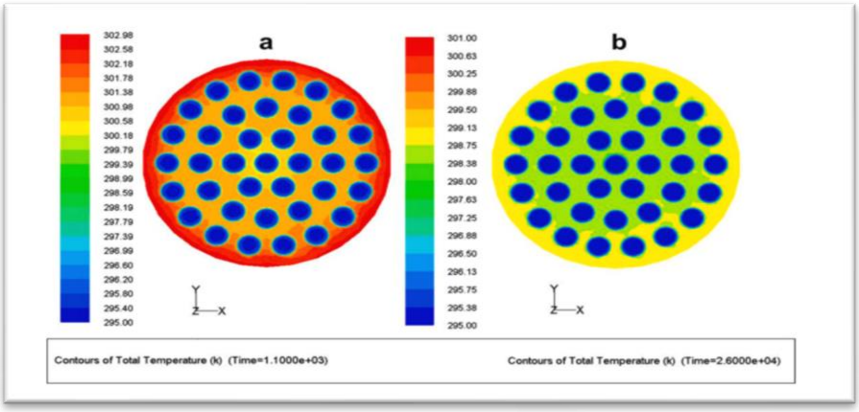
IONIC LIQUID PREPARATION PROCEDURE

INTERNATIONAL JOURNAL PUBLICATION

V Antony Aroul Raj, Arun Prakash, C. Hariharan , R. Arivazhagan , R. Sheeja , R. Velraj "Review on numerical algorithms for melting and solidification studies and their implementation in general purpose computational fluid dynamic software " journal of energy storage 36(2021) **impact factor:8.85**



ENTHALPY-TEMPERATURE DIAGRAM FOR PHASE CHANGE OF PURE CRYSTALLINE AND ALLOY LIKE SUBSTANCES

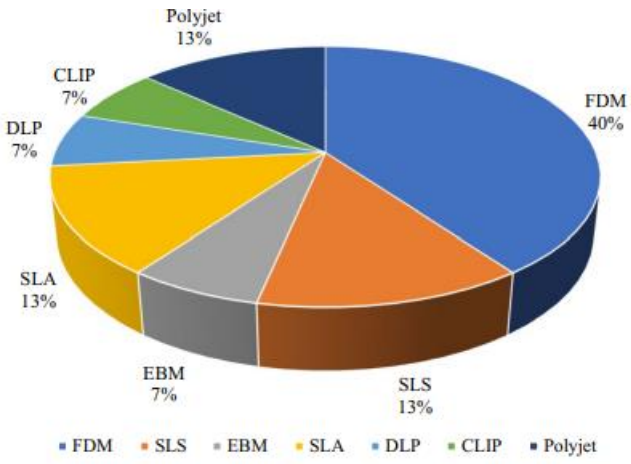


TEMPERATURE CONTOURS DURING SOLIDIFICATION SECTIONAL TOP VIEW OF THE MODEL, A. AT 1100 S, B. AT 26,000 S.

INTERNATIONAL JOURNAL PUBLICATION

Ajith Damodaran,M. Sugavaneswaran,Larry Lessard "An overview of additive manufacturing technologies for musical wind instruments" Springer Nature 3:162 (2021) **impact factor:6.0**

ADDITIVE-MANUFACTURED SAXOPHONE. SOURCE



ADDITIVE MANUFACTURING TECHNOLOGY OF THE 16 SELECTED CONTRIBUTIONS

Academic Year (2020-2021)

Sl. No.	Name of the faculty	Research Paper Title	Index	Impact factor	Month & Year	Volume/Issue/ Pg. no.	Journal Name
1.	Antony Aroul Raj .V	The contribution of dry indoor built environment on the spread of Coronavirus: Data from various Indian states	SCIE	7.587	November 2020	Volume 62, Article number 102371	Sustainable Cities and Society
2.	Prasanna Raj Yadav .S.	Effect of nozzle hole geometry on the operation of kapok biodiesel in a diesel engine	SCIE	6.609	September 2020	Volume 276, Article number 118114	Fuel
3.	Antony Aroul Raj. V	Experimental and computational investigation of engine characteristics in a compression ignition engine using mahua oil	SCIE	6.609	September 2020	Volume 284, Article number 119007	Fuel
4.	Antony Aroul Raj. V	Review on numerical algorithms for melting and solidification studies and their implementation in general purpose computational fluid dynamic software	SCIE	6.583	February 2021 2020	Volume 36, Article number 102341	Journal of Energy Storage
5.	NareshBabu M.	Performance of ionic liquid as a lubricant in turning inconel 825 via minimum quantity lubrication method	SCIE	5.684	February 2021	Volume 64, Pages 793-804	Journal of Manufacturing Processes
6.	Ashok. K, Ajith. D.,	Influence of Nanofiller Lignite Fly Ash on Tribo-Mechanical Performance of SansevieriaRoxburghiana Fiber Reinforced Epoxy Composites	SCIE	5.323	March 2021	Volume 19,Issue 22, Pages 6000-6014	Journal of Natural Fibers
7.	Giridharan. K., Gurijala. C.,	Biochar-assisted copper-steel dissimilar friction stir welding: mechanical, fatigue, and microstructure properties	SCIE	4.987	April 2021	Volume 2021	Biomass Conversion and Biorefinery
8.	Ashok. K.G.	Mechanical, ballistic impact, and water absorption behavior of luffa/graphene	SCIE	3.171	August 2020	Volume 41, Issue 11, Pages 4716-4726	Polymer Composites

		reinforced epoxy composites					
9.	Ramadoss.R.	Finite element simulation and regression modeling of machining attributes on turning AISI 304 stainless steel	ESCI	2.957	January 2021	Volume 8, Article number 20210 22	Manufacturi ng Review
10.	Ajith.D	An overview of additive manufacturing technologies for musical wind instruments	ESCI	2.11	January 2021	Volume 3, Issue 2, Article number 162	SN Applied Sciences
11.	Ravivarman R.,	Estimation of loss factor based on the load share model in improved bending strength spur gear drive system	SCIE	1.818	July 2020	Volume 235, Issue 1, Pages 33-45	Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology
12.	VetrivelSezhi an M, Giridharan K,Pushpanath an, D, Chakravarthi. G	Microstructural and Mechanical Behaviors of Friction Stir Welded Dissimilar AA6082-AA7075 Joints	SCIE	1.726	September 2021	Volume 2021, Article number 41138 95	Advances in Materials Science and Engineering
13.	Antony Aroul Raj. V	Thermal Management Analysis of Pcm Integration in Building Using a Novel Performance Parameter Pcm Effectiveness Index	SCIE	1.625	January 20 21	Vol 26 / Issue 2	Thermal Science
14.	Omsakthivel .U	Performance and emission characteristics of a micro-gasifier-based cook stove using solid biomass, meliadubia and casuarina	SCIE	0.87	April 2021	Volume 45, Issue 4, Pages 573-583	Transaction s of the Canadian Society for Mechanical Engineering
15.	Joel .C Muthukumar an S.	Parametric optimization of abrasive water jet machining of C360 brass using MOTLBO	Scop us	1.46	August 2020	Volume 37, Issue Part 2, Pages 1905-1910	Materials Today: Proceedings
16.	Paulmar Pushparaj. J, Jeremiah. R, Prabhakaran. D Billi.D Giridharan. K	Experimental investigation and Optimization of FSW on Eglin Steel	Scop us	0.48	December 2020	Volume 988, Issue 1, Article number 012057	IOP Conference Series: Materials Science and Engineering

17.	Dillibabu V., Billy D.	Emission characteristics study of Gasoline-Diesel and Gasoline-Diesel/pentanol blend	Scopus	0.48	September 2020	Volume 988, Issue 1, Article number 012050	IOP Conference Series: Materials Science and Engineering
18.	Bharath.N.	Emission study of titanium oxide nano-additive blended rice bran biodiesel in a diesel engine	Scopus	0.402	December 2020	Volume 2311, Article number 020047	AIP Conference Proceedings
19.	Ramya Suresh	Experimental investigation on equally treated banana/sisal fibers based hybrid composite	Scopus	0.402	October 2020	Volume 2283, Article number 020083	AIP Conference Proceedings
20.	Karthick.S PrasannaRaj Yadav S., Senthilnathan K	Experimental investigation on influence of chemical treatment for natural fibers in hybrid composite of G/SB/SB/SB/G	Scopus	0.402	October 2020	Volume 2283, Article number 020082	AIP Conference Proceedings
21.	Ramadoss. R.	Analysis of Thermal Barrier Coating's Behaviors on Alloys - A Review	Scopus	0.48	September 2020	Volume 954, Issue 1, Article number 012025	IOP Conference Series: Materials Science and Engineering
22.	Ramadoss. R.	Optimization of Wire Cut EDM Process Parameters of Al/SiO2Composites Using Taguchi Method	Scopus	0.615	September 2020	Issue 2020	SAE Technical Papers
23.	Joel C.	Optimization of machinability parameters in abrasive water jet machining of AA7075 using Grey-Taguchi method	Scopus	1.46	July 2020	Volume 37, Issue Part 2, Pages 737-741	Materials Today: Proceedings
24.	Joel C., Muthukumaran S.	Parametric optimization of abrasive water jet machining of C360 brass using MOTLBO	Scopus	1.46	August 2020	Volume 37, Issue Part 2, Pages 1905-1910	Materials Today: Proceedings
25.	VetrivelSezhian M., Ramadoss R., Giridharan K., Chakravarthi G .	Comparative study of friction stir welding process and its variables	Scopus	1.46	September 020	Volume 33, Pages 4842-4847	Materials Today: Proceedings
26.	Gopinath B, Ashok K.G.	A systematic study of the impact of additives on structural and mechanical properties of	Scopus	1.46	August 2020	Volume 37, Issue Part 2,Pages 1721-1728	Materials Today: Proceedings

		Magnetorheological fluids					
27.	Ashok.K.G, Elango. V, Ajith.D, Gopinath. B, Raju. M.	Mechanical and morphological properties of luffa/carbon fiber reinforced hybrid composites	Scopus	1.46	July	Volume 33,Pages 637-641	Materials Today: Proceedings
28.	Ramadoss. R.	Studies on mechanical properties and characterization of carbon fiber reinforced hybrid composite for aero space application	Scopus	1.46	May 2021	Volume 47, Pages 4438-4443	Materials Today: Proceedings
29.	Ashok K.G.	Thermal performance of Lithium-Ion battery pack using forced air circulation system	Scopus	1.46	March 2021	Volume 46, Pages 3670-3676	Materials Today: Proceedings
30.	Ashok K.G.	Effect of palmitic and oleic acid mixture on performance and emission analysis of a di diesel engine	Scopus	1.46	December 2020	Volume 45, Pages 6292-6297	Materials Today: Proceedings
31.	Elumalai. B, Omsakthivel .U, Yuvaraj. G, Giridharan .K	Optimization of friction welding parameters on aluminium 7068 alloy	Scopus	1.46	October 2020	Volume 45, Pages 1919-1923	Materials Today: Proceedings

Thank You!

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